Python 3.5.1 documentation

Welcome! This is the documentation for Python 3.5.1, last updated Dec 06, 2015.

Parts of the documentation:

What's new in Python 3.5? or all "What's new" documents since 2.0

Tutorial
start here

Library Reference
keep this under your pillow

Language Reference
describes syntax and language elements

Python Setup and Usage
how to use Python on different platforms

Python HOWTOs
in-depth documents on specific topics

Installing Python Modules
installing from the Python Package Index & other sources

Distributing Python Modules
publishing modules for installation by others

Extending and Embedding
tutorial for C/C++ programmers

Python/C API
reference for C/C++ programmers

FAQs
frequently asked questions (with answers!)

Indices and tables:
## Python Module Index

<p>| _ | <strong>future</strong> | Future statement definitions |
| a | abc | Abstract base classes according to PEP 3119. |
| aifc | Read and write audio files in AIFF or AIFC format. |
| argparse | Command-line option and argument parsing library. |
| array | Space efficient arrays of uniformly typed numeric values. |
| ast | Abstract Syntax Tree classes and manipulation. |
| asynchat | Support for asynchronous |</p>
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<th>Description</th>
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<td>asyncio</td>
<td>Asynchronous I/O, event loop, coroutines and tasks.</td>
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<td>asyncore</td>
<td>A base class for developing asynchronous socket handling services.</td>
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<td>atexit</td>
<td>Register and execute cleanup functions.</td>
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<td>audioop</td>
<td>Manipulate raw audio data.</td>
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<td>base64</td>
<td>RFC 3548: Base16, Base32, Base64 Data Encodings; Base85 and Ascii85</td>
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<td>bdb</td>
<td>Debugger framework.</td>
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<td>binascii</td>
<td>Tools for converting between binary and various ASCII-encoded binary representations.</td>
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<td>binhex</td>
<td>Encode and decode files in binhex4 format.</td>
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<tr>
<td>bisect</td>
<td>Array bisection algorithms for binary searching.</td>
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<tr>
<td>builtins</td>
<td>The module that provides the built-in namespace.</td>
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<td>bz2</td>
<td>Interfaces for bzip2 compression and decompression.</td>
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<tr>
<td>Module</td>
<td>Description</td>
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<tr>
<td>calendar</td>
<td>Functions for working with calendars, including some emulation of the Unix cal program.</td>
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<td>cgi</td>
<td>Helpers for running Python scripts via the Common Gateway Interface.</td>
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<td>cgitb</td>
<td>Configurable traceback handler for CGI scripts.</td>
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<td>chunk</td>
<td>Module to read IFF chunks.</td>
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<td>cmath</td>
<td>Mathematical functions for complex numbers.</td>
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<td>cmd</td>
<td>Build line-oriented command interpreters.</td>
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<td>code</td>
<td>Facilities to implement read-eval-print loops.</td>
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<td>codecs</td>
<td>Encode and decode data and streams.</td>
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<td>codeop</td>
<td>Compile (possibly incomplete) Python code.</td>
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<td>collections</td>
<td>Container datatypes</td>
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<td></td>
<td>Abstract base classes for containers</td>
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<td>colorsys</td>
<td>Conversion functions between RGB and other color systems.</td>
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<tr>
<td>compileall</td>
<td>Tools for byte-compiling all Python source files in a directory tree.</td>
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<td>concurrent</td>
<td>Execute computations</td>
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<td>concurrent.futures</td>
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<td>Module</td>
<td>Description</td>
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<td>configparser</td>
<td>Configuration file parser.</td>
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<td>contextlib</td>
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<td>copy</td>
<td>Shallow and deep copy operations.</td>
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<td>copyreg</td>
<td>Register pickle support functions.</td>
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<td>cProfile</td>
<td>The crypt() function used to check Unix passwords.</td>
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<td>crypt (Unix)</td>
<td>Write and read tabular data to and from delimited files.</td>
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<td>csv</td>
<td>A foreign function library for Python.</td>
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<td>csv</td>
<td>An interface to the curses library, providing portable terminal handling.</td>
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<tr>
<td>curses (Unix)</td>
<td>Constants and set-membership functions for ASCII characters.</td>
</tr>
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<td>curses.ascii</td>
<td>Emacs-like input editing in a curses window.</td>
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<tr>
<td>d</td>
<td>Basic date and time types.</td>
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</table>
| dbm          | Interfaces to various...
Unix "database" formats.

**dbm.dumb**  
Portable implementation of the simple DBM interface.

**dbm.gnu** *(Unix)*  
GNU's reinterpretation of dbm.

**dbm.ndbm** *(Unix)*  
The standard "database" interface, based on ndbm.

**decimal**  

**difflib**  
Helpers for computing differences between objects.

**dis**  
Disassembler for Python bytecode.

**distutils**  
Support for building and installing Python modules into an existing Python installation.

**distutils.archive_util**  
Utility functions for creating archive files (tarballs, zip files, ...)

**distutils.bcppcompiler**  
**distutils.ccompiler**  
Abstract CCompiler class

**distutils.cmd**  
This module provides the abstract base class Command. This class is subclassed by the modules in the distutils.command subpackage.

**distutils.command**  
This subpackage
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<th>Module</th>
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<td><code>distutils.command.bdist</code></td>
<td>Build a binary installer for a package</td>
</tr>
<tr>
<td><code>distutils.command.bdist_dumb</code></td>
<td>Build a &quot;dumb&quot; installer - a simple archive of files</td>
</tr>
<tr>
<td><code>distutils.command.bdist_msi</code></td>
<td>Build a binary distribution as a Windows MSI file</td>
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<tr>
<td><code>distutils.command.bdist_packager</code></td>
<td>Abstract base class for packagers</td>
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<tr>
<td><code>distutils.command.bdist_rpm</code></td>
<td>Build a binary distribution as a Redhat RPM and SRPM</td>
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<tr>
<td><code>distutils.command.bdist_wininst</code></td>
<td>Build a Windows installer</td>
</tr>
<tr>
<td><code>distutils.command.build</code></td>
<td>Build all files of a package</td>
</tr>
<tr>
<td><code>distutils.command.build_clib</code></td>
<td>Build any C libraries in a package</td>
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<tr>
<td><code>distutils.command.build_ext</code></td>
<td>Build any extensions in a package</td>
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<tr>
<td><code>distutils.command.build_py</code></td>
<td>Build the .py/.pyc files of a package</td>
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<td><code>distutils.command.build_scripts</code></td>
<td>Build the scripts of a package</td>
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<tr>
<td><code>distutils.command.check</code></td>
<td>Check the metadata of a package</td>
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<td><code>distutils.command.clean</code></td>
<td>Clean a package build area</td>
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<td><code>distutils.command.config</code></td>
<td>Perform package configuration</td>
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<td><code>distutils.command.install</code></td>
<td>Install a package</td>
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<td><code>distutils.command.install_data</code></td>
<td>Install data files from a package</td>
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</table>
**distutils.command.install_headers**
Install C/C++ header files from a package

**distutils.command.install_lib**
Install library files from a package

**distutils.command.install_scripts**
Install script files from a package

**distutils.command.register**
Register a module with the Python Package Index

**distutils.command.sdist**
Build a source distribution

**distutils.core**
The core Distutils functionality

**distutils.cygwinccompiler**
Provides the debug flag for distutils

**distutils.debug**
Utility functions for simple dependency checking

**distutils.dep_util**
Utility functions for operating on directories and directory trees

**distutils.dist**
Provides the Distribution class, which represents the module distribution being built-installed/distributed

**distutils.errors**
Provides standard distutils exceptions

**distutils.extension**
Provides the Extension class, used to describe C/C++ extension modules in setup scripts

**distutils.fancy_getopt**
Additional getopt functionality
distutils.file_util
Utility functions for operating on single files

distutils.filelist
The FileList class, used for poking about the file system and building lists of files.

distutils.log
A simple logging mechanism, 282-style

distutils.msvccompiler
Microsoft Compiler

distutils.spawn
Provides the spawn() function

distutils.sysconfig
Low-level access to configuration information of the Python interpreter.

distutils.text_file
provides the TextFile class, a simple interface to text files

distutils.unixccompiler
UNIX C Compiler

distutils.util
Miscellaneous other utility functions

distutils.version
implements classes that represent module version numbers.

doctest
Test pieces of code within docstrings.

dummy_threading
Drop-in replacement for the threading module.

e
email
Package supporting the parsing, manipulating, and generating email messages, including MIME documents.

email.charset
Character Sets
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<tr>
<th>Module</th>
<th>Description</th>
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<td><code>email.contentmanager</code></td>
<td>Storing and Retrieving Content from MIME Parts</td>
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<td><code>email.encoders</code></td>
<td>Encoders for email message payloads.</td>
</tr>
<tr>
<td><code>email.errors</code></td>
<td>The exception classes used by the email package.</td>
</tr>
<tr>
<td><code>email.generator</code></td>
<td>Generate flat text email messages from a message structure.</td>
</tr>
<tr>
<td><code>email.header</code></td>
<td>Representing non-ASCII headers</td>
</tr>
<tr>
<td><code>email.headerregistry</code></td>
<td>Automatic Parsing of headers based on the field name</td>
</tr>
<tr>
<td><code>email.iterators</code></td>
<td>Iterate over a message object tree.</td>
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<tr>
<td><code>email.message</code></td>
<td>The base class representing email messages.</td>
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<tr>
<td><code>email.mime</code></td>
<td>Build MIME messages.</td>
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<tr>
<td><code>email.parser</code></td>
<td>Parse flat text email messages to produce a message object structure.</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><code>email.policy</code></td>
<td>Controlling the parsing and generating of messages</td>
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<tr>
<td><code>email.utils</code></td>
<td>Miscellaneous email package utilities.</td>
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<td><code>encodings</code></td>
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<td><code>encodings.idna</code></td>
<td>Internationalized Domain Names implementation Windows ANSI</td>
</tr>
<tr>
<td>Module</td>
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<td>--------------------------------------------------</td>
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<td>encodings.mbcsc</td>
<td>codepage</td>
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<td>encodings.utf_8_sig</td>
<td>UTF-8 codec with BOM signature</td>
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<td>ensurepip</td>
<td>Bootstrapping the &quot;pip&quot; installer into an existing Python installation or virtual environment.</td>
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<td>enum</td>
<td>Implementation of an enumeration class.</td>
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<td>errno</td>
<td>Standard errno system symbols.</td>
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<td>f</td>
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<td>faulthandler</td>
<td>Dump the Python traceback.</td>
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<td>fcntl (Unix)</td>
<td>The fcntl() and ioctl() system calls.</td>
</tr>
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<td>filecmp</td>
<td>Compare files efficiently.</td>
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<tr>
<td>fileinput</td>
<td>Loop over standard input or a list of files.</td>
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<tr>
<td>fnmatch</td>
<td>Unix shell style filename pattern matching.</td>
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<td>formatter</td>
<td>Deprecated: Generic output formatter and device interface.</td>
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<td>fpectl (Unix)</td>
<td>Provide control for floating point exception handling.</td>
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<td>fractions</td>
<td>Rational numbers.</td>
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<td>ftplib</td>
<td>FTP protocol client (requires sockets).</td>
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<td>functools</td>
<td>Higher-order functions and operations on</td>
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callable objects.

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<th>g</th>
<th>gc</th>
<th>Interface to the cycle-detecting garbage collector.</th>
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<td>g</td>
<td>getopt</td>
<td>Portable parser for command line options; support both short and long option names.</td>
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<tr>
<td>g</td>
<td>getpass</td>
<td>Portable reading of passwords and retrieval of the userid.</td>
</tr>
<tr>
<td>g</td>
<td>gettext</td>
<td>Multilingual internationalization services.</td>
</tr>
<tr>
<td>g</td>
<td>glob</td>
<td>Unix shell style pathname pattern expansion.</td>
</tr>
<tr>
<td>g</td>
<td>grp (Unix)</td>
<td>The group database (getgrnam() and friends).</td>
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<tr>
<td>g</td>
<td>gzip</td>
<td>Interfaces for gzip compression and decompression using file objects.</td>
</tr>
</tbody>
</table>

<p>| h  | hashlib | Secure hash and message digest algorithms. |
| h  | heapq | Heap queue algorithm (a.k.a. priority queue). |
| h  | hmac | Keyed-Hashing for Message Authentication (HMAC) implementation |</p>
<table>
<thead>
<tr>
<th>Package</th>
<th>Description</th>
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<tr>
<td>html</td>
<td>Helpers for manipulating HTML.</td>
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<td>html.entities</td>
<td>Definitions of HTML general entities.</td>
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<tr>
<td>html.parser</td>
<td>A simple parser that can handle HTML and XHTML.</td>
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<td>http</td>
<td>HTTP status codes and messages</td>
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<td>http.client</td>
<td>HTTP and HTTPS protocol client (requires sockets).</td>
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<td>http.cookiejar</td>
<td>Classes for automatic handling of HTTP cookies.</td>
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<tr>
<td>http.cookies</td>
<td>Support for HTTP state management (cookies).</td>
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<td>http.server</td>
<td>HTTP server and request handlers.</td>
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<tr>
<td>imaplib</td>
<td>IMAP4 protocol client (requires sockets).</td>
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<td>imghdr</td>
<td>Determine the type of image contained in a file or byte stream.</td>
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<td>imp</td>
<td>Deprecated: Access the implementation of the import statement.</td>
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<tr>
<td>importlib</td>
<td>The implementation of the import machinery.</td>
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<tr>
<td>importlib.abc</td>
<td>Abstract base classes related to import</td>
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<td>importlib.machinery</td>
<td>Importers and path hooks</td>
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<tr>
<td>Package</td>
<td>Description</td>
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<td>importlib.util</td>
<td>Utility code for importers</td>
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<tr>
<td>inspect</td>
<td>Extract information and source code from live objects.</td>
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<td>io</td>
<td>Core tools for working with streams.</td>
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<td>ipaddress</td>
<td>IPv4/IPv6 manipulation library.</td>
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<td>itertools</td>
<td>Functions creating iterators for efficient looping.</td>
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<td>j</td>
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<td>json</td>
<td>Encode and decode the JSON format.</td>
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<td>json.tool</td>
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<td>k</td>
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<td>keyword</td>
<td>Test whether a string is a keyword in Python.</td>
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<td>lib2to3</td>
<td>the 2to3 library</td>
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<tr>
<td>linecache</td>
<td>This module provides random access to individual lines from text files.</td>
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<td>locale</td>
<td>Internationalization services.</td>
</tr>
<tr>
<td>logging</td>
<td>Flexible event logging system for applications.</td>
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<td>logging.config</td>
<td>Configuration of the logging module.</td>
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<td>logging.handlers</td>
<td>Handlers for the logging module.</td>
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<td>Description</td>
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<td>------------------------------------------------------------------------------</td>
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<tr>
<td><strong>lzma</strong></td>
<td>A Python wrapper for the liblzma compression library.</td>
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<td><strong>m</strong></td>
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</tr>
<tr>
<td>macpath</td>
<td>Mac OS 9 path manipulation functions.</td>
</tr>
<tr>
<td>mailbox</td>
<td>Manipulate mailboxes in various formats.</td>
</tr>
<tr>
<td>mailcap</td>
<td>Mailcap file handling.</td>
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<tr>
<td>marshal</td>
<td>Convert Python objects to streams of bytes and back (with different constraints).</td>
</tr>
<tr>
<td>math</td>
<td>Mathematical functions (sin() etc.).</td>
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<tr>
<td>mimetypes</td>
<td>Mapping of filename extensions to MIME types.</td>
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<tr>
<td>mmap</td>
<td>Interface to memory-mapped files for Unix and Windows.</td>
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<td>modulefinder</td>
<td>Find modules used by a script.</td>
</tr>
<tr>
<td>msilib</td>
<td>Creation of Microsoft Installer files, and CAB files.</td>
</tr>
<tr>
<td>msvcruntime</td>
<td>Miscellaneous useful routines from the MS VC++ runtime.</td>
</tr>
<tr>
<td>multiprocessing</td>
<td>Process-based parallelism.</td>
</tr>
<tr>
<td>multiprocessing.connection</td>
<td>API for dealing with sockets.</td>
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<tr>
<td>multiprocessing.dummy</td>
<td>Dumb wrapper around</td>
</tr>
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</table>
### multiprocessing.managers

Share data between process with shared objects.

### multiprocessing.pool

Create pools of processes.

### multiprocessing.sharedctypes

Allocate ctypes objects from shared memory.

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<th>n</th>
<th>netrc</th>
<th>Loading of .netrc files.</th>
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<td>nis (Unix)</td>
<td>Interface to Sun's NIS (Yellow Pages) library.</td>
<td></td>
</tr>
<tr>
<td>nntplib</td>
<td>NNTP protocol client (requires sockets).</td>
<td></td>
</tr>
<tr>
<td>numbers</td>
<td>Numeric abstract base classes (Complex, Real, Integral, etc.).</td>
<td></td>
</tr>
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</table>

<table>
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<th>o</th>
<th>operator</th>
<th>Functions corresponding to the standard operators.</th>
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<td>optparse</td>
<td><strong>Deprecated:</strong> Command-line option parsing library.</td>
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<tr>
<td>os</td>
<td>Miscellaneous operating system interfaces.</td>
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<td>os.path</td>
<td>Operations on pathnames.</td>
<td></td>
</tr>
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<td>ossaudiodev (Linux, FreeBSD)</td>
<td>Access to OSS-compatible audio devices.</td>
<td></td>
</tr>
</tbody>
</table>
parser
Access parse trees for Python source code.

pathlib
Object-oriented filesystem paths

pdb
The Python debugger for interactive interpreters.

pickle
Convert Python objects to streams of bytes and back.

pickletools
Contains extensive comments about the pickle protocols and pickle-machine opcodes, as well as some useful functions.

pipes (Unix)
A Python interface to Unix shell pipelines.

pkgutil
Utilities for the import system.

platform
Retrieves as much platform identifying data as possible.

plistlib
Generate and parse Mac OS X plist files.

poplib
POP3 protocol client (requires sockets).

posix (Unix)
The most common POSIX system calls (normally used via module os).

pprint
Data pretty printer.

profile
Python source profiler.

pstats
Statistics object for use with the profiler.
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<th>Library</th>
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<td>pty (Linux)</td>
<td>Pseudo-Terminal Handling for Linux.</td>
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<td>pwd (Unix)</td>
<td>The password database (getpwnam() and friends).</td>
</tr>
<tr>
<td>py_compile</td>
<td>Generate byte-code files from Python source files.</td>
</tr>
<tr>
<td>pyclbr</td>
<td>Supports information extraction for a Python class browser.</td>
</tr>
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<td>pydoc</td>
<td>Documentation generator and online help system.</td>
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<tr>
<td>queue</td>
<td>A synchronized queue class.</td>
</tr>
<tr>
<td>quopri</td>
<td>Encode and decode files using the MIME quoted-printable encoding.</td>
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<tr>
<td>random</td>
<td>Generate pseudo-random numbers with various common distributions.</td>
</tr>
<tr>
<td>re</td>
<td>Regular expression operations.</td>
</tr>
<tr>
<td>readline (Unix)</td>
<td>GNU readline support for Python.</td>
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<tr>
<td>reprlib</td>
<td>Alternate repr() implementation with size limits.</td>
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</tbody>
</table>
**resource** *(Unix)*

An interface to provide resource usage information on the current process.

**rlcompleter**

Python identifier completion, suitable for the GNU readline library.

**runpy**

Locate and run Python modules without importing them first.

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Determine type of a sound file.

socket  
Low-level networking interface.

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A framework for network servers.

spwd  (Unix)  
The shadow password database (getspnam() and friends).

sqlite3  
A DB-API 2.0 implementation using SQLite 3.x.

ssl  
TLS/SSL wrapper for socket objects

stat  
Utilities for interpreting the results of os.stat(), os.lstat() and os.fstat().

statistics  
Mathematical statistics functions

string  
Common string operations.

stringprep  
String preparation, as per RFC 3453

struct  
Interpret bytes as packed binary data.

subprocess  
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symbol  
Constants representing internal nodes of the parse tree.

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zlib
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decompression routines compatible with gzip.
What’s New In Python 3.5

Editors: Elvis Pranskevichus <elvis@magic.io>, Yury Selivanov <yury@magic.io>

This article explains the new features in Python 3.5, compared to 3.4. Python 3.5 was released on September 13, 2015. See the changelog for a full list of changes.

See also: PEP 478 - Python 3.5 Release Schedule
Summary – Release highlights

New syntax features:

- PEP 492, coroutines with async and await syntax.
- PEP 465, a new matrix multiplication operator: $a \@ b$.
- PEP 448, additional unpacking generalizations.

New library modules:

- typing: PEP 484 – Type Hints.
- zipapp: PEP 441 Improving Python ZIP Application Support.

New built-in features:

- bytes % args, bytearray % args: PEP 461 – Adding % formatting to bytes and bytearray.
- New `bytes.hex()`, `bytearray.hex()` and `memoryview.hex()` methods. (Contributed by Arnon Yaari in issue 9951.)
- `memoryview` now supports tuple indexing (including multidimensional). (Contributed by Antoine Pitrou in issue 23632.)
- Generators have a new `gi_yieldfrom` attribute, which returns the object being iterated by `yield from` expressions. (Contributed by Benno Leslie and Yury Selivanov in issue 24450.)
- A new `RecursionError` exception is now raised when maximum recursion depth is reached. (Contributed by Georg Brandl in issue 19235.)

CPython implementation improvements:

- When the LC_TYPE locale is the POSIX locale (C locale), `sys.stdin` and `sys.stdout` now use the surrogateescape
error handler, instead of the strict error handler. (Contributed by Victor Stinner in issue 19977.)

- .pyo files are no longer used and have been replaced by a more flexible scheme that includes the optimization level explicitly in .pyc name. (See PEP 488 overview.)
- Built-in and extension modules are now initialized in a multi-phase process, which is similar to how Python modules are loaded. (See PEP 489 overview.)

Significant improvements in the standard library:

- `collections.OrderedDict` is now implemented in C, which makes it 4 to 100 times faster.
- The `ssl` module gained support for Memory BIO, which decouples SSL protocol handling from network IO.
- The new `os.scandir()` function provides a better and significantly faster way of directory traversal.
- `functools.lru_cache()` has been mostly reimplemented in C, yielding much better performance.
- The new `subprocess.run()` function provides a streamlined way to run subprocesses.
- The `traceback` module has been significantly enhanced for improved performance and developer convenience.

Security improvements:

- SSLv3 is now disabled throughout the standard library. It can still be enabled by instantiating a `ssl.SSLContext` manually. (See issue 22638 for more details; this change was backported to CPython 3.4 and 2.7.)
- HTTP cookie parsing is now stricter, in order to protect against potential injection attacks. (Contributed by Antoine Pitrou in issue 22796.)
Windows improvements:

- A new installer for Windows has replaced the old MSI. See Using Python on Windows for more information.
- Windows builds now use Microsoft Visual C++ 14.0, and extension modules should use the same.

Please read on for a comprehensive list of user-facing changes, including many other smaller improvements, CPython optimizations, deprecations, and potential porting issues.
New Features

PEP 492 - Coroutines with async and await syntax

PEP 492 greatly improves support for asynchronous programming in Python by adding awaitable objects, coroutine functions, asynchronous iteration, and asynchronous context managers.

Coroutine functions are declared using the new async def syntax:

```python
>>> async def coro():
    ...    return 'spam'
```

Inside a coroutine function, the new await expression can be used to suspend coroutine execution until the result is available. Any object can be awaited, as long as it implements the awaitable protocol by defining the __await__() method.

PEP 492 also adds async for statement for convenient iteration over asynchronous iterables.

An example of a rudimentary HTTP client written using the new syntax:

```python
import asyncio
async def http_get(domain):
    reader, writer = await asyncio.open_connection(domain)
    writer.write(b'
'.join([
    b'GET / HTTP/1.1',
    b'Host: %b' % domain.encode('latin-1'),
    b'Connection: close',
    b'', b''])
```
```python
async for line in reader:
    print('>>>', line)

writer.close()

loop = asyncio.get_event_loop()
try:
    loop.run_until_complete(http_get('example.com'))
finally:
    loop.close()
```

Similarly to asynchronous iteration, there is a new syntax for asynchronous context managers. The following script:

```python
import asyncio
async def coro(name, lock):
    print('coro {}: waiting for lock'.format(name))
    async with lock:
        print('coro {}: holding the lock'.format(name))
        await asyncio.sleep(1)
        print('coro {}: releasing the lock'.format(name))

loop = asyncio.get_event_loop()
lock = asyncio.Lock()
coros = asyncio.gather(coro(1, lock), coro(2, lock))
try:
    loop.run_until_complete(coros)
finally:
    loop.close()
```

will output:
Note that both `async for` and `async with` can only be used inside a coroutine function declared with `async def`.

Coroutine functions are intended to be run inside a compatible event loop, such as the `asyncio` loop.

**See also:**

PEP 492 – Coroutines with async and await syntax
PEP written and implemented by Yury Selivanov.

PEP 465 - A dedicated infix operator for matrix multiplication

PEP 465 adds the `@` infix operator for matrix multiplication. Currently, no built-in Python types implement the new operator, however, it can be implemented by defining `__matmul__()`, `__rmatmul__()`, and `__imatmul__()` for regular, reflected, and in-place matrix multiplication. The semantics of these methods is similar to that of methods defining other infix arithmetic operators.

Matrix multiplication is a notably common operation in many fields of mathematics, science, engineering, and the addition of `@` allows writing cleaner code:
\[ S = (H \circ \beta - r).T \circ \text{inv}(H \circ V \circ H.T) \circ (H \circ \beta) \]

instead of:

\[ S = \text{dot}((\text{dot}(H, \beta) - r).T, \text{dot}(\text{inv}(\text{dot}(\text{dot}(H, V), H.T)), \text{dot}(H, \beta)) \]

NumPy 1.10 has support for the new operator:

```python
>>> import numpy

>>> x = numpy.ones(3)
>>> x
array([ 1., 1., 1.])

>>> m = numpy.eye(3)
>>> m
array([[ 1., 0., 0.],
       [ 0., 1., 0.],
       [ 0., 0., 1.]])

>>> x @ m
array([ 1., 1., 1.])
```

See also:

**PEP 465** – A dedicated infix operator for matrix multiplication

PEP written by Nathaniel J. Smith; implemented by Benjamin Peterson.

**PEP 448** - Additional Unpacking Generalizations

**PEP 448** extends the allowed uses of the * iterable unpacking
operator and ** dictionary unpacking operator. It is now possible to use an arbitrary number of unpackings in function calls:

```python
>>> print(*[1], *[2], 3, *[4, 5])
1 2 3 4 5
```

```python
>>> def fn(a, b, c, d):
...     print(a, b, c, d)
...
```

```python
>>> fn(**{ 'a': 1, 'c': 3 }, **{ 'b': 2, 'd': 4 })
1 2 3 4
```

Similarly, tuple, list, set, and dictionary displays allow multiple unpackings:

```python
>>> *range(4), 4
(0, 1, 2, 3, 4)
```

```python
>>> [*range(4), 4]
[0, 1, 2, 3, 4]
```

```python
>>> {*range(4), 4, *(5, 6, 7)}
{0, 1, 2, 3, 4, 5, 6, 7}
```

```python
>>> {'x': 1, **{'y': 2}}
{'x': 1, 'y': 2}
```

See also:

**PEP 448 – Additional Unpacking Generalizations**

PEP written by Joshua Landau; implemented by Neil Girdhar, Thomas Wouters, and Joshua Landau.
PEP 461 - % formatting support for bytes and bytearray

**PEP 461** adds support for the `% interpolation operator to bytes and bytearray.

While interpolation is usually thought of as a string operation, there are cases where interpolation on bytes or bytearrays makes sense, and the work needed to make up for this missing functionality detracts from the overall readability of the code. This issue is particularly important when dealing with wire format protocols, which are often a mixture of binary and ASCII compatible text.

Examples:

```python
>>> b'Hello %b!' % b'World'
b'Hello World!'

>>> b'x=%i y=%f' % (1, 2.5)
b'x=1 y=2.500000'
```

Unicode is not allowed for `%b`, but it is accepted by `%a` (equivalent of `repr(obj).encode('ascii', 'backslashreplace')`):

```python
>>> b'Hello %b!' % 'World'
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: %b requires bytes, or an object that implements __bytes__, not 'str'

>>> b'price: %a % '10€'
b'price: '10\u20ac''
```

Note that `%s` and `%r` conversion types, although supported, should
only be used in codebases that need compatibility with Python 2.

See also:

**PEP 461 – Adding % formatting to bytes and bytearray**

PEP written by Ethan Furman; implemented by Neil Schemenauer and Ethan Furman.

**PEP 484 - Type Hints**

Function annotation syntax has been a Python feature since version 3.0 (**PEP 3107**), however the semantics of annotations has been left undefined.

Experience has shown that the majority of function annotation uses were to provide type hints to function parameters and return values. It became evident that it would be beneficial for Python users, if the standard library included the base definitions and tools for type annotations.

**PEP 484** introduces a provisional module to provide these standard definitions and tools, along with some conventions for situations where annotations are not available.

For example, here is a simple function whose argument and return type are declared in the annotations:

```python
def greeting(name: str) -> str:
    return 'Hello ' + name
```

While these annotations are available at runtime through the usual `__annotations__` attribute, *no automatic type checking happens at runtime*. Instead, it is assumed that a separate off-line type checker
(e.g. mypy) will be used for on-demand source code analysis.

The type system supports unions, generic types, and a special type named Any which is consistent with (i.e. assignable to and from) all types.

See also:

- typing module documentation
- **PEP 484** – Type Hints
  PEP written by Guido van Rossum, Jukka Lehtosalo, and Łukasz Langa; implemented by Guido van Rossum.
- **PEP 483** – The Theory of Type Hints
  PEP written by Guido van Rossum

PEP 471 - os.scandir() function – a better and faster directory iterator

**PEP 471** adds a new directory iteration function, os.scandir(), to the standard library. Additionally, os.walk() is now implemented using scandir, which makes it 3 to 5 times faster on POSIX systems and 7 to 20 times faster on Windows systems. This is largely achieved by greatly reducing the number of calls to os.stat() required to walk a directory tree.

Additionally, scandir returns an iterator, as opposed to returning a list of file names, which improves memory efficiency when iterating over very large directories.

The following example shows a simple use of os.scandir() to display all the files (excluding directories) in the given path that don't
start with '. '. The `entry.is_file()` call will generally not make an additional system call:

```python
for entry in os.scandir(path):
    if not entry.name.startswith('.') and entry.is_file():
        print(entry.name)
```

See also:

- **PEP 471** – `os.scandir()` function – a better and faster directory iterator
  PEP written and implemented by Ben Hoyt with the help of Victor Stinner.

**PEP 475: Retry system calls failing with EINTR**

An `errno.EINTR` error code is returned whenever a system call, that is waiting for I/O, is interrupted by a signal. Previously, Python would raise `InterruptedError` in such cases. This meant that, when writing a Python application, the developer had two choices:

1. Ignore the `InterruptedError`.
2. Handle the `InterruptedError` and attempt to restart the interrupted system call at every call site.

The first option makes an application fail intermittently. The second option adds a large amount of boilerplate that makes the code nearly unreadable. Compare:

```python
print("Hello World")
```

and:
while True:
    try:
        print("Hello World")
        break
    except InterruptedError:
        continue

PEP 475 implements automatic retry of system calls on EINTR. This removes the burden of dealing with EINTR or InterruptedError in user code in most situations and makes Python programs, including the standard library, more robust. Note that the system call is only retried if the signal handler does not raise an exception.

Below is a list of functions which are now retried when interrupted by a signal:

- `open()` and `io.open()`;
- functions of the `faulthandler` module;
- `os` functions: `fchdir()`, `fchmod()`, `fchown()`, `fdatasync()`, `fstat()`, `fstatvfs()`, `fsync()`, `ftruncate()`, `mkfifo()`, `mknod()`, `open()`, `posix_fadvise()`, `posix_fallocate()`, `pread()`, `pwrite()`, `read()`, `readv()`, `sendfile()`, `wait3()`, `wait4()`, `wait()`, `waitid()`, `waitpid()`, `write()`, `writev()`;
- special cases: `os.close()` and `os.dup2()` now ignore EINTR errors; the syscall is not retried (see the PEP for the rationale);
- `select` functions: `devpoll.poll()`, `epoll.poll()`, `kqueue.control()`, `poll.poll()`, `select()``;
- methods of the `socket` class: `accept()`, `connect()` (except for non-blocking sockets), `recv()`, `recvfrom()`, `recvmsg()`, `send()`, `sendall()`, `sendmsg()`, `sendto()``;
- `signal.sigtimedwait()` and `signal.sigwaitinfo()``;
- `time.sleep()`.
See also:

PEP 475 – Retry system calls failing with EINTR

PEP and implementation written by Charles-François Natali and Victor Stinner, with the help of Antoine Pitrou (the French connection).

PEP 479: Change StopIteration handling inside generators

The interaction of generators and StopIteration in Python 3.4 and earlier was sometimes surprising, and could conceal obscure bugs. Previously, StopIteration raised accidentally inside a generator function was interpreted as the end of the iteration by the loop construct driving the generator.

PEP 479 changes the behavior of generators: when a StopIteration exception is raised inside a generator, it is replaced with a RuntimeError before it exits the generator frame. The main goal of this change is to ease debugging in the situation where an unguarded next() call raises StopIteration and causes the iteration controlled by the generator to terminate silently. This is particularly pernicious in combination with the yield from construct.

This is a backwards incompatible change, so to enable the new behavior, a __future__ import is necessary:

```python
>>> from __future__ import generator_stop

>>> def gen():
...     next(iter([]))
...     yield
```
>>> next(gen())
Traceback (most recent call last):
  File "<stdin>", line 2, in gen
StopIteration

The above exception was the direct cause of the following exception:

Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  RuntimeError: generator raised StopIteration

Without a __future__ import, a PendingDeprecationWarning will be raised whenever a StopIteration exception is raised inside a generator.

See also:

**PEP 479** – **Change StopIteration handling inside generators**

PEP written by Chris Angelico and Guido van Rossum. Implemented by Chris Angelico, Yury Selivanov and Nick Coghlan.

PEP 485: A function for testing approximate equality

**PEP 485** adds the `math.isclose()` and `cmath.isclose()` functions which tell whether two values are approximately equal or “close” to each other. Whether or not two values are considered close is determined according to given absolute and relative tolerances. Relative tolerance is the maximum allowed difference between `isclose` arguments, relative to the larger absolute value:
>>> import math
>>> a = 5.0
>>> b = 4.99998
>>> math.isclose(a, b, rel_tol=1e-5)
True
>>> math.isclose(a, b, rel_tol=1e-6)
False

It is also possible to compare two values using absolute tolerance, which must be a non-negative value:

>>> import math
>>> a = 5.0
>>> b = 4.99998
>>> math.isclose(a, b, abs_tol=0.00003)
True
>>> math.isclose(a, b, abs_tol=0.00001)
False

See also:

**PEP 485** – A function for testing approximate equality

PEP written by Christopher Barker; implemented by Chris Barker and Tal Einat.

**PEP 486**: Make the Python Launcher aware of virtual environments

**PEP 486** makes the Windows launcher (see **PEP 397**) aware of an active virtual environment. When the default interpreter would be used and the VIRTUAL_ENV environment variable is set, the interpreter in the virtual environment will be used.
PEP 486 – Make the Python Launcher aware of virtual environments
PEP written and implemented by Paul Moore.

PEP 488: Elimination of PYO files

PEP 488 does away with the concept of .pyo files. This means that .pyc files represent both unoptimized and optimized bytecode. To prevent the need to constantly regenerate bytecode files, .pyc files now have an optional opt- tag in their name when the bytecode is optimized. This has the side-effect of no more bytecode file name clashes when running under either -O or -OO. Consequently, bytecode files generated from -O, and -OO may now exist simultaneously. importlib.util.cache_from_source() has an updated API to help with this change.

PEP 489: Multi-phase extension module initialization

PEP 489 updates extension module initialization to take advantage of the two step module loading mechanism introduced by PEP 451 in Python 3.4.

This change brings the import semantics of extension modules that
opt-in to using the new mechanism much closer to those of Python source and bytecode modules, including the ability to use any valid identifier as a module name, rather than being restricted to ASCII.

See also:

**PEP 489** – Multi-phase extension module initialization

PEP written by Petr Viktorin, Stefan Behnel, and Nick Coghlan; implemented by Petr Viktorin.
**Other Language Changes**

Some smaller changes made to the core Python language are:

- Added the "namereplace" error handlers. The "backslashreplace" error handlers now work with decoding and translating. (Contributed by Serhiy Storchaka in issue 19676 and issue 22286.)
- The `-b` option now affects comparisons of `bytes` with `int`. (Contributed by Serhiy Storchaka in issue 23681.)
- New Kazakh `kz1048` and Tajik `koi8_t` codecs. (Contributed by Serhiy Storchaka in issue 22682 and issue 22681.)
- Property docstrings are now writable. This is especially useful for `collections.namedtuple()` docstrings. (Contributed by Berker Peksag in issue 24064.)
- Circular imports involving relative imports are now supported. (Contributed by Brett Cannon and Antoine Pitrou in issue 17636.)
New Modules

typing

The new **typing provisional** module provides standard definitions and tools for function type annotations. See [Type Hints](#) for more information.

zipapp

The new **zipapp** module (specified in **PEP 441**) provides an API and command line tool for creating executable Python Zip Applications, which were introduced in Python 2.6 in issue **1739468**, but which were not well publicized, either at the time or since.

With the new module, bundling your application is as simple as putting all the files, including a `__main__.py` file, into a directory `myapp` and running:

```
$ python -m zipapp myapp
$ python myapp.pyz
```

The module implementation has been contributed by Paul Moore in issue **23491**.

See also: **PEP 441** – Improving Python ZIP Application Support
Improved Modules

argparse

The ArgumentParser class now allows to disable abbreviated usage of long options by setting allow_abbrev to False. (Contributed by Jonathan Paugh, Steven Bethard, paul j3 and Daniel Eriksson in issue 14910.)

asyncio

Since the asyncio module is provisional, all changes introduced in Python 3.5 have also been backported to Python 3.4.x.

Notable changes in the asyncio module since Python 3.4.0:

- New debugging APIs: loop.set_debug() and loop.get_debug() methods. (Contributed by Victor Stinner.)
- The proactor event loop now supports SSL. (Contributed by Antoine Pitrou and Victor Stinner in issue 22560.)
- A new loop.is_closed() method to check if the event loop is closed. (Contributed by Victor Stinner in issue 21326.)
- A new loop.create_task() to conveniently create and schedule a new Task for a coroutine. The create_task method is also used by all asyncio functions that wrap coroutines into tasks, such as asyncio.wait(), asyncio.gather(), etc. (Contributed by Victor Stinner.)
- A new transport.get_write_buffer_limits() method to inquire for high- and low- water limits of the flow control. (Contributed by Victor Stinner.)
- The async() function is deprecated in favor of ensure_future(). (Contributed by Yury Selivanov.)
• New `loop.set_task_factory()` and `loop.set_task_factory()` methods to customize the task factory that `loop.create_task()` method uses. (Contributed by Yury Selivanov.)

• New `Queue.join()` and `Queue.task_done()` queue methods. (Contributed by Victor Stinner.)

• The `JoinableQueue` class was removed, in favor of the `asyncio.Queue` class. (Contributed by Victor Stinner.)

Updates in 3.5.1:

• The `ensure_future()` function and all functions that use it, such as `loop.run_until_complete()`, now accept all kinds of `awaitable objects`. (Contributed by Yury Selivanov.)

bz2

The `BZ2Decompressor.decompress` method now accepts an optional `max_length` argument to limit the maximum size of decompressed data. (Contributed by Nikolaus Rath in issue 15955.)

cgi

The `FieldStorage` class now supports the context manager protocol. (Contributed by Berker Peksag in issue 20289.)

cmath

A new function `isclose()` provides a way to test for approximate equality. (Contributed by Chris Barker and Tal Einat in issue 24270.)
The `InteractiveInterpreter.showtraceback()` method now prints the full chained traceback, just like the interactive interpreter. (Contributed by Claudiu Popa in issue 17442.)

collections

The `OrderedDict` class is now implemented in C, which makes it 4 to 100 times faster. (Contributed by Eric Snow in issue 16991.)

`OrderedDict.items()`, `OrderedDict.keys()`, `OrderedDict.values()` views now support `reversed()` iteration. (Contributed by Serhiy Storchaka in issue 19505.)

The `deque` class now defines `index()`, `insert()`, and `copy()`, and supports the `+` and `*` operators. This allows deques to be recognized as a `MutableSequence` and improves their substitutability for lists. (Contributed by Raymond Hettinger in issue 23704.)

Docstrings produced by `namedtuple()` can now be updated:

```python
Point = namedtuple('Point', ['x', 'y'])
Point.__doc__ += ': Cartesian coordinate'
Point.x.__doc__ = 'abscissa'
Point.y.__doc__ = 'ordinate'
```

(Contributed by Berker Peksag in issue 24064.)

The `UserString` class now implements the `__getnewargs__()`, `__rmod__()`, `casefold()`, `format_map()`, `isprintable()`, and
maketrans() methods to match the corresponding methods of str. (Contributed by Joe Jevnik in issue 22189.)

collections.abc

The Sequence.index() method now accepts start and stop arguments to match the corresponding methods of tuple, list, etc. (Contributed by Devin Jeanpierre in issue 23086.)

A new Generator abstract base class. (Contributed by Stefan Behnel in issue 24018.)

New Awaitable, Coroutine, AsyncIterator, and AsyncIterable abstract base classes. (Contributed by Yury Selivanov in issue 24184.)

For earlier Python versions, a backport of the new ABCs is available in an external PyPI package.

compileall

A new compileall option, -j N, allows to run N workers simultaneously to perform parallel bytecode compilation. The compile_dir() function has a corresponding workers parameter. (Contributed by Claudiu Popa in issue 16104.)

Another new option, -r, allows to control the maximum recursion level for subdirectories. (Contributed by Claudiu Popa in issue 19628.)

The -q command line option can now be specified more than once, in which case all output, including errors, will be suppressed. The corresponding quiet parameter in compile_dir(),
compile_file(), and compile_path() can now accept an integer value indicating the level of output suppression. (Contributed by Thomas Kluyver in issue 21338.)

concurrent.futures

The Executor.map() method now accepts a chunksize argument to allow batching of tasks to improve performance when ProcessPoolExecutor() is used. (Contributed by Dan O'Reilly in issue 11271.)

The number of workers in the ThreadPoolExecutor constructor is optional now. The default value is 5 times the number of CPUs. (Contributed by Claudiu Popa in issue 21527.)

configparser

configparser now provides a way to customize the conversion of values by specifying a dictionary of converters in the ConfigParser constructor, or by defining them as methods in ConfigParser subclasses. Converters defined in a parser instance are inherited by its section proxies.

Example:

```python
>>> import configparser
>>> conv = {}
>>> conv['list'] = lambda v: [e.strip() for e in v.split]
>>> cfg = configparser.ConfigParser(converters=conv)
>>> cfg.read_string(""
... [s]
... list = a b c d e f g
... """)
```
```python
>>> cfg.get('s', 'list')
'a b c d e f g'
>>> cfg.getlist('s', 'list')
['a', 'b', 'c', 'd', 'e', 'f', 'g']
>>> section = cfg['s']
>>> section.getlist('list')
['a', 'b', 'c', 'd', 'e', 'f', 'g']
```

(Contributed by Łukasz Langa in issue 18159.)

**contextlib**

The new `redirect_stderr()` context manager (similar to `redirect_stdout()`) makes it easier for utility scripts to handle inflexible APIs that write their output to `sys.stderr` and don't provide any options to redirect it:

```python
>>> import contextlib, io, logging
>>> f = io.StringIO()
>>> with contextlib.redirect_stderr(f):
...     logging.warning('warning')
...
>>> f.getvalue()
'WARNING:root:warning
'
```

(Contributed by Berker Peksag in issue 22389.)

**CSV**

The `writerow()` method now supports arbitrary iterables, not just sequences. (Contributed by Serhiy Storchaka in issue 23171.)
curses

The new `update_lines_cols()` function updates the LINES and COLS environment variables. This is useful for detecting manual screen resizing. (Contributed by Arnon Yaari in issue 4254.)

dbm

dumb.open always creates a new database when the flag has the value "n". (Contributed by Claudiu Popa in issue 18039.)

difflib

The charset of HTML documents generated by `HtmlDiff.make_file()` can now be customized by using a new `charset` keyword-only argument. The default charset of HTML document changed from "ISO-8859-1" to "utf-8". (Contributed by Berker Peksag in issue 2052.)

The `diff_bytes()` function can now compare lists of byte strings. This fixes a regression from Python 2. (Contributed by Terry J. Reedy and Greg Ward in issue 17445.)

distutils

Both the build and build_ext commands now accept a -j option to enable parallel building of extension modules. (Contributed by Antoine Pitrou in issue 5309.)

The `distutils` module now supports xz compression, and can be
enabled by passing xztar as an argument to bdist --format. (Contributed by Serhiy Storchaka in issue 16314.)

doctest

The DocTestSuite() function returns an empty unittest.TestSuite if module contains no docstrings, instead of raising ValueError. (Contributed by Glenn Jones in issue 15916.)

e-mail

A new policy option Policy.mangle_from_ controls whether or not lines that start with "From " in email bodies are prefixed with a ">" character by generators. The default is True for compat32 and False for all other policies. (Contributed by Milan Oberkirch in issue 20098.)

A new Message.get_content_disposition() method provides easy access to a canonical value for the Content-Disposition header. (Contributed by Abhilash Raj in issue 21083.)

A new policy option EmailPolicy.utf8 can be set to True to encode email headers using the UTF-8 charset instead of using encoded words. This allows Messages to be formatted according to RFC 6532 and used with an SMTP server that supports the RFC 6531 SMTPUTF8 extension. (Contributed by R. David Murray in issue 24211.)

The mime.text.MIMEText constructor now accepts a charset.Charset instance. (Contributed by Claude Paroz and Berker Peksag in issue 16324.)
enum

The Enum callable has a new parameter start to specify the initial number of enum values if only names are provided:

```python
>>> Animal = enum.Enum('Animal', 'cat dog', start=10)
>>> Animal.cat
<Animal.cat: 10>
>>> Animal.dog
<Animal.dog: 11>
```

(Contributed by Ethan Furman in issue 21706.)

faulthandler

The enable(), register(), dump_traceback() and dump_traceback_later() functions now accept file descriptors in addition to file-like objects. (Contributed by Wei Wu in issue 23566.)

functools

Most of the lru_cache() machinery is now implemented in C, making it significantly faster. (Contributed by Matt Joiner, Alexey Kachayev, and Serhiy Storchaka in issue 14373.)

glob

The iglob() and glob() functions now support recursive search in subdirectories, using the "***" pattern. (Contributed by Serhiy Storchaka in issue 13968.)
gzip

The mode argument of the GzipFile constructor now accepts "x" to request exclusive creation. (Contributed by Tim Heaney in issue 19222.)

heapq

Element comparison in merge() can now be customized by passing a key function in a new optional key keyword argument, and a new optional reverse keyword argument can be used to reverse element comparison:

```python
>>> import heapq
>>> a = ['9', '777', '55555']
>>> b = ['88', '6666']
>>> list(heapq.merge(a, b, key=len))
['9', '88', '777', '6666', '55555']
>>> list(heapq.merge(reversed(a), reversed(b), key=len))
['55555', '6666', '777', '88', '9']
```

(Contributed by Raymond Hettinger in issue 13742.)

http

A new HTTPStatus enum that defines a set of HTTP status codes, reason phrases and long descriptions written in English. (Contributed by Demian Brecht in issue 21793.)

http.client
HTTPConnection.getresponse() now raises a RemoteDisconnected exception when a remote server connection is closed unexpectedly. Additionally, if a ConnectionError (of which RemoteDisconnected is a subclass) is raised, the client socket is now closed automatically, and will reconnect on the next request:

```python
import http.client
conn = http.client.HTTPConnection('www.python.org')
for retries in range(3):
    try:
        conn.request('GET', '/')
        resp = conn.getresponse()
    except http.client.RemoteDisconnected:
        pass
```

(Contributed by Martin Panter in issue 3566.)

**idlelib and IDLE**

Since idlelib implements the IDLE shell and editor and is not intended for import by other programs, it gets improvements with every release. See Lib/idlelib/NEWS.txt for a cumulative list of changes since 3.4.0, as well as changes made in future 3.5.x releases. This file is also available from the IDLE Help ➤ About IDLE dialog.

**imaplib**

The IMAP4 class now supports the context manager protocol. When used in a `with` statement, the IMAP4 LOGOUT command will be called automatically at the end of the block. (Contributed by Tarek Ziadé and Serhiy Storchaka in issue 4972.)
The `imaplib` module now supports **RFC 5161** (ENABLE Extension) and **RFC 6855** (UTF-8 Support) via the `IMAP4.enable()` method. A new `IMAP4.utf8_enabled` attribute tracks whether or not **RFC 6855** support is enabled. (Contributed by Milan Oberkirch, R. David Murray, and Maciej Szulik in issue 21800.)

The `imaplib` module now automatically encodes non-ASCII string usernames and passwords using UTF-8, as recommended by the RFCs. (Contributed by Milan Oberkirch in issue 21800.)

**imghdr**

The `what()` function now recognizes the OpenEXR format (contributed by Martin Vignali and Claudiu Popa in issue 20295), and the WebP format (contributed by Fabrice Aneche and Claudiu Popa in issue 20197.)

**importlib**

The `util.LazyLoader` class allows for lazy loading of modules in applications where startup time is important. (Contributed by Brett Cannon in issue 17621.)

The `abc.InspectLoader.source_to_code()` method is now a static method. This makes it easier to initialize a module object with code compiled from a string by running `exec(code, module.__dict__)`. (Contributed by Brett Cannon in issue 21156.)

The new `util.module_from_spec()` function is now the preferred way to create a new module. As opposed to creating a `types.ModuleType` instance directly, this new function will set the
various import-controlled attributes based on the passed-in spec object. (Contributed by Brett Cannon in issue 20383.)

inspect

Both the Signature and Parameter classes are now picklable and hashable. (Contributed by Yury Selivanov in issue 20726 and issue 20334.)

A new BoundArguments.apply_defaults() method provides a way to set default values for missing arguments:

```python
>>> def foo(a, b='ham', *args): pass
>>> ba = inspect.signature(foo).bind('spam')
>>> ba.apply_defaults()
>>> ba.arguments
OrderedDict([('a', 'spam'), ('b', 'ham'), ('args', (])
```

(Contributed by Yury Selivanov in issue 24190.)

A new class method Signature.from_callable() makes subclassing of Signature easier. (Contributed by Yury Selivanov and Eric Snow in issue 17373.)

The signature() function now accepts a follow_wrapped optional keyword argument, which, when set to False, disables automatic following of __wrapped__ links. (Contributed by Yury Selivanov in issue 20691.)

A set of new functions to inspect coroutine functions and coroutine objects has been added: iscoroutine(), iscoroutinefunction(), isawaitable(),
getcoroutinelocals(), and getcoroutinestate().
(Contributed by Yury Selivanov in issue 24017 and issue 24400.)

The stack(), trace(), getouterframes(), and getinnerframes() functions now return a list of named tuples.
(Contributed by Daniel Shahaf in issue 16808.)

io

A new BufferedIOBase.readinto1() method, that uses at most one call to the underlying raw stream's RawIOBase.read() or RawIOBase.readinto() methods. (Contributed by Nikolaus Rath in issue 20578.)

ipaddress

Both the IPv4Network and IPv6Network classes now accept an (address, netmask) tuple argument, so as to easily construct network objects from existing addresses:

```python
>>> import ipaddress
>>> ipaddress.IPv4Network(('127.0.0.0', 8))
IPv4Network('127.0.0.0/8')
>>> ipaddress.IPv4Network(('127.0.0.0', '255.0.0.0'))
IPv4Network('127.0.0.0/8')
```

(Contributed by Peter Moody and Antoine Pitrou in issue 16531.)

A new reverse_pointer attribute for the IPv4Network and IPv6Network classes returns the name of the reverse DNS PTR record:
```python
>>> import ipaddress
>>> addr = ipaddress.IPv4Address('127.0.0.1')
>>> addr.reverse_pointer
'1.0.0.127.in-addr.arpa'
>>> addr6 = ipaddress.IPv6Address('::1')
>>> addr6.reverse_pointer
'1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.ip6.arpa'

(Contributed by Leon Weber in issue 20480.)

json

The **json.tool** command line interface now preserves the order of keys in JSON objects passed in input. The new `--sort-keys` option can be used to sort the keys alphabetically. (Contributed by Berker Peksag in issue 21650.)

JSON decoder now raises `JSONDecodeError` instead of `ValueError` to provide better context information about the error. (Contributed by Serhiy Storchaka in issue 19361.)

linecache

A new `lazycache()` function can be used to capture information about a non-file-based module to permit getting its lines later via `getline()`. This avoids doing I/O until a line is actually needed, without having to carry the module globals around indefinitely. (Contributed by Robert Collins in issue 17911.)

locale
A new \texttt{delocalize()} function can be used to convert a string into a normalized number string, taking the LC\_NUMERIC settings into account:

\begin{verbatim}
>>> import locale
>>> locale.setlocale(locale.LC_NUMERIC, 'de_DE.UTF-8')
>>> locale.delocalize('1.234,56')
'1234.56'
>>> locale.setlocale(locale.LC_NUMERIC, 'en_US.UTF-8')
>>> locale.delocalize('1,234.56')
'1234.56'
\end{verbatim}

(Contributed by Cédric Krier in issue 13918.)

\section*{logging}

All logging methods (\texttt{Logger log()}, \texttt{exception()}, \texttt{critical()}, \texttt{debug()}, etc.), now accept exception instances as an \texttt{exc_info} argument, in addition to boolean values and exception tuples:

\begin{verbatim}
>>> import logging
>>> try:
...    1/0
...    except ZeroDivisionError as ex:
...      logging.error('exception', exc_info=ex)
ERROR:root:exception
\end{verbatim}

(Contributed by Yury Selivanov in issue 20537.)

The \texttt{handlers.HTTPHandler} class now accepts an optional \texttt{ssl.SSLContext} instance to configure SSL settings used in an
HTTP connection. (Contributed by Alex Gaynor in issue 22788.)

The `handlers.QueueListener` class now takes a `respect_handler_level` keyword argument which, if set to True, will pass messages to handlers taking handler levels into account. (Contributed by Vinay Sajip.)

Izma

The `LZMADecompressor.decompress()` method now accepts an optional `max_length` argument to limit the maximum size of decompressed data. (Contributed by Martin Panter in issue 15955.)

math

Two new constants have been added to the `math` module: `inf` and `nan`. (Contributed by Mark Dickinson in issue 23185.)

A new function `isclose()` provides a way to test for approximate equality. (Contributed by Chris Barker and Tal Einat in issue 24270.)

A new `gcd()` function has been added. The `fractions.gcd()` function is now deprecated. (Contributed by Mark Dickinson and Serhiy Storchaka in issue 22486.)

multiprocessing

`sharedctypes.synchronized()` objects now support the context manager protocol. (Contributed by Charles-François Natali in issue 21565.)
operator

attrgetter(), itemgetter(), and methodcaller() objects now support pickling. (Contributed by Josh Rosenberg and Serhiy Storchaka in issue 22955.)

New matmul() and imatmul() functions to perform matrix multiplication. (Contributed by Benjamin Peterson in issue 21176.)

OS

The new scandir() function returning an iterator of DirEntry objects has been added. If possible, scandir() extracts file attributes while scanning a directory, removing the need to perform subsequent system calls to determine file type or attributes, which may significantly improve performance. (Contributed by Ben Hoyt with the help of Victor Stinner in issue 22524.)

On Windows, a new stat_result.st_file_attributes attribute is now available. It corresponds to the dwFileAttributes member of the BY_HANDLE_FILE_INFORMATION structure returned by GetFileInformationByHandle(). (Contributed by Ben Hoyt in issue 21719.)

The urandom() function now uses the getrandom() syscall on Linux 3.17 or newer, and getentropy() on OpenBSD 5.6 and newer, removing the need to use /dev/urandom and avoiding failures due to potential file descriptor exhaustion. (Contributed by Victor Stinner in issue 22181.)

New get_blocking() and set_blocking() functions allow to get
and set a file descriptor’s blocking mode (\texttt{0\_NONBLOCK}.)(Contributed by Victor Stinner in \texttt{issue 22054}.)

The \texttt{truncate()} and \texttt{ftruncate()} functions are now supported on Windows. (Contributed by Steve Dower in \texttt{issue 23668}.)

There is a new \texttt{os.path.commonpath()} function returning the longest common sub-path of each passed pathname. Unlike the \texttt{os.path.commonprefix()} function, it always returns a valid path:

\begin{verbatim}
>>> os.path.commonprefix(['/usr/lib', '/usr/local/lib', '/usr/1']
>>> os.path.commonpath(['/usr/lib', '/usr/local/lib', '/usr']
\end{verbatim}

(Contributed by Rafik Draoui and Serhiy Storchaka in \texttt{issue 10395}.)

\texttt{pathlib}

The new \texttt{Path.samefile()} method can be used to check whether the path points to the same file as another path, which can be either another \texttt{Path} object, or a string:

\begin{verbatim}
>>> import pathlib
>>> p1 = pathlib.Path('/etc/hosts')
>>> p2 = pathlib.Path('/etc/..etc/hosts')
>>> p1.samefile(p2)
True
\end{verbatim}

(Contributed by Vajrasky Kok and Antoine Pitrou in \texttt{issue 19775}.)

The \texttt{Path.mkdir()} method now accepts a new optional \texttt{exist_ok}
argument to match `mkdir -p` and `os.makedirs()` functionality. (Contributed by Berker Peksag in issue 21539.)

There is a new `Path.expanduser()` method to expand ~ and ~user prefixes. (Contributed by Serhiy Storchaka and Claudiu Popa in issue 19776.)

A new `Path.home()` class method can be used to get a `Path` instance representing the user’s home directory. (Contributed by Victor Salgado and Mayank Tripathi in issue 19777.)

New `Path.write_text()`, `Path.read_text()`, `Path.write_bytes()`, `Path.read_bytes()` methods to simplify read/write operations on files.

The following code snippet will create or rewrite existing file ~/spam42:

```python
>>> import pathlib
>>> p = pathlib.Path('~/spam42')
>>> p.expanduser().write_text('ham')
3
```

(Contributed by Christopher Welborn in issue 20218.)

**pickle**

Nested objects, such as unbound methods or nested classes, can now be pickled using `pickle protocols` older than protocol version 4. Protocol version 4 already supports these cases. (Contributed by Serhiy Storchaka in issue 23611.)

**poplib**
A new `POP3.utf8()` command enables **RFC 6856** (Internationalized Email) support, if a POP server supports it. (Contributed by Milan OberKirch in issue 21804.)

**re**

References and conditional references to groups with fixed length are now allowed in lookbehind assertions:

```python
>>> import re
>>> pat = re.compile(r'(a|b).(?<=\1)c')
>>> pat.match('aac')
<_sre.SRE_Match object; span=(0, 3), match='aac'>
>>> pat.match('bbc')
<_sre.SRE_Match object; span=(0, 3), match='bbc'>
```

(Contributed by Serhiy Storchaka in issue 9179.)

The number of capturing groups in regular expressions is no longer limited to 100. (Contributed by Serhiy Storchaka in issue 22437.)

The `sub()` and `subn()` functions now replace unmatched groups with empty strings instead of raising an exception. (Contributed by Serhiy Storchaka in issue 1519638.)

The `re.error` exceptions have new attributes, `msg`, `pattern`, `pos`, `lineno`, and `colno`, that provide better context information about the error:

```python
>>> re.compile('""'
...     (?x)
...     ...
...     .++
...     """
)```
The new `append_history_file()` function can be used to append the specified number of trailing elements in history to the given file. (Contributed by Bruno Cauet in issue 22940.)

**selectors**

The new `DevpollSelector` supports efficient `/dev/poll` polling on Solaris. (Contributed by Giampaolo Rodola’ in issue 18931.)

**shutil**

The `move()` function now accepts a `copy_function` argument, allowing, for example, the `copy()` function to be used instead of the default `copy2()` if there is a need to ignore file metadata when moving. (Contributed by Claudiu Popa in issue 19840.)

The `make_archive()` function now supports the `xztar` format. (Contributed by Serhiy Storchaka in issue 5411.)

**signal**

On Windows, the `set_wakeup_fd()` function now also supports socket handles. (Contributed by Victor Stinner in issue 22018.)
Various SIG* constants in the `signal` module have been converted into ` Enums`. This allows meaningful names to be printed during debugging, instead of integer “magic numbers”. (Contributed by Giampaolo Rodola’ in issue 21076.)

**smtpd**

Both the `SMTPServer` and `SMTPChannel` classes now accept a `decode_data` keyword argument to determine if the DATA portion of the SMTP transaction is decoded using the "utf-8" codec or is instead provided to the `SMTPServer.process_message()` method as a byte string. The default is True for backward compatibility reasons, but will change to False in Python 3.6. If `decode_data` is set to False, the process_message method must be prepared to accept keyword arguments. (Contributed by Maciej Szulik in issue 19662.)

The `SMTPServer` class now advertises the 8BITMIME extension ([RFC 6152](https://tools.ietf.org/html/rfc6152)) if `decode_data` has been set True. If the client specifies BODY=8BITMIME on the MAIL command, it is passed to `SMTPServer.process_message()` via the `mail_options` keyword. (Contributed by Milan Oberkirich and R. David Murray in issue 21795.)

The `SMTPServer` class now also supports the SMTPUTF8 extension ([RFC 6531](https://tools.ietf.org/html/rfc6531): Internationalized Email). If the client specified SMTPUTF8 BODY=8BITMIME on the MAIL command, they are passed to `SMTPServer.process_message()` via the `mail_options` keyword. It is the responsibility of the process_message method to correctly handle the SMTPUTF8 data. (Contributed by Milan Oberkirich in issue 21725.)
It is now possible to provide, directly or via name resolution, IPv6 addresses in the SMTPServer constructor, and have it successfully connect. (Contributed by Milan Oberkirch in issue 14758.)

smtplib

A new SMTP.auth() method provides a convenient way to implement custom authentication mechanisms. (Contributed by Milan Oberkirch in issue 15014.)

The SMTP.set_debuglevel() method now accepts an additional debuglevel (2), which enables timestamps in debug messages. (Contributed by Gavin Chappell and Maciej Szulik in issue 16914.)

Both the SMTP.sendmail() and SMTP.send_message() methods now support support RFC 6531 (SMTPUTF8). (Contributed by Milan Oberkirch and R. David Murray in issue 22027.)

sndhdr

The what() and whathdr() functions now return a namedtuple(). (Contributed by Claudiu Popa in issue 18615.)

socket

Functions with timeouts now use a monotonic clock, instead of a system clock. (Contributed by Víctor Stinner in issue 22043.)

A new socket.sendfile() method allows to send a file over a socket by using the high-performance os.sendfile() function on UNIX, resulting in uploads being from 2 to 3 times faster than when
using plain `socket.send()`. (Contributed by Giampaolo Rodola' in issue 17552.)

The `socket.sendall()` method no longer resets the socket timeout every time bytes are received or sent. The socket timeout is now the maximum total duration to send all data. (Contributed by Victor Stinner in issue 23853.)

The `backlog` argument of the `socket.listen()` method is now optional. By default it is set to `SOMAXCONN` or to 128, whichever is less. (Contributed by Charles-François Natali in issue 21455.)

ssl

Memory BIO Support

(Contributed by Geert Jansen in issue 21965.)

The new `SSLObject` class has been added to provide SSL protocol support for cases when the network I/O capabilities of `SSLSocket` are not necessary or are suboptimal. `SSLObject` represents an SSL protocol instance, but does not implement any network I/O methods, and instead provides a memory buffer interface. The new `MemoryBIO` class can be used to pass data between Python and an SSL protocol instance.

The memory BIO SSL support is primarily intended to be used in frameworks implementing asynchronous I/O for which `SSLSocket`'s readiness model (“select/poll”) is inefficient.

A new `SSLContext.wrap_bio()` method can be used to create a new `SSLObject` instance.
Application-Layer Protocol Negotiation Support

(Contributed by Benjamin Peterson in issue 20188.)

Where OpenSSL support is present, the ssl module now implements the Application-Layer Protocol Negotiation TLS extension as described in RFC 7301.

The new SSLContext.set_alpn_protocols() can be used to specify which protocols a socket should advertise during the TLS handshake.

The new SSLSocket.selected_alpn_protocol() returns the protocol that was selected during the TLS handshake. The HAS_ALPN flag indicates whether ALPN support is present.

Other Changes

There is a new SSLSocket.version() method to query the actual protocol version in use. (Contributed by Antoine Pitrou in issue 20421.)

The SSLSocket class now implements a SSLSocket.sendfile() method. (Contributed by Giampaolo Rodola’ in issue 17552.)

The SSLSocket.send() method now raises either the ssl.SSLWantReadError or ssl.SSLWantWriteError exception on a non-blocking socket if the operation would block. Previously, it would return 0. (Contributed by Nikolaus Rath in issue 20951.)

The cert_time_to_seconds() function now interprets the input time as UTC and not as local time, per RFC 5280. Additionally, the return value is always an int. (Contributed by Akira Li in issue 19940.)
New `SSLObject.shared_ciphers()` and `SSLSocket.shared_ciphers()` methods return the list of ciphers sent by the client during the handshake. (Contributed by Benjamin Peterson in issue 23186.)

The `SSLSocket.do_handshake()`, `SSLSocket.read()`, `SSLSocket.shutdown()`, and `SSLSocket.write()` methods of the `SSLSocket` class no longer reset the socket timeout every time bytes are received or sent. The socket timeout is now the maximum total duration of the method. (Contributed by Victor Stinner in issue 23853.)

The `match_hostname()` function now supports matching of IP addresses. (Contributed by Antoine Pitrou in issue 23239.)

### sqlite3

The `Row` class now fully supports the sequence protocol, in particular `reversed()` iteration and slice indexing. (Contributed by Claudiu Popa in issue 10203; by Lucas Sinclair, Jessica McKellar, and Serhiy Storchaka in issue 13583.)

### subprocess

The new `run()` function has been added. It runs the specified command and returns a `CompletedProcess` object, which describes a finished process. The new API is more consistent and is the recommended approach to invoking subprocesses in Python code that does not need to maintain compatibility with earlier Python versions. (Contributed by Thomas Kluyver in issue 23342.)
Examples:

```python
>>> subprocess.run(['ls', '-l'])  # doesn't capture
CompletedProcess(args=['ls', '-l'], returncode=0)

>>> subprocess.run('exit 1', shell=True, check=True)
Traceback (most recent call last):
...  
subprocess.CalledProcessError: Command 'exit 1' returned non-zero exit status 1

>>> subprocess.run(['ls', '-l', '/dev/null'], stdout=sys.stdout)
CompletedProcess(args=['ls', '-l', '/dev/null'], returncode=0,
stdout=b'crw-rw-rw- 1 root root 1, 3 Jan 23 16:23 /dev/null'
```

sys

A new `set_coroutine_wrapper()` function allows setting a global hook that will be called whenever a coroutine object is created by an `async def` function. A corresponding `get_coroutine_wrapper()` can be used to obtain a currently set wrapper. Both functions are provisional, and are intended for debugging purposes only. (Contributed by Yury Selivanov in issue 24017.)

A new `is_finalizing()` function can be used to check if the Python interpreter is shutting down. (Contributed by Antoine Pitrou in issue 22696.)

sysconfig

The name of the user scripts directory on Windows now includes the first two components of the Python version. (Contributed by Paul Moore in issue 23437.)
The *mode* argument of the `open()` function now accepts "x" to request exclusive creation. (Contributed by Berker Peksag in issue 21717.)

The `TarFile.extractall()` and `TarFile.extract()` methods now take a keyword argument `numeric_only`. If set to True, the extracted files and directories will be owned by the numeric uid and gid from the tarfile. If set to False (the default, and the behavior in versions prior to 3.5), they will be owned by the named user and group in the tarfile. (Contributed by Michael Vogt and Eric Smith in issue 23193.)

The `TarFile.list()` now accepts an optional `members` keyword argument that can be set to a subset of the list returned by `TarFile.getmembers()`. (Contributed by Serhiy Storchaka in issue 21549.)

### threading

Both the `Lock.acquire()` and `RLock.acquire()` methods now use a monotonic clock for timeout management. (Contributed by Victor Stinner in issue 22043.)

### time

The `monotonic()` function is now always available. (Contributed by Victor Stinner in issue 22043.)
timeit

A new command line option -u or --unit=U can be used to specify the time unit for the timer output. Supported options are usec, msec, or sec. (Contributed by Julian Gindi in issue 18983.)

The timeit() function has a new globals parameter for specifying the namespace in which the code will be running. (Contributed by Ben Roberts in issue 2527.)

tkinter

The tkinter._fix module used for setting up the Tcl/Tk environment on Windows has been replaced by a private function in the _tkinter module which makes no permanent changes to environment variables. (Contributed by Zachary Ware in issue 20035.)

traceback

New walk_stack() and walk_tb() functions to conveniently traverse frame and traceback objects. (Contributed by Robert Collins in issue 17911.)

New lightweight classes: TracebackException, StackSummary, and FrameSummary. (Contributed by Robert Collins in issue 17911.)

Both the print_tb() and print_stack() functions now support negative values for the limit argument. (Contributed by Dmitry Kazakov in issue 22619.)

types
A new coroutine() function to transform generator and generator-like objects into awaitables. (Contributed by Yury Selivanov in issue 24017.)

A new type called CoroutineType, which is used for coroutine objects created by async def functions. (Contributed by Yury Selivanov in issue 24400.)

unicodedata

The unicodedata module now uses data from Unicode 8.0.0.

unittest

The TestLoader.loadTestsFromModule() method now accepts a keyword-only argument pattern which is passed to load_tests as the third argument. Found packages are now checked for load_tests regardless of whether their path matches pattern, because it is impossible for a package name to match the default pattern. (Contributed by Robert Collins and Barry A. Warsaw in issue 16662.)

Unittest discovery errors now are exposed in the TestLoader.errors attribute of the TestLoader instance. (Contributed by Robert Collins in issue 19746.)

A new command line option --locals to show local variables in tracebacks. (Contributed by Robert Collins in issue 22936.)

unittest.mock
The **Mock** class has the following improvements:

- The class constructor has a new *unsafe* parameter, which causes mock objects to raise *AttributeError* on attribute names starting with "assert". (Contributed by Kushal Das in issue 21238.)

- A new **Mock.assert_not_called()** method to check if the mock object was called. (Contributed by Kushal Das in issue 21262.)

The **MagicMock** class now supports **__truediv__()**, **__divmod__()** and **__matmul__()** operators. (Contributed by Johannes Baiter in issue 20968, and Håkan Lövdahl in issue 23581 and issue 23568.)

It is no longer necessary to explicitly pass create=True to the **patch()** function when patching builtin names. (Contributed by Kushal Das in issue 17660.)

**urllib**

A new **request.HTTPPasswordMgrWithPriorAuth** class allows HTTP Basic Authentication credentials to be managed so as to eliminate unnecessary 401 response handling, or to unconditionally send credentials on the first request in order to communicate with servers that return a 404 response instead of a 401 if the Authorization header is not sent. (Contributed by Matej Cepl in issue 19494 and Akshit Khurana in issue 7159.)

A new **quote_via** argument for the **parse.urlencode()** function provides a way to control the encoding of query parts if needed. (Contributed by Samwyse and Arnon Yaari in issue 13866.)
The `request.urlopen()` function accepts an `ssl.SSLContext` object as a `context` argument, which will be used for the HTTPS connection. (Contributed by Alex Gaynor in issue 22366.)

The `parse.urljoin()` was updated to use the RFC 3986 semantics for the resolution of relative URLs, rather than RFC 1808 and RFC 2396. (Contributed by Demian Brecht and Senthil Kumaran in issue 22118.)

**wsgiref**

The `headers` argument of the `headers.Headers` class constructor is now optional. (Contributed by Pablo Torres Navarrete and SilentGhost in issue 5800.)

**xmlrpc**

The `client.ServerProxy` class now supports the context manager protocol. (Contributed by Claudiu Popa in issue 20627.)

The `client.ServerProxy` constructor now accepts an optional `ssl.SSLContext` instance. (Contributed by Alex Gaynor in issue 22960.)

**xml.sax**

SAX parsers now support a character stream of the `xmlreader.InputSource` object. (Contributed by Serhiy Storchaka in issue 2175.)

`parseString()` now accepts a `str` instance. (Contributed by Serhiy
zipfile

ZIP output can now be written to unseekable streams. (Contributed by Serhiy Storchaka in issue 23252.)

The mode argument of `ZipFile.open()` method now accepts "x" to request exclusive creation. (Contributed by Serhiy Storchaka in issue 21717.)
Other module-level changes

Many functions in the *mmap*, *ossaudiodev*, *socket*, *ssl*, and *codecs* modules now accept writable *bytes-like objects*. (Contributed by Serhiy Storchaka in *issue 23001*.)
Optimizations

The `os.walk()` function has been sped up by 3 to 5 times on POSIX systems, and by 7 to 20 times on Windows. This was done using the new `os.scandir()` function, which exposes file information from the underlying readdir or FindFirstFile/FindNextFile system calls. (Contributed by Ben Hoyt with help from Victor Stinner in issue 23605.)

Construction of `bytes(int)` (filled by zero bytes) is faster and uses less memory for large objects. `calloc()` is used instead of `malloc()` to allocate memory for these objects. (Contributed by Victor Stinner in issue 21233.)

Some operations on `ipaddress` IPv4Network and IPv6Network have been massively sped up, such as `subnets()`, `supernet()`, `summarize_address_range()`, `collapse_addresses()`. The speed up can range from 3 to 15 times. (Contributed by Antoine Pitrou, Michel Albert, and Markus in issue 21486, issue 21487, issue 20826, issue 23266.)

Pickling of `ipaddress` objects was optimized to produce significantly smaller output. (Contributed by Serhiy Storchaka in issue 23133.)

Many operations on `io.BytesIO` are now 50% to 100% faster. (Contributed by Serhiy Storchaka in issue 15381 and David Wilson in issue 22003.)

The `marshal.dumps()` function is now faster: 65-85% with versions 3 and 4, 20-25% with versions 0 to 2 on typical data, and up to 5 times in best cases. (Contributed by Serhiy Storchaka in issue 20416 and...
The UTF-32 encoder is now 3 to 7 times faster. (Contributed by Serhiy Storchaka in issue 15027.)

Regular expressions are now parsed up to 10% faster. (Contributed by Serhiy Storchaka in issue 19380.)

The `json.dumps()` function was optimized to run with `ensure_ascii=False` as fast as with `ensure_ascii=True`. (Contributed by Naoki Inada in issue 23206.)

The `PyObject_IsInstance()` and `PyObject_IsSubclass()` functions have been sped up in the common case that the second argument has `type` as its metaclass. (Contributed Georg Brandl by in issue 22540.)

Method caching was slightly improved, yielding up to 5% performance improvement in some benchmarks. (Contributed by Antoine Pitrou in issue 22847.)

Objects from the `random` module now use 50% less memory on 64-bit builds. (Contributed by Serhiy Storchaka in issue 23488.)

The `property()` getter calls are up to 25% faster. (Contributed by Joe Jevnik in issue 23910.)

Instantiation of `fractions.Fraction` is now up to 30% faster. (Contributed by Stefan Behnel in issue 22464.)

String methods `find()`, `rfind()`, `split()`, `partition()` and the `in` string operator are now significantly faster for searching 1-character substrings. (Contributed by Serhiy Storchaka in issue 23573.)
Build and C API Changes

New calloc functions were added:

- `PyMem_RawCalloc()`,
- `PyMem_Calloc()`,
- `PyObject_Calloc()`,
- `_PyObject_GC_Calloc()`.

(Contributed by Victor Stinner in issue 21233.)

New encoding/decoding helper functions:

- `Py_DecodeLocale()` (replaced `_Py_char2wchar()`),
- `Py_EncodeLocale()` (replaced `_Py_wchar2char()`).

(Contributed by Victor Stinner in issue 18395.)

A new `PyCodec_NameReplaceErrors()` function to replace the unicode encode error with \N{...} escapes. (Contributed by Serhiy Storchaka in issue 19676.)

A new `PyErr_FormatV()` function similar to `PyErr_Format()`, but accepts a `va_list` argument. (Contributed by Antoine Pitrou in issue 18711.)

A new `PyExc_RecursionError` exception. (Contributed by Georg Brandl in issue 19235.)

New `PyModule_FromDefAndSpec()`, `PyModule_FromDefAndSpec2()`, and `PyModule_ExecDef()` functions introduced by PEP 489 – multi-phase extension module initialization. (Contributed by Petr Viktorin in issue 24268.)
New \texttt{PyNumber\_MatrixMultiply()} and \texttt{PyNumber\_InPlaceMatrixMultiply()} functions to perform matrix multiplication. (Contributed by Benjamin Peterson in issue 21176. See also \textbf{PEP 465} for details.)

The \texttt{PyTypeObject\_tp\_finalize} slot is now part of the stable ABI.

Windows builds now require Microsoft Visual C++ 14.0, which is available as part of \textbf{Visual Studio 2015}.

Extension modules now include a platform information tag in their filename on some platforms (the tag is optional, and CPython will import extensions without it, although if the tag is present and mismatched, the extension won't be loaded):

- On Linux, extension module filenames end with \texttt{.cpython-<major><minor>m-<architecture>-<os>\_pyd}:
  - \texttt{<major>} is the major number of the Python version; for Python 3.5 this is 3.
  - \texttt{<minor>} is the minor number of the Python version; for Python 3.5 this is 5.
  - \texttt{<architecture>} is the hardware architecture the extension module was built to run on. It's most commonly either \texttt{i386} for 32-bit Intel platforms or \texttt{x86\_64} for 64-bit Intel (and AMD) platforms.
  - \texttt{<os>} is always \texttt{linux-gnu}, except for extensions built to talk to the 32-bit ABI on 64-bit platforms, in which case it is \texttt{linux-gnu32} (and \texttt{<architecture>} will be \texttt{x86\_64}).
- On Windows, extension module filenames end with \texttt{<debug>.cp<major><minor>-<platform>.pyd}:
  - \texttt{<major>} is the major number of the Python version; for Python 3.5 this is 3.
  - \texttt{<minor>} is the minor number of the Python version; for
Python 3.5 this is 5.
- `<platform>` is the platform the extension module was built for, either `win32` for Win32, `win_amd64` for Win64, `win_ia64` for Windows Itanium 64, and `win_arm` for Windows on ARM.
- If built in debug mode, `<debug>` will be `_d`, otherwise it will be blank.
- On OS X platforms, extension module filenames now end with `-darwin.so`.
- On all other platforms, extension module filenames are the same as they were with Python 3.4.
Deprecated

New Keywords

async and await are not recommended to be used as variable, class, function or module names. Introduced by PEP 492 in Python 3.5, they will become proper keywords in Python 3.7.

Deprecated Python Behavior

Raising the StopIteration exception inside a generator will now generate a silent PendingDeprecationWarning, which will become a non-silent deprecation warning in Python 3.6 and will trigger a RuntimeError in Python 3.7. See PEP 479: Change StopIteration handling inside generators for details.

Unsupported Operating Systems

Windows XP is no longer supported by Microsoft, thus, per PEP 11, CPython 3.5 is no longer officially supported on this OS.

Deprecated Python modules, functions and methods

The formatter module has now graduated to full deprecation and is still slated for removal in Python 3.6.

The asyncio.async() function is deprecated in favor of ensure_future().
The \texttt{smtpd} module has in the past always decoded the DATA portion of email messages using the \texttt{utf-8} codec. This can now be controlled by the new \texttt{decode_data} keyword to \texttt{SMTPServer}. The default value is \texttt{True}, but this default is deprecated. Specify the \texttt{decode_data} keyword with an appropriate value to avoid the deprecation warning.

Directly assigning values to the \texttt{key}, \texttt{value} and \texttt{coded_value} of \texttt{http.cookies.Morsel} objects is deprecated. Use the \texttt{set()} method instead. In addition, the undocumented \texttt{LegalChars} parameter of \texttt{set()} is deprecated, and is now ignored.

Passing a format string as keyword argument \texttt{format_string} to the \texttt{format()} method of the \texttt{string.Formatter} class has been deprecated. (Contributed by Serhiy Storchaka in issue \texttt{23671}).

The \texttt{platform.dist()} and \texttt{platform.linux_distribution()} functions are now deprecated and will be removed in Python 3.7. Linux distributions use too many different ways of describing themselves, so the functionality is left to a package. (Contributed by Vajrasky Kok and Berker Peksag in issue \texttt{1322}).

The previously undocumented \texttt{from_function} and \texttt{from_builtin} methods of \texttt{inspect.Signature} are deprecated. Use the new \texttt{Signature.from_callable()} method instead. (Contributed by Yury Selivanov in issue \texttt{24248}).

The \texttt{inspect.getargspec()} function is deprecated and scheduled to be removed in Python 3.6. (See issue \texttt{20438} for details.)

The \texttt{inspect} \texttt{getfullargspec()}, \texttt{getargvalues()}, \texttt{getcallargs()}, \texttt{getargvalues()}, \texttt{formatargspec()}, and
formatargvalues() functions are deprecated in favor of the inspect.signature() API. (Contributed by Yury Selivanov in issue 20438.)

Use of re.LOCALE flag with str patterns or re.ASCII is now deprecated. (Contributed by Serhiy Storchaka in issue 22407.)

Use of unrecognized special sequences consisting of '\' and an ASCII letter in regular expression patterns and replacement patterns now raises a deprecation warning and will be forbidden in Python 3.6. (Contributed by Serhiy Storchaka in issue 23622.)

The undocumented and unofficial use_load_tests default argument of the unittest.TestLoader.loadTestsFromModule() method now is deprecated and ignored. (Contributed by Robert Collins and Barry A. Warsaw in issue 16662.)
Removed

API and Feature Removals

The following obsolete and previously deprecated APIs and features have been removed:

- The `__version__` attribute has been dropped from the `email` package. The email code hasn’t been shipped separately from the `stdlib` for a long time, and the `__version__` string was not updated in the last few releases.
- The internal `Netrc` class in the `ftplib` module was deprecated in 3.4, and has now been removed. (Contributed by Matt Chaput in issue 6623.)
- The concept of `.pyo` files has been removed.
- The `JoinableQueue` class in the provisional `asyncio` module was deprecated in 3.4.4 and is now removed. (Contributed by A. Jesse Jiryu Davis in issue 23464.)
Porting to Python 3.5

This section lists previously described changes and other bugfixes that may require changes to your code.

Changes in Python behavior

- Due to an oversight, earlier Python versions erroneously accepted the following syntax:

  ```python
  f(1 for x in [1], *args)
  f(1 for x in [1], **kwargs)
  ```

  Python 3.5 now correctly raises a `SyntaxError`, as generator expressions must be put in parentheses if not a sole argument to a function.

Changes in the Python API

- **PEP 475**: System calls are now retried when interrupted by a signal instead of raising `InterruptedError` if the Python signal handler does not raise an exception.
- Before Python 3.5, a `datetime.time` object was considered to be false if it represented midnight in UTC. This behavior was considered obscure and error-prone and has been removed in Python 3.5. See issue 13936 for full details.
- The `ssl.SSLSocket.send()` method now raises either `ssl.SSLWantReadError` or `ssl.SSLWantWriteError` on a non-blocking socket if the operation would block. Previously, it would return 0. (Contributed by Nikolaus Rath in issue 20951.)
- The `__name__` attribute of generators is now set from the function
name, instead of being set from the code name. Use gen.gi_code.co_name to retrieve the code name. Generators also have a new __qualname__ attribute, the qualified name, which is now used for the representation of a generator (repr(gen)). (Contributed by Victor Stinner in issue 21205.)

- The deprecated “strict” mode and argument of HTMLParser, HTMLParser.error(), and the HTMLParserError exception have been removed. (Contributed by Ezio Melotti in issue 15114.) The convert_charrefs argument of HTMLParser is now True by default. (Contributed by Berker Peksag in issue 21047.)

- Although it is not formally part of the API, it is worth noting for porting purposes (ie: fixing tests) that error messages that were previously of the form “sometype’ does not support the buffer protocol” are now of the form “a bytes-like object is required, not ‘sometype’”. (Contributed by Ezio Melotti in issue 16518.)

- If the current directory is set to a directory that no longer exists then FileNotFoundError will no longer be raised and instead find_spec() will return None without caching None in sys.path_importer_cache, which is different than the typical case (issue 22834).

- HTTP status code and messages from http.client and http.server were refactored into a common HTTPStatus enum. The values in http.client and http.server remain available for backwards compatibility. (Contributed by Demian Brecht in issue 21793.)

- When an import loader defines importlib.machinery.Loader.exec_module() it is now expected to also define create_module() (raises a DeprecationWarning now, will be an error in Python 3.6). If the loader inherits from importlib.abc.Loader then there is nothing to do, else simply define create_module() to return None. (Contributed by Brett Cannon in issue 23014.)

- The re.split() function always ignored empty pattern
matches, so the "x*" pattern worked the same as "x+", and the "\b" pattern never worked. Now re.split() raises a warning if the pattern could match an empty string. For compatibility, use patterns that never match an empty string (e.g. "x+" instead of "x*"). Patterns that could only match an empty string (such as "\b") now raise an error. (Contributed by Serhiy Storchaka in issue 22818.)

- The http.cookies.Morsel dict-like interface has been made self-consistent: morsel comparison now takes the key and value into account, copy() now results in a Morsel instance rather than a dict, and update() will now raise an exception if any of the keys in the update dictionary are invalid. In addition, the undocumented LegalChars parameter of set() is deprecated and is now ignored. (Contributed by Demian Brecht in issue 2211.)

- PEP 488 has removed .pyo files from Python and introduced the optional opt- tag in .pyc file names. The importlib.util.cache_from_source() has gained an optimization parameter to help control the opt- tag. Because of this, the debug_override parameter of the function is now deprecated. .pyo files are also no longer supported as a file argument to the Python interpreter and thus serve no purpose when distributed on their own (i.e. sourcless code distribution). Due to the fact that the magic number for bytecode has changed in Python 3.5, all old .pyo files from previous versions of Python are invalid regardless of this PEP.

- The socket module now exports the CAN_RAW_FD_FRAMES constant on linux 3.6 and greater.

- The ssl.cert_time_to_seconds() function now interprets the input time as UTC and not as local time, per RFC 5280. Additionally, the return value is always an int. (Contributed by Akira Li in issue 19940.)

- The pygettext.py Tool now uses the standard +NNNN format
for timezones in the POT-Creation-Date header.

- The `smtplib` module now uses `sys.stderr` instead of the previous module-level `stderr` variable for debug output. If your (test) program depends on patching the module-level variable to capture the debug output, you will need to update it to capture `sys.stderr` instead.

- The `str.startswith()` and `str.endswith()` methods no longer return `True` when finding the empty string and the indexes are completely out of range. (Contributed by Serhiy Storchaka in issue 24284.)

- The `inspect.getdoc()` function now returns documentation strings inherited from base classes. Documentation strings no longer need to be duplicated if the inherited documentation is appropriate. To suppress an inherited string, an empty string must be specified (or the documentation may be filled in). This change affects the output of the `pydoc` module and the `help()` function. (Contributed by Serhiy Storchaka in issue 15582.)

- Nested `functools.partial()` calls are now flattened. If you were relying on the previous behavior, you can now either add an attribute to a `functools.partial()` object or you can create a subclass of `functools.partial()`. (Contributed by Alexander Belopolsky in issue 7830.)

Changes in the C API

- The undocumented format member of the (non-public) `PyMemoryViewObject` structure has been removed. All extensions relying on the relevant parts in `memoryobject.h` must be rebuilt.

- The `PyMemAllocator` structure was renamed to `PyMemAllocatorEx` and a new `calloc` field was added.

- Removed non-documented macro `PyObject_REPR` which leaked
references. Use format character %R in `PyUnicode_FromFormat()`-like functions to format the `repr()` of the object. (Contributed by Serhiy Storchaka in issue 22453.)

- Because the lack of the `__module__` attribute breaks pickling and introspection, a deprecation warning is now raised for builtin types without the `__module__` attribute. This would be an `AttributeError` in the future. (Contributed by Serhiy Storchaka in issue 20204.)

- As part of the **PEP 492** implementation, the `tp_reserved` slot of `PyTypeObject` was replaced with a `tp_as_async` slot. Refer to **Coroutine Objects** for new types, structures and functions.
What’s New In Python 3.4

Author: R. David Murray <rdmurray@bitdance.com> (Editor)

This article explains the new features in Python 3.4, compared to 3.3. Python 3.4 was released on March 16, 2014. For full details, see the changelog.

See also: PEP 429 – Python 3.4 Release Schedule
Summary – Release Highlights

New syntax features:

- No new syntax features were added in Python 3.4.

Other new features:

- **pip should always be available** (**PEP 453**).
- Newly created file descriptors are non-inheritable (**PEP 446**).
- command line option for isolated mode (issue 16499).
- improvements in the handling of codecs that are not text encodings (multiple issues).
- **A ModuleSpec Type** for the Import System (**PEP 451**). (Affects importer authors.)
- The **marshal** format has been made more compact and efficient (issue 16475).

New library modules:

- **asyncio**: New provisional API for asynchronous IO (**PEP 3156**).
- **ensurepip**: Bootstrapping the pip installer (**PEP 453**).
- **enum**: Support for enumeration types (**PEP 435**).
- **pathlib**: Object-oriented filesystem paths (**PEP 428**).
- **selectors**: High-level and efficient I/O multiplexing, built upon the **select** module primitives (part of **PEP 3156**).
- **statistics**: A basic numerically stable statistics library (**PEP 450**).
- **tracemalloc**: Trace Python memory allocations (**PEP 454**).

Significantly improved library modules:

- **Single-dispatch generic functions in functools** (**PEP 443**).
- New **pickle protocol 4** (**PEP 3154**).
- `multiprocessing` now has an option to avoid using `os.fork` on Unix (issue 8713).
- `email` has a new submodule, `contentmanager`, and a new `Message` subclass (`EmailMessage`) that simplify MIME handling (issue 18891).
- The `inspect` and `pydoc` modules are now capable of correct introspection of a much wider variety of callable objects, which improves the output of the Python `help()` system.
- The `ipaddress` module API has been declared stable.

Security improvements:

- Secure and interchangeable hash algorithm (PEP 456).
- Make newly created file descriptors non-inheritable (PEP 446) to avoid leaking file descriptors to child processes.
- New command line option for isolated mode, (issue 16499).
- `multiprocessing` now has an option to avoid using `os.fork` on Unix. `spawn` and `forkserver` are more secure because they avoid sharing data with child processes.
- `multiprocessing` child processes on Windows no longer inherit all of the parent's inheritable handles, only the necessary ones.
- A new `hashlib.pbkdf2_hmac()` function provides the PKCS#5 password-based key derivation function 2.
- TLSv1.1 and TLSv1.2 support for `ssl`.
- Retrieving certificates from the Windows system cert store support for `ssl`.
- Server-side SNI (Server Name Indication) support for `ssl`.
- The `ssl.SSLContext` class has a lot of improvements.
- All modules in the standard library that support SSL now support server certificate verification, including hostname matching (`ssl.match_hostname()`) and CRLs (Certificate Revocation lists, see `ssl.SSLContext.load_verify_locations()`).
CPython implementation improvements:

- Safe object finalization (PEP 442).
- Leveraging PEP 442, in most cases module globals are no longer set to None during finalization (issue 18214).
- Configurable memory allocators (PEP 445).
- Argument Clinic (PEP 436).

Please read on for a comprehensive list of user-facing changes, including many other smaller improvements, CPython optimizations, deprecations, and potential porting issues.
New Features

PEP 453: Explicit Bootstrapping of PIP in Python Installations

Bootstrapping pip By Default

The new `ensurepip` module (defined in PEP 453) provides a standard cross-platform mechanism to bootstrap the pip installer into Python installations and virtual environments. The version of pip included with Python 3.4.0 is pip 1.5.4, and future 3.4.x maintenance releases will update the bundled version to the latest version of pip that is available at the time of creating the release candidate.

By default, the commands `pipX` and `pipX.Y` will be installed on all platforms (where X.Y stands for the version of the Python installation), along with the pip Python package and its dependencies. On Windows and in virtual environments on all platforms, the unversioned pip command will also be installed. On other platforms, the system wide unversioned pip command typically refers to the separately installed Python 2 version.

The `pyvenv` command line utility and the `venv` module make use of the `ensurepip` module to make pip readily available in virtual environments. When using the command line utility, pip is installed by default, while when using the `venv` module API installation of pip must be requested explicitly.

For CPython source builds on POSIX systems, the make install and make altinstall commands bootstrap pip by default. This behaviour can be controlled through configure options, and overridden
through Makefile options.

On Windows and Mac OS X, the CPython installers now default to installing `pip` along with CPython itself (users may opt out of installing it during the installation process). Window users will need to opt in to the automatic PATH modifications to have `pip` available from the command line by default, otherwise it can still be accessed through the Python launcher for Windows as `py -m pip`.

As discussed in the PEP, platform packagers may choose not to install these commands by default, as long as, when invoked, they provide clear and simple directions on how to install them on that platform (usually using the system package manager).

**Note:** To avoid conflicts between parallel Python 2 and Python 3 installations, only the versioned `pip3` and `pip3.4` commands are bootstrapped by default when `ensurepip` is invoked directly - the `-default-pip` option is needed to also request the unversioned `pip` command. `pyvenv` and the Windows installer ensure that the unqualified `pip` command is made available in those environments, and `pip` can always be invoked via the `-m` switch rather than directly to avoid ambiguity on systems with multiple Python installations.

**Documentation Changes**

As part of this change, the Installing Python Modules and Distributing Python Modules sections of the documentation have been completely redesigned as short getting started and FAQ documents. Most packaging documentation has now been moved out to the Python Packaging Authority maintained Python Packaging User Guide and the documentation of the individual projects.
However, as this migration is currently still incomplete, the legacy versions of those guides remaining available as Installing Python Modules (Legacy version) and Distributing Python Modules (Legacy version).

See also:

**PEP 453** – Explicit bootstrapping of pip in Python installations
PEP written by Donald Stufft and Nick Coghlan, implemented by Donald Stufft, Nick Coghlan, Martin von Löwis and Ned Deily.

PEP 446: Newly Created File Descriptors Are Non-Inheritable

**PEP 446** makes newly created file descriptors non-inheritable. In general, this is the behavior an application will want: when launching a new process, having currently open files also open in the new process can lead to all sorts of hard to find bugs, and potentially to security issues.

However, there are occasions when inheritance is desired. To support these cases, the following new functions and methods are available:

- `os.get_inheritable()`, `os.set_inheritable()`
- `os.get_handle_inheritable()`, `os.set_handle_inheritable()`
- `socket.socket.get_inheritable()`, `socket.socket.set_inheritable()`

See also:

**PEP 446** – Make newly created file descriptors non-inheritable
Improvements to Codec Handling

Since it was first introduced, the `codecs` module has always been intended to operate as a type-neutral dynamic encoding and decoding system. However, its close coupling with the Python text model, especially the type restricted convenience methods on the builtin `str`, `bytes` and `bytearray` types, has historically obscured that fact.

As a key step in clarifying the situation, the `codecs.encode()` and `codecs.decode()` convenience functions are now properly documented in Python 2.7, 3.3 and 3.4. These functions have existed in the `codecs` module (and have been covered by the regression test suite) since Python 2.4, but were previously only discoverable through runtime introspection.

Unlike the convenience methods on `str`, `bytes` and `bytearray`, the `codecs` convenience functions support arbitrary codecs in both Python 2 and Python 3, rather than being limited to Unicode text encodings (in Python 3) or `basestring` <-> `basestring` conversions (in Python 2).

In Python 3.4, the interpreter is able to identify the known non-text encodings provided in the standard library and direct users towards these general purpose convenience functions when appropriate:

```python
>>> b"abcdef".decode("hex")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
LookupError: 'hex' is not a text encoding; use codecs
```
In a related change, whenever it is feasible without breaking backwards compatibility, exceptions raised during encoding and decoding operations are wrapped in a chained exception of the same type that mentions the name of the codec responsible for producing the error:

```python
>>> import codecs
>>> codecs.decode(b"abcdefgh", "hex")
Traceback (most recent call last):
  File "/usr/lib/python3.4/encodings/hex_codec.py", line 128, in <module>
    return (binascii.a2b_hex(input), len(input))
binascii.Error: Non-hexadecimal digit found
```

The above exception was the direct cause of the following exception:

```python
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
binascii.Error: decoding with 'hex' codec failed (Error: Non-hexadecimal digit found)
```
The above exception was the direct cause of the following exception:

```
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: encoding with 'bz2' codec failed (TypeError: 'str' does not support the buffer interface)
```

Finally, as the examples above show, these improvements have permitted the restoration of the convenience aliases for the non-Unicode codecs that were themselves restored in Python 3.2. This means that encoding binary data to and from its hexadecimal representation (for example) can now be written as:

```
>>> from codecs import encode, decode
>>> encode(b"hello", "hex")
b'68656c6c6f'
>>> decode(b'68656c6c6f', "hex")
b'hello'
```

The binary and text transforms provided in the standard library are detailed in Binary Transforms and Text Transforms.

(Contributed by Nick Coghlan in issue 7475, issue 17827, issue 17828 and issue 19619.)

**PEP 451: A ModuleSpec Type for the Import System**

**PEP 451** provides an encapsulation of the information about a module that the import machinery will use to load it (that is, a module specification). This helps simplify both the import implementation and
several import-related APIs. The change is also a stepping stone for several future import-related improvements.

The public-facing changes from the PEP are entirely backward-compatible. Furthermore, they should be transparent to everyone but importer authors. Key finder and loader methods have been deprecated, but they will continue working. New importers should use the new methods described in the PEP. Existing importers should be updated to implement the new methods. See the Deprecated section for a list of methods that should be replaced and their replacements.

Other Language Changes

Some smaller changes made to the core Python language are:

- Unicode database updated to UCD version 6.3.
- min() and max() now accept a default keyword-only argument that can be used to specify the value they return if the iterable they are evaluating has no elements. (Contributed by Julian Berman in issue 18111.)
- Module objects are now weakref‘able.
- Module __file__ attributes (and related values) should now always contain absolute paths by default, with the sole exception of __main__.__file__ when a script has been executed directly using a relative path. (Contributed by Brett Cannon in issue 18416.)
- All the UTF-* codecs (except UTF-7) now reject surrogates during both encoding and decoding unless the surrogatepass error handler is used, with the exception of the UTF-16 decoder (which accepts valid surrogate pairs) and the UTF-16 encoder (which produces them while encoding non-BMP characters). (Contributed by Victor Stinner, Kang-Hao (Kenny) Lu and Serhiy Storchaka in issue 12892.)
- New German EBCDIC codec cp273. (Contributed by Michael Bierenfeld and Andrew Kuchling in issue 1097797.)
- New Ukrainian codec cp1125. (Contributed by Serhiy Storchaka in issue 19668.)
- bytes.join() and bytearray.join() now accept arbitrary buffer objects as arguments. (Contributed by Antoine Pitrou in issue 15958.)
- The int constructor now accepts any object that has an __index__ method for its base argument. (Contributed by Mark Dickinson in issue 16772.)
- Frame objects now have a clear() method that clears all references to local variables from the frame. (Contributed by Antoine Pitrou in issue 17934.)
- memoryview is now registered as a Sequence, and supports the reversed() builtin. (Contributed by Nick Coghlan and Claudiu Popa in issue 18690 and issue 19078.)
- Signatures reported by help() have been modified and improved in several cases as a result of the introduction of Argument Clinic and other changes to the inspect and pydoc modules.
- __length_hint__() is now part of the formal language specification (see PEP 424). (Contributed by Armin Ronacher in issue 16148.)
New Modules

asyncio

The new asyncio module (defined in PEP 3156) provides a standard pluggable event loop model for Python, providing solid asynchronous IO support in the standard library, and making it easier for other event loop implementations to interoperate with the standard library and each other.

For Python 3.4, this module is considered a provisional API.

See also:

PEP 3156 – Asynchronous IO Support Rebooted: the “asyncio” Module
PEP written and implementation led by Guido van Rossum.

ensurepip

The new ensurepip module is the primary infrastructure for the PEP 453 implementation. In the normal course of events end users will not need to interact with this module, but it can be used to manually bootstrap pip if the automated bootstrapping into an installation or virtual environment was declined.

ensurepip includes a bundled copy of pip, up-to-date as of the first release candidate of the release of CPython with which it ships (this applies to both maintenance releases and feature releases). ensurepip does not access the internet. If the installation has Internet access, after ensurepip is run the bundled pip can be used
to upgrade pip to a more recent release than the bundled one. (Note that such an upgraded version of pip is considered to be a separately installed package and will not be removed if Python is uninstalled.)

The module is named ensurepip because if called when pip is already installed, it does nothing. It also has an --upgrade option that will cause it to install the bundled copy of pip if the existing installed version of pip is older than the bundled copy.

enum

The new enum module (defined in PEP 435) provides a standard implementation of enumeration types, allowing other modules (such as socket) to provide more informative error messages and better debugging support by replacing opaque integer constants with backwards compatible enumeration values.

See also:

PEP 435 – Adding an Enum type to the Python standard library

PEP written by Barry Warsaw, Eli Bendersky and Ethan Furman, implemented by Ethan Furman.

pathlib

The new pathlib module offers classes representing filesystem paths with semantics appropriate for different operating systems. Path classes are divided between pure paths, which provide purely computational operations without I/O, and concrete paths, which inherit from pure paths but also provide I/O operations.
For Python 3.4, this module is considered a provisional API.

See also:

**PEP 428** – The `pathlib` module – object-oriented filesystem paths
PEP written and implemented by Antoine Pitrou.

selectors

The new `selectors` module (created as part of implementing [PEP 3156](#)) allows high-level and efficient I/O multiplexing, built upon the `select` module primitives.

statistics

The new `statistics` module (defined in [PEP 450](#)) offers some core statistics functionality directly in the standard library. This module supports calculation of the mean, median, mode, variance and standard deviation of a data series.

See also:

**PEP 450** – Adding A Statistics Module To The Standard Library
PEP written and implemented by Steven D’Aprano

tracemalloc

The new `tracemalloc` module (defined in [PEP 454](#)) is a debug tool to trace memory blocks allocated by Python. It provides the following information:
• Trace where an object was allocated
• Statistics on allocated memory blocks per filename and per line number: total size, number and average size of allocated memory blocks
• Compute the differences between two snapshots to detect memory leaks

See also:

**PEP 454** – Add a new tracemalloc module to trace Python memory allocations
  PEP written and implemented by Victor Stinner
Improved Modules

abc

New function \texttt{abc.get_cache_token()} can be used to know when to invalidate caches that are affected by changes in the object graph. (Contributed by Łukasz Langa in \texttt{issue 16832}.)

New class \texttt{ABC} has \texttt{ABCMeta} as its meta class. Using \texttt{ABC} as a base class has essentially the same effect as specifying \texttt{metaclass=abc.ABCMeta}, but is simpler to type and easier to read. (Contributed by Bruno Dupuis in \texttt{issue 16049}.)

aifc

The \texttt{getparams()} method now returns a namedtuple rather than a plain tuple. (Contributed by Claudiu Popa in \texttt{issue 17818}.)

\texttt{aifc.open()} now supports the context management protocol: when used in a \texttt{with} block, the \texttt{close()} method of the returned object will be called automatically at the end of the block. (Contributed by Serhiy Storchacha in \texttt{issue 16486}.)

The \texttt{writeframesraw()} and \texttt{writeframes()} methods now accept any \texttt{bytes-like object}. (Contributed by Serhiy Storchaka in \texttt{issue 8311}.)

argparse

The \texttt{FileType} class now accepts \texttt{encoding} and \texttt{errors} arguments, which are passed through to \texttt{open()}. (Contributed by Lucas Maystre in \texttt{issue 11175}.)
audioop

audioop now supports 24-bit samples. (Contributed by Serhiy Storchaka in issue 12866.)

New byteswap() function converts big-endian samples to little-endian and vice versa. (Contributed by Serhiy Storchaka in issue 19641.)

All audioop functions now accept any bytes-like object. Strings are not accepted: they didn’t work before, now they raise an error right away. (Contributed by Serhiy Storchaka in issue 16685.)

base64

The encoding and decoding functions in base64 now accept any bytes-like object in cases where it previously required a bytes or bytearray instance. (Contributed by Nick Coghlan in issue 17839.)

New functions a85encode(), a85decode(), b85encode(), and b85decode() provide the ability to encode and decode binary data from and to Ascii85 and the git/mercurial Base85 formats, respectively. The a85 functions have options that can be used to make them compatible with the variants of the Ascii85 encoding, including the Adobe variant. (Contributed by Martin Morrison, the Mercurial project, Serhiy Storchaka, and Antoine Pitrou in issue 17618.)

collections

The ChainMap.new_child() method now accepts an m argument specifying the child map to add to the chain. This allows an existing
mapping and/or a custom mapping type to be used for the child. (Contributed by Vinay Sajip in issue 16613.)

colorsys

The number of digits in the coefficients for the RGB — YIQ conversions have been expanded so that they match the FCC NTSC versions. The change in results should be less than 1% and may better match results found elsewhere. (Contributed by Brian Landers and Serhiy Storchaka in issue 14323.)

contextlib

The new contextlib.suppress context manager helps to clarify the intent of code that deliberately suppresses exceptions from a single statement. (Contributed by Raymond Hettinger in issue 15806 and Zero Piraeus in issue 19266.)

The new contextlib.redirect_stdout() context manager makes it easier for utility scripts to handle inflexible APIs that write their output to sys.stdout and don’t provide any options to redirect it. Using the context manager, the sys.stdout output can be redirected to any other stream or, in conjunction with io.StringIO, to a string. The latter can be especially useful, for example, to capture output from a function that was written to implement a command line interface. It is recommended only for utility scripts because it affects the global state of sys.stdout. (Contributed by Raymond Hettinger in issue 15805.)

The contextlib documentation has also been updated to include a discussion of the differences between single use, reusable and
reentrant context managers.

**dbm**

dbm.open() objects now support the context management protocol. When used in a with statement, the close method of the database object will be called automatically at the end of the block. (Contributed by Claudiu Popa and Nick Coghlan in issue 19282.)

**dis**

Functions show_code(), dis(), distb(), and disassemble() now accept a keyword-only file argument that controls where they write their output.

The dis module is now built around an Instruction class that provides object oriented access to the details of each individual bytecode operation.

A new method, get_instructions(), provides an iterator that emits the Instruction stream for a given piece of Python code. Thus it is now possible to write a program that inspects and manipulates a bytecode object in ways different from those provided by the dis module itself. For example:

```python
>>> import dis
>>> for instr in dis.get_instructions(lambda x: x + ...
...     print(instr.opname)
LOAD_FAST
LOAD_CONST
BINARY_ADD
RETURN_VALUE
```
The various display tools in the `dis` module have been rewritten to use these new components.

In addition, a new application-friendly class `Bytecode` provides an object-oriented API for inspecting bytecode in both in human-readable form and for iterating over instructions. The `Bytecode` constructor takes the same arguments that `get_instruction()` does (plus an optional `current_offset`), and the resulting object can be iterated to produce `Instruction` objects. But it also has a `dis` method, equivalent to calling `dis` on the constructor argument, but returned as a multi-line string:

```python
>>> bytecode = dis.Bytecode(lambda x: x + 1, current_offset=0)
>>> for instr in bytecode:
...     print('{}({})'.format(instr.opname, instr.argval))
LOAD_FAST (124)
LOAD_CONST (100)
BINARY_ADD (23)
RETURN_VALUE (83)
```

`Bytecode` also has a class method, `from_traceback()`, that provides the ability to manipulate a traceback (that is, `print(Bytecode.from_traceback(tb).dis())` is equivalent to `distb(tb)`).

(Contributed by Nick Coghlan, Ryan Kelly and Thomas Kluyver in issue 11816 and Claudiu Popa in issue 17916.)
New function `stack_effect()` computes the effect on the Python stack of a given opcode and argument, information that is not otherwise available. (Contributed by Larry Hastings in issue 19722.)

**doctest**

A new option flag, `FAIL_FAST`, halts test running as soon as the first failure is detected. (Contributed by R. David Murray and Daniel Urban in issue 16522.)

The `doctest` command line interface now uses `argparse`, and has two new options, `-o` and `-f`. `-o` allows `doctest options` to be specified on the command line, and `-f` is a shorthand for `-o FAIL_FAST` (to parallel the similar option supported by the `unittest` CLI). (Contributed by R. David Murray in issue 11390.)

`doctest` will now find doctests in extension module `__doc__` strings. (Contributed by Zachary Ware in issue 3158.)

**email**

`as_string()` now accepts a `policy` argument to override the default policy of the message when generating a string representation of it. This means that `as_string` can now be used in more circumstances, instead of having to create and use a `generator` in order to pass formatting parameters to its `flatten` method. (Contributed by R. David Murray in issue 18600.)

New method `as_bytes()` added to produce a bytes representation of the message in a fashion similar to how `as_string` produces a string representation. It does not accept the `maxheaderlen` argument, but
does accept the `unixfrom` and `policy` arguments. The `Message.__bytes__()` method calls it, meaning that `bytes(mymsg)` will now produce the intuitive result: a bytes object containing the fully formatted message. (Contributed by R. David Murray in issue 18600.)

The `Message.set_param()` message now accepts a `replace` keyword argument. When specified, the associated header will be updated without changing its location in the list of headers. For backward compatibility, the default is `False`. (Contributed by R. David Murray in issue 18891.)

A pair of new subclasses of `Message` have been added (`EmailMessage` and `MIMEPart`), along with a new sub-module, `contentmanager` and a new `policy` attribute `content_manager`. All documentation is currently in the new module, which is being added as part of email's new provisional API. These classes provide a number of new methods that make extracting content from and inserting content into email messages much easier. For details, see the `contentmanager` documentation and the Examples using the Provisional API. These API additions complete the bulk of the work that was planned as part of the email6 project. The currently provisional API is scheduled to become final in Python 3.5 (possibly with a few minor additions in the area of error handling). (Contributed by R. David Murray in issue 18891.)

**filecmp**

A new `clear_cache()` function provides the ability to clear the `filecmp` comparison cache, which uses `os.stat()` information to determine if the file has changed since the last compare. This can be used, for example, if the file might have been changed and re-checked.
in less time than the resolution of a particular filesystem’s file
modification time field. (Contributed by Mark Levitt in issue 18149.)

New module attribute DEFAULT_IGNORES provides the list of
directories that are used as the default value for the ignore parameter
of the dircmp() function. (Contributed by Eli Bendersky in issue
15442.)

functools

The new partialmethod() descriptor brings partial argument
application to descriptors, just as partial() provides for normal
callables. The new descriptor also makes it easier to get arbitrary
callables (including partial() instances) to behave like normal
instance methods when included in a class definition. (Contributed by
Alon Horev and Nick Coghlan in issue 4331.)

The new singledispatch() decorator brings support for single-
dispatch generic functions to the Python standard library. Where object
oriented programming focuses on grouping multiple operations on a
common set of data into a class, a generic function focuses on
grouping multiple implementations of an operation that allows it to
work with different kinds of data.

See also:

PEP 443 – Single-dispatch generic functions
    PEP written and implemented by Łukasz Langa.

total_ordering() now supports a return value of
NotImplemented from the underlying comparison function.
(Contributed by Katie Miller in issue 10042.)
A pure-python version of the `partial()` function is now in the stdlib; in CPython it is overridden by the C accelerated version, but it is available for other implementations to use. (Contributed by Brian Thorne in issue 12428.)

**gc**

New function `get_stats()` returns a list of three per-generation dictionaries containing the collections statistics since interpreter startup. (Contributed by Antoine Pitrou in issue 16351.)

**glob**

A new function `escape()` provides a way to escape special characters in a filename so that they do not become part of the globbing expansion but are instead matched literally. (Contributed by Serhiy Storchaka in issue 8402.)

**hashlib**

A new `hashlib.pbkdf2_hmac()` function provides the PKCS#5 password-based key derivation function 2. (Contributed by Christian Heimes in issue 18582.)

The `name` attribute of `hashlib` hash objects is now a formally supported interface. It has always existed in CPython's `hashlib` (although it did not return lower case names for all supported hashes), but it was not a public interface and so some other Python implementations have not previously supported it. (Contributed by Jason R. Coombs in issue 18532.)
**hmac**

`hmac` now accepts `bytearray` as well as `bytes` for the `key` argument to the `new()` function, and the `msg` parameter to both the `new()` function and the `update()` method now accepts any type supported by the `hashlib` module. (Contributed by Jonas Borgström in issue 18240.)

The `digestmod` argument to the `hmac.new()` function may now be any hash digest name recognized by `hashlib`. In addition, the current behavior in which the value of `digestmod` defaults to MD5 is deprecated: in a future version of Python there will be no default value. (Contributed by Christian Heimes in issue 17276.)

With the addition of `block_size` and `name` attributes (and the formal documentation of the `digest_size` attribute), the `hmac` module now conforms fully to the PEP 247 API. (Contributed by Christian Heimes in issue 18775.)

**html**

New function `unescape()` function converts HTML5 character references to the corresponding Unicode characters. (Contributed by Ezio Melotti in issue 2927.)

`HTMLParser` accepts a new keyword argument `convert_charrefs` that, when True, automatically converts all character references. For backward-compatibility, its value defaults to False, but it will change to True in a future version of Python, so you are invited to set it explicitly and update your code to use this new feature. (Contributed by Ezio Melotti in issue 13633.)
The *strict* argument of `HTMLParser` is now deprecated. (Contributed by Ezio Melotti in issue 15114.)

**http**

`send_error()` now accepts an optional additional `explain` parameter which can be used to provide an extended error description, overriding the hardcoded default if there is one. This extended error description will be formatted using the `error_message_format` attribute and sent as the body of the error response. (Contributed by Karl Cow in issue 12921.)

The `http.server` command line interface now has a `-b/--bind` option that causes the server to listen on a specific address. (Contributed by Malte Swart in issue 17764.)

**idlelib and IDLE**

Since idlelib implements the IDLE shell and editor and is not intended for import by other programs, it gets improvements with every release. See Lib/idlelib/NEWS.txt for a cumulative list of changes since 3.3.0, as well as changes made in future 3.4.x releases. This file is also available from the IDLE Help ➤ About IDLE dialog.

**importlib**

The `InspectLoader` ABC defines a new method, `source_to_code()` that accepts source data and a path and returns a code object. The default implementation is equivalent to `compile(data, path, 'exec', dont_inherit=True)`. (Contributed by Eric Snow and Brett Cannon in issue 15627.)
InspectLoader also now has a default implementation for the get_code() method. However, it will normally be desirable to override the default implementation for performance reasons. (Contributed by Brett Cannon in issue 18072.)

The reload() function has been moved from imp to importlib as part of the imp module deprecation. (Contributed by Berker Peksag in issue 18193.)

importlib.util now has a MAGIC_NUMBER attribute providing access to the bytecode version number. This replaces the get_magic() function in the deprecated imp module. (Contributed by Brett Cannon in issue 18192.)

New importlib.util functions cache_from_source() and source_from_cache() replace the same-named functions in the deprecated imp module. (Contributed by Brett Cannon in issue 18194.)

The importlib bootstrap NamespaceLoader now conforms to the InspectLoader ABC, which means that runpy and python -m can now be used with namespace packages. (Contributed by Brett Cannon in issue 18058.)

importlib.util has a new function decode_source() that decodes source from bytes using universal newline processing. This is useful for implementing InspectLoader.get_source() methods.

importlib.machinery.ExtensionFileLoader now has a get_filename() method. This was inadvertently omitted in the original implementation. (Contributed by Eric Snow in issue 19152.)
**inspect**

The *inspect* module now offers a basic command line interface to quickly display source code and other information for modules, classes and functions. (Contributed by Claudiu Popa and Nick Coghlan in issue 18626.)

*unwrap()* makes it easy to unravel wrapper function chains created by *functools.wraps()* (and any other API that sets the *__wrapped__* attribute on a wrapper function). (Contributed by Daniel Urban, Aaron Iles and Nick Coghlan in issue 13266.)

As part of the implementation of the new *enum* module, the *inspect* module now has substantially better support for custom *__dir__* methods and dynamic class attributes provided through metaclasses. (Contributed by Ethan Furman in issue 18929 and issue 19030.)

*getfullargspec()* and *getargspec()* now use the *signature()* API. This allows them to support a much broader range of callables, including those with *__signature__* attributes, those with metadata provided by argument clinic, *functools.partial()* objects and more. Note that, unlike *signature()* these functions still ignore *__wrapped__* attributes, and report the already bound first argument for bound methods, so it is still necessary to update your code to use *signature()* directly if those features are desired. (Contributed by Yury Selivanov in issue 17481.)

*signature()* now supports duck types of CPython functions, which adds support for functions compiled with Cython. (Contributed by Stefan Behnel and Yury Selivanov in issue 17159.)
ipaddress

`ipaddress` was added to the standard library in Python 3.3 as a provisional API. With the release of Python 3.4, this qualification has been removed: `ipaddress` is now considered a stable API, covered by the normal standard library requirements to maintain backwards compatibility.

A new `is_global` property is True if an address is globally routeable. (Contributed by Peter Moody in issue 17400.)

logging

The `TimedRotatingFileHandler` has a new `atTime` parameter that can be used to specify the time of day when rollover should happen. (Contributed by Ronald Oussoren in issue 9556.)

`SocketHandler` and `DatagramHandler` now support Unix domain sockets (by setting `port` to None). (Contributed by Vinay Sajip in commit ce46195b56a9.)

`fileConfig()` now accepts a `configparser.RawConfigParser` subclass instance for the `fname` parameter. This facilitates using a configuration file when logging configuration is just a part of the overall application configuration, or where the application modifies the configuration before passing it to `fileConfig()`. (Contributed by Vinay Sajip in issue 16110.)

Logging configuration data received from a socket via the `logging.config.listen()` function can now be validated before being processed by supplying a verification function as the argument to the new `verify` keyword argument. (Contributed by Vinay Sajip in
marshal

The default **marshal** version has been bumped to 3. The code implementing the new version restores the Python2 behavior of recording only one copy of interned strings and preserving the interning on deserialization, and extends this “one copy” ability to any object type (including handling recursive references). This reduces both the size of `.pyc` files and the amount of memory a module occupies in memory when it is loaded from a `.pyc` (or `.pyo`) file. (Contributed by Kristján Valur Jónsson in issue 16475, with additional speedups by Antoine Pitrou in issue 19219.)

mmap

mmap objects can now be [weakref](https://docs.python.org/3/library/weakref.html)ed. (Contributed by Valerie Lambert in issue 4885.)

multiprocessing

On Unix two new start methods, spawn and forkserver, have been added for starting processes using [multiprocessing](https://docs.python.org/3/library/multiprocessing.html). These make the mixing of processes with threads more robust, and the spawn method matches the semantics that multiprocessing has always used on Windows. New function `get_all_start_methods()` reports all start methods available on the platform, `get_start_method()` reports the current start method, and `set_start_method()` sets the start method. (Contributed by Richard Oudkerk in issue 8713.)

[context](https://docs.python.org/3/library/contextlib.html) multiprocessing also now has the concept of a context, which
determines how child processes are created. New function `get_context()` returns a context that uses a specified start method. It has the same API as the `multiprocessing` module itself, so you can use it to create `Pools` and other objects that will operate within that context. This allows a framework and an application or different parts of the same application to use multiprocessing without interfering with each other. (Contributed by Richard Oudkerk in issue 18999.)

Except when using the old `fork` start method, child processes no longer inherit unneeded handles/file descriptors from their parents (part of issue 8713).

`multiprocessing` now relies on `runpy` (which implements the `-m` switch) to initialise `__main__` appropriately in child processes when using the `spawn` or `forkserver` start methods. This resolves some edge cases where combining multiprocessing, the `-m` command line switch, and explicit relative imports could cause obscure failures in child processes. (Contributed by Nick Coghlan in issue 19946.)

**operator**

New function `length_hint()` provides an implementation of the specification for how the `__length_hint__()` special method should be used, as part of the PEP 424 formal specification of this language feature. (Contributed by Armin Ronacher in issue 16148.)

There is now a pure-python version of the `operator` module available for reference and for use by alternate implementations of Python. (Contributed by Zachary Ware in issue 16694.)

**OS**
There are new functions to get and set the *inheritable flag* of a file descriptor (`os.get_inheritable()`, `os.set_inheritable()`) or a Windows handle (`os.get_handle_inheritable()`, `os.set_handle_inheritable()`).

New function `cpu_count()` reports the number of CPUs available on the platform on which Python is running (or None if the count can’t be determined). The `multiprocessing.cpu_count()` function is now implemented in terms of this function. (Contributed by Trent Nelson, Yogesh Chaudhari, Victor Stinner, and Charles-François Natali in issue 17914.)

`os.path.samestat()` is now available on the Windows platform (and the `os.path.samefile()` implementation is now shared between Unix and Windows). (Contributed by Brian Curtin in issue 11939.)

`os.path.ismount()` now recognizes volumes mounted below a drive root on Windows. (Contributed by Tim Golden in issue 9035.)

`os.open()` supports two new flags on platforms that provide them, `O_PATH` (un-opened file descriptor), and `O_TMPFILE` (unnamed temporary file; as of 3.4.0 release available only on Linux systems with a kernel version of 3.11 or newer that have uapi headers). (Contributed by Christian Heimes in issue 18673 and Benjamin Peterson, respectively.)

**pdb**

*Pdb* has been enhanced to handle generators, `yield`, and `yield from` in a more useful fashion. This is especially helpful when debugging *asyncio* based programs. (Contributed by Andrew Svetlov
and Xavier de Gaye in issue 16596.)

The print command has been removed from pdb, restoring access to the Python print() function from the pdb command line. Python2's pdb did not have a print command; instead, entering print executed the print statement. In Python3 print was mistakenly made an alias for the pdb p command. p, however, prints the repr of its argument, not the str like the Python2 print command did. Worse, the Python3 pdb print command shadowed the Python3 print function, making it inaccessible at the pdb prompt. (Contributed by Connor Osborn in issue 18764.)

pickle

pickle now supports (but does not use by default) a new pickle protocol, protocol 4. This new protocol addresses a number of issues that were present in previous protocols, such as the serialization of nested classes, very large strings and containers, and classes whose __new__() method takes keyword-only arguments. It also provides some efficiency improvements.

See also:

PEP 3154 – Pickle protocol 4

PEP written by Antoine Pitrou and implemented by Alexandre Vassalotti.

plistlib

plistlib now has an API that is similar to the standard pattern for stdlib serialization protocols, with new load(), dump(), loads(),
and `dumps()` functions. (The older API is now deprecated.) In addition to the already supported XML plist format (`FMT_XML`), it also now supports the binary plist format (`FMT_BINARY`). (Contributed by Ronald Oussoren and others in issue 14455.)

**poplib**

Two new methods have been added to `poplib`: `capa()`, which returns the list of capabilities advertised by the POP server, and `stls()`, which switches a clear-text POP3 session into an encrypted POP3 session if the POP server supports it. (Contributed by Lorenzo Catucci in issue 4473.)

**pprint**

The `pprint` module's `PrettyPrinter` class and its `pformat()`, and `pprint()` functions have a new option, `compact`, that controls how the output is formatted. Currently setting `compact` to `True` means that sequences will be printed with as many sequence elements as will fit within `width` on each (indented) line. (Contributed by Serhiy Storchaka in issue 19132.)

Long strings are now wrapped using Python’s normal line continuation syntax. (Contributed by Antoine Pitrou in issue 17150.)

**pty**

`pty.spawn()` now returns the status value from `os.waitpid()` on the child process, instead of `None`. (Contributed by Gregory P. Smith.)
The `pydoc` module is now based directly on the `inspect.signature()` introspection API, allowing it to provide signature information for a wider variety of callable objects. This change also means that `__wrapped__` attributes are now taken into account when displaying help information. (Contributed by Larry Hastings in issue 19674.)

The `pydoc` module no longer displays the `self` parameter for already bound methods. Instead, it aims to always display the exact current signature of the supplied callable. (Contributed by Larry Hastings in issue 20710.)

In addition to the changes that have been made to `pydoc` directly, its handling of custom `__dir__` methods and various descriptor behaviours has also been improved substantially by the underlying changes in the `inspect` module.

As the `help()` builtin is based on `pydoc`, the above changes also affect the behaviour of `help()`.

New `fullmatch()` function and `regex.fullmatch()` method anchor the pattern at both ends of the string to match. This provides a way to be explicit about the goal of the match, which avoids a class of subtle bugs where $ characters get lost during code changes or the addition of alternatives to an existing regular expression. (Contributed by Matthew Barnett in issue 16203.)
The repr of regex objects now includes the pattern and the flags; the repr of match objects now includes the start, end, and the part of the string that matched. (Contributed by Hugo Lopes Tavares and Serhiy Storchaka in issue 13592 and issue 17087.)

**resource**

New prlimit() function, available on Linux platforms with a kernel version of 2.6.36 or later and glibc of 2.13 or later, provides the ability to query or set the resource limits for processes other than the one making the call. (Contributed by Christian Heimes in issue 16595.)

On Linux kernel version 2.6.36 or later, there are also some new Linux specific constants: RLIMIT_MSGQUEUE, RLIMIT_NICE, RLIMIT_RTPRIO, RLIMIT_RTTIME, and RLIMIT.SIGPENDING. (Contributed by Christian Heimes in issue 19324.)

On FreeBSD version 9 and later, there are some new FreeBSD specific constants: RLIMIT_SBSIZE, RLIMIT_SWAP, and RLIMIT.NPTS. (Contributed by Claudiu Popa in issue 19343.)

**select**

epoll objects now support the context management protocol. When used in a with statement, the close() method will be called automatically at the end of the block. (Contributed by Serhiy Storchaka in issue 16488.)

devpoll objects now have fileno() and close() methods, as well as a new attribute closed. (Contributed by Victor Stinner in issue 18794.)
**shelve**

Shelf instances may now be used in `with` statements, and will be automatically closed at the end of the `with` block. (Contributed by Filip Gruszczyński in [issue 13896](https://example.com/issue/13896).)

**shutil**

copyfile() now raises a specific Error subclass, SameFileError, when the source and destination are the same file, which allows an application to take appropriate action on this specific error. (Contributed by Atsuo Ishimoto and Hynek Schlawack in [issue 1492704](https://example.com/issue/1492704).)

**smtpd**

The SMTPServer and SMTPChannel classes now accept a `map` keyword argument which, if specified, is passed in to asynchat.async_chat as its `map` argument. This allows an application to avoid affecting the global socket map. (Contributed by Vinay Sajip in [issue 11959](https://example.com/issue/11959).)

**smtplib**

SMTPException is now a subclass of OSError, which allows both socket level errors and SMTP protocol level errors to be caught in one try/except statement by code that only cares whether or not an error occurred. (Contributed by Ned Jackson Lovely in [issue 2118](https://example.com/issue/2118).)

**socket**
The socket module now supports the CAN_BCM protocol on platforms that support it. (Contributed by Brian Thorne in issue 15359.)

Socket objects have new methods to get or set their inheritable flag, get_inheritable() and set_inheritable().

The socket.AF_* and socket.SOCK_* constants are now enumeration values using the new enum module. This allows meaningful names to be printed during debugging, instead of integer “magic numbers”.

The AF_LINK constant is now available on BSD and OSX.

inet_ntop() and inet_ntop() are now supported on Windows. (Contributed by Atsuo Ishimoto in issue 7171.)

sqlite3

A new boolean parameter to the connect() function, uri, can be used to indicate that the database parameter is a uri (see the SQLite URI documentation). (Contributed by poq in issue 13773.)

ssl

PROTOCOL_TLSv1_1 and PROTOCOL_TLSv1_2 (TLSv1.1 and TLSv1.2 support) have been added; support for these protocols is only available if Python is linked with OpenSSL 1.0.1 or later. (Contributed by Michele Orrù and Antoine Pitrou in issue 16692.)

New function create_default_context() provides a standard way to obtain an SSLContext whose settings are intended to be a reasonable balance between compatibility and security. These settings
are more stringent than the defaults provided by the SSLContext constructor, and may be adjusted in the future, without prior deprecation, if best-practice security requirements change. The new recommended best practice for using stdlib libraries that support SSL is to use create_default_context() to obtain an SSLContext object, modify it if needed, and then pass it as the context argument of the appropriate stdlib API. (Contributed by Christian Heimes in issue 19689.)

SSLContext method load_verify_locations() accepts a new optional argument cadata, which can be used to provide PEM or DER encoded certificates directly via strings or bytes, respectively. (Contributed by Christian Heimes in issue 18138.)

New function get_default_verify_paths() returns a named tuple of the paths and environment variables that the set_default_verify_paths() method uses to set OpenSSL's default cafile and capath. This can be an aid in debugging default verification issues. (Contributed by Christian Heimes in issue 18143.)

SSLContext has a new method, cert_store_stats(), that reports the number of loaded X.509 certs, X.509 CA certs, and certificate revocation lists (crls), as well as a get_ca_certs() method that returns a list of the loaded CA certificates. (Contributed by Christian Heimes in issue 18147.)

If OpenSSL 0.9.8 or later is available, SSLContext has an new attribute verify_flags that can be used to control the certificate verification process by setting it to some combination of the new constants VERIFY_DEFAULT, VERIFY_CRL_CHECK_LEAF, VERIFY_CRL_CHECK_CHAIN, or VERIFY_X509 STRICT. OpenSSL does not do any CRL verification by default. (Contributed by Christien
New SSLContext method `load_default_certs()` loads a set of default “certificate authority” (CA) certificates from default locations, which vary according to the platform. It can be used to load both TLS web server authentication certificates (`purpose=SERVER_AUTH`) for a client to use to verify a server, and certificates for a server to use in verifying client certificates (`purpose=CLIENT_AUTH`). (Contributed by Christian Heimes in issue 19292.)

Two new windows-only functions, `enum_certificates()` and `enum_crls()` provide the ability to retrieve certificates, certificate information, and CRLs from the Windows cert store. (Contributed by Christian Heimes in issue 17134.)

Support for server-side SNI (Server Name Indication) using the new `ssl.SSLContext.set_servername_callback()` method. (Contributed by Daniel Black in issue 8109.)

The dictionary returned by `SSLSocket.getpeercert()` contains additional X509v3 extension items: `crlDistributionPoints`, `caIssuers`, and OCSP URIs. (Contributed by Christian Heimes in issue 18379.)

`stat`

The `stat` module is now backed by a C implementation in `_stat`. A C implementation is required as most of the values aren’t standardized and are platform-dependent. (Contributed by Christian Heimes in issue 11016.)

The module supports new `ST_MODE` flags, `S_IFDOOR`, `S_IFPORT`, and
S_IFWHT. (Contributed by Christian Hiemes in issue 11016.)

struct

New function iter_unpack and a new struct.Struct.iter_unpack() method on compiled formats provide streamed unpacking of a buffer containing repeated instances of a given format of data. (Contributed by Antoine Pitrou in issue 17804.)

subprocess

check_output() now accepts an input argument that can be used to provide the contents of stdin for the command that is run. (Contributed by Zack Weinberg in issue 16624.)

getstatus() and getstatusoutput() now work on Windows. This change was actually inadvertently made in 3.3.4. (Contributed by Tim Golden in issue 10197.)

sunau

The getparams() method now returns a namedtuple rather than a plain tuple. (Contributed by Claudiu Popa in issue 18901.)

sunau.open() now supports the context management protocol: when used in a with block, the close method of the returned object will be called automatically at the end of the block. (Contributed by Serhiy Storchaka in issue 18878.)

AU_write.setsampwidth() now supports 24 bit samples, thus
adding support for writing 24 sample using the module. (Contributed by Serhiy Storchaka in issue 19261.)

The `writeframesraw()` and `writeframes()` methods now accept any `bytes-like object`. (Contributed by Serhiy Storchaka in issue 8311.)

**sys**

New function `sys.getallocatedblocks()` returns the current number of blocks allocated by the interpreter. (In CPython with the default `--with-pymalloc` setting, this is allocations made through the `PyObject_Malloc()` API.) This can be useful for tracking memory leaks, especially if automated via a test suite. (Contributed by Antoine Pitrou in issue 13390.)

When the Python interpreter starts in interactive mode, it checks for an `__interactivehook__` attribute on the `sys` module. If the attribute exists, its value is called with no arguments just before interactive mode is started. The check is made after the `PYTHONSTARTUP` file is read, so it can be set there. The `site` module sets it to a function that enables tab completion and history saving (in `~/.python-history`) if the platform supports `readline`. If you do not want this (new) behavior, you can override it in `PYTHONSTARTUP`, `sitecustomize`, or `usercustomize` by deleting this attribute from `sys` (or setting it to some other callable). (Contributed by Éric Araujo and Antoine Pitrou in issue 5845.)

**tarfile**

The `tarfile` module now supports a simple **Command Line Interface** when called as a script directly or via `-m`. This can be used to create
and extract tarfile archives. (Contributed by Berker Peksag in issue 13477.)

textrawp

The TextWrapper class has two new attributes/constructor arguments: max_lines, which limits the number of lines in the output, and placeholder, which is a string that will appear at the end of the output if it has been truncated because of max_lines. Building on these capabilities, a new convenience function shorten() collapses all of the whitespace in the input to single spaces and produces a single line of a given width that ends with the placeholder (by default, [...]). (Contributed by Antoine Pitrou and Serhiy Storchaka in issue 18585 and issue 18725.)

threading

The Thread object representing the main thread can be obtained from the new main_thread() function. In normal conditions this will be the thread from which the Python interpreter was started. (Contributed by Andrew Svetlov in issue 18882.)

traceback

A new traceback.clear_frames() function takes a traceback object and clears the local variables in all of the frames it references, reducing the amount of memory consumed. (Contributed by Andrew Kuchling in issue 1565525.)

types
A new `DynamicClassAttribute()` descriptor provides a way to define an attribute that acts normally when looked up through an instance object, but which is routed to the `class __getattr__` when looked up through the class. This allows one to have properties active on a class, and have virtual attributes on the class with the same name (see `Enum` for an example). (Contributed by Ethan Furman in issue 19030.)

**urllib**

`urllib.request` now supports data: URLs via the `DataHandler` class. (Contributed by Mathias Panzenböck in issue 16423.)

The `http` method that will be used by a `Request` class can now be specified by setting a `method` class attribute on the subclass. (Contributed by Jason R Coombs in issue 18978.)

`Request` objects are now reusable: if the `full_url` or `data` attributes are modified, all relevant internal properties are updated. This means, for example, that it is now possible to use the same `Request` object in more than one `OpenerDirector.open()` call with different `data` arguments, or to modify a `Request`'s `url` rather than recomputing it from scratch. There is also a new `remove_header()` method that can be used to remove headers from a `Request`. (Contributed by Alexey Kachayev in issue 16464, Daniel Wozniak in issue 17485, and Damien Brecht and Senthil Kumaran in issue 17272.)

`HTTPError` objects now have a `headers` attribute that provides access to the HTTP response headers associated with the error. (Contributed by Berker Peksag in issue 15701.)
unittest

The `TestCase` class has a new method, `subTest()`, that produces a context manager whose `with` block becomes a “sub-test”. This context manager allows a test method to dynamically generate subtests by, say, calling the `subTest` context manager inside a loop. A single test method can thereby produce an indefinite number of separately-identified and separately-counted tests, all of which will run even if one or more of them fail. For example:

```python
class NumbersTest(unittest.TestCase):
    def test_even(self):
        for i in range(6):
            with self.subTest(i=i):
                self.assertEqual(i % 2, 0)
```

will result in six subtests, each identified in the unittest verbose output with a label consisting of the variable name `i` and a particular value for that variable (`i=0, i=1, etc`). See Distinguishing test iterations using subtests for the full version of this example. (Contributed by Antoine Pitrou in issue 16997.)

`unittest.main()` now accepts an iterable of test names for `defaultTest`, where previously it only accepted a single test name as a string. (Contributed by Jyrki Pulliainen in issue 15132.)

If `SkipTest` is raised during test discovery (that is, at the module level in the test file), it is now reported as a skip instead of an error. (Contributed by Zach Ware in issue 16935.)

discover() now sorts the discovered files to provide consistent test ordering. (Contributed by Martin Melin and Jeff Ramnani in issue 16709.)
**TestSuite** now drops references to tests as soon as the test has been run, if the test is successful. On Python interpreters that do garbage collection, this allows the tests to be garbage collected if nothing else is holding a reference to the test. It is possible to override this behavior by creating a **TestSuite** subclass that defines a custom `_removeTestAtIndex` method. (Contributed by Tom Wardill, Matt McClure, and Andrew Svetlov in issue 11798.)

A new test assertion context-manager, `assertLogs()`, will ensure that a given block of code emits a log message using the **logging** module. By default the message can come from any logger and have a priority of `INFO` or higher, but both the logger name and an alternative minimum logging level may be specified. The object returned by the context manager can be queried for the **LogRecords** and/or formatted messages that were logged. (Contributed by Antoine Pitrou in issue 18937.)

Test discovery now works with namespace packages (Contributed by Claudiu Popa in issue 17457.)

**unittest.mock** objects now inspect their specification signatures when matching calls, which means an argument can now be matched by either position or name, instead of only by position. (Contributed by Antoine Pitrou in issue 17015.)

mock_open() objects now have readline and readlines methods. (Contributed by Toshio Kuratomi in issue 17467.)

**venv**

**venv** now includes activation scripts for the csh and fish shells.
EnvBuilder and the create() convenience function take a new keyword argument with_pip, which defaults to False, that controls whether or not EnvBuilder ensures that pip is installed in the virtual environment. (Contributed by Nick Coghlan in issue 19552 as part of the PEP 453 implementation.)

wave

The getparams() method now returns a namedtuple rather than a plain tuple. (Contributed by Claudiu Popa in issue 17487.)

wave.open() now supports the context management protocol. (Contributed by Claudiu Popa in issue 17616.)

wave can now write output to unseekable files. (Contributed by David Jones, Guilherme Polo, and Serhiy Storchaka in issue 5202.)

The writeframesraw() and writeframes() methods now accept any bytes-like object. (Contributed by Serhiy Storchaka in issue 8311.)

weakref

New WeakMethod class simulates weak references to bound methods. (Contributed by Antoine Pitrou in issue 14631.)

New finalize class makes it possible to register a callback to be invoked when an object is garbage collected, without needing to carefully manage the lifecycle of the weak reference itself. (Contributed by Richard Oudkerk in issue 15528.)
The callback, if any, associated with a `ref` is now exposed via the `__callback__` attribute. (Contributed by Mark Dickinson in issue 17643.)

**xml.etree**

A new parser, `XMLPullParser`, allows a non-blocking applications to parse XML documents. An example can be seen at Pull API for non-blocking parsing. (Contributed by Antoine Pitrou in issue 17741.)

The `xml.etree.ElementTree tostring()` and `tostringlist()` functions, and the `ElementTree write()` method, now have a `short_empty_elements` keyword-only parameter providing control over whether elements with no content are written in abbreviated (`<tag />`) or expanded (`<tag></tag>`) form. (Contributed by Ariel Poliak and Serhiy Storchaka in issue 14377.)

**zipfile**

The `writepy()` method of the `PyZipFile` class has a new `filterfunc` option that can be used to control which directories and files are added to the archive. For example, this could be used to exclude test files from the archive. (Contributed by Christian Tismer in issue 19274.)

The `allowZip64` parameter to `ZipFile` and `PyZipfile` is now True by default. (Contributed by William Mallard in issue 17201.)
CPython Implementation Changes

PEP 445: Customization of CPython Memory Allocators

**PEP 445** adds new C level interfaces to customize memory allocation in the CPython interpreter.

See also:

**PEP 445** – Add new APIs to customize Python memory allocators

PEP written and implemented by Victor Stinner.

PEP 442: Safe Object Finalization

**PEP 442** removes the current limitations and quirks of object finalization in CPython. With it, objects with `__del__()` methods, as well as generators with `finally` clauses, can be finalized when they are part of a reference cycle.

As part of this change, module globals are no longer forcibly set to `None` during interpreter shutdown in most cases, instead relying on the normal operation of the cyclic garbage collector. This avoids a whole class of interpreter-shutdown-time errors, usually involving `__del__` methods, that have plagued Python since the cyclic GC was first introduced.

See also:

**PEP 442** – Safe object finalization
PEP 456: Secure and Interchangeable Hash Algorithm

PEP 456 follows up on earlier security fix work done on Python’s hash algorithm to address certain DOS attacks to which public facing APIs backed by dictionary lookups may be subject. (See issue 14621 for the start of the current round of improvements.) The PEP unifies CPython’s hash code to make it easier for a packager to substitute a different hash algorithm, and switches Python’s default implementation to a SipHash implementation on platforms that have a 64 bit data type. Any performance differences in comparison with the older FNV algorithm are trivial.

The PEP adds additional fields to the sys.hash_info struct sequence to describe the hash algorithm in use by the currently executing binary. Otherwise, the PEP does not alter any existing CPython APIs.

PEP 436: Argument Clinic

“Argument Clinic” (PEP 436) is now part of the CPython build process and can be used to simplify the process of defining and maintaining accurate signatures for builtins and standard library extension modules implemented in C.

Some standard library extension modules have been converted to use Argument Clinic in Python 3.4, and pydoc and inspect have been updated accordingly.

It is expected that signature metadata for programmatic introspection
will be added to additional callables implemented in C as part of Python 3.4 maintenance releases.

**Note:** The Argument Clinic PEP is not fully up to date with the state of the implementation. This has been deemed acceptable by the release manager and core development team in this case, as Argument Clinic will not be made available as a public API for third party use in Python 3.4.

See also:

**PEP 436 – The Argument Clinic DSL**

PEP written and implemented by Larry Hastings.

Other Build and C API Changes

- The new `PyType_GetSlot()` function has been added to the stable ABI, allowing retrieval of function pointers from named type slots when using the limited API. (Contributed by Martin von Löwis in issue 17162.)
- The new `Py_SetStandardStreamEncoding()` pre-initialization API allows applications embedding the CPython interpreter to reliably force a particular encoding and error handler for the standard streams. (Contributed by Bastien Montagne and Nick Coghlan in issue 16129.)
- Most Python C APIs that don't mutate string arguments are now correctly marked as accepting `const char *` rather than `char *`. (Contributed by Serhiy Storchaka in issue 1772673.)
- A new shell version of `python-config` can be used even when a python interpreter is not available (for example, in cross compilation scenarios).
- `PyUnicode_FromFormat()` now supports width and precision
specifications for %s, %A, %U, %V, %S, and %R. (Contributed by Ysj Ray and Victor Stinner in issue 7330.)

- New function `PyStructSequence_InitType2()` supplements the existing `PyStructSequence_InitType()` function. The difference is that it returns 0 on success and -1 on failure.
- The CPython source can now be compiled using the address sanity checking features of recent versions of GCC and clang: the false alarms in the small object allocator have been silenced. (Contributed by Dhiru Kholia in issue 18596.)
- The Windows build now uses Address Space Layout Randomization and Data Execution Prevention. (Contributed by Christian Heimes in issue 16632.)
- New function `PyObject_LengthHint()` is the C API equivalent of `operator.length_hint()`. (Contributed by Armin Ronacher in issue 16148.)

Other Improvements

- The `python` command has a new option, -I, which causes it to run in “isolated mode”, which means that `sys.path` contains neither the script's directory nor the user's site-packages directory, and all `PYTHON*` environment variables are ignored (it implies both -s and -E). Other restrictions may also be applied in the future, with the goal being to isolate the execution of a script from the user’s environment. This is appropriate, for example, when Python is used to run a system script. On most POSIX systems it can and should be used in the `#!` line of system scripts. (Contributed by Christian Heimes in issue 16499.)
- Tab-completion is now enabled by default in the interactive interpreter on systems that support `readline`. History is also enabled by default, and is written to (and read from) the file `~/.python-history`. (Contributed by Antoine Pitrou and Éric Araujo in issue 5845.)
• Invoking the Python interpreter with --version now outputs the version to standard output instead of standard error (issue 18338). Similar changes were made to argparse (issue 18920) and other modules that have script-like invocation capabilities (issue 18922).

• The CPython Windows installer now adds .py to the PATHEXT variable when extensions are registered, allowing users to run a python script at the windows command prompt by just typing its name without the .py extension. (Contributed by Paul Moore in issue 18569.)

• A new make target coverage-report will build python, run the test suite, and generate an HTML coverage report for the C codebase using gcov and lcov.

• The -R option to the python regression test suite now also checks for memory allocation leaks, using sys.getallocatedblocks(). (Contributed by Antoine Pitrou in issue 13390.)

• python -m now works with namespace packages.

• The stat module is now implemented in C, which means it gets the values for its constants from the C header files, instead of having the values hard-coded in the python module as was previously the case.

• Loading multiple python modules from a single OS module (.so, .dll) now works correctly (previously it silently returned the first python module in the file). (Contributed by Václav Šmilauer in issue 16421.)

• A new opcode, LOAD_CLASSDEREF, has been added to fix a bug in the loading of free variables in class bodies that could be triggered by certain uses of __prepare__. (Contributed by Benjamin Peterson in issue 17853.)

• A number of MemoryError-related crashes were identified and fixed by Victor Stinner using his PEP 445-based pyfailmalloc tool (issue 18408, issue 18520).
The `pyvenv` command now accepts a `--copies` option to use copies rather than symlinks even on systems where symlinks are the default. (Contributed by Vinay Sajip in issue 18807.)

The `pyvenv` command also accepts a `--without-pip` option to suppress the otherwise-automatic bootstrapping of pip into the virtual environment. (Contributed by Nick Coghlan in issue 19552 as part of the PEP 453 implementation.)

The encoding name is now optional in the value set for the `PYTHONIOENCODING` environment variable. This makes it possible to set just the error handler, without changing the default encoding. (Contributed by Serhiy Storchaka in issue 18818.)

The `bz2`, `lzma`, and `gzip` module open functions now support `x` (exclusive creation) mode. (Contributed by Tim Heaney and Vajrasky Kok in issue 19201, issue 19222, and issue 19223.)

Significant Optimizations

- The UTF-32 decoder is now 3x to 4x faster. (Contributed by Serhiy Storchaka in issue 14625.)
- The cost of hash collisions for sets is now reduced. Each hash table probe now checks a series of consecutive, adjacent key/hash pairs before continuing to make random probes through the hash table. This exploits cache locality to make collision resolution less expensive. The collision resolution scheme can be described as a hybrid of linear probing and open addressing. The number of additional linear probes defaults to nine. This can be changed at compile-time by defining `LINEAR_PROBES` to be any value. Set `LINEAR_PROBES=0` to turn-off linear probing entirely. (Contributed by Raymond Hettinger in issue 18771.)
- The interpreter starts about 30% faster. A couple of measures lead to the speedup. The interpreter loads fewer modules on startup, e.g. the `re`, `collections` and `locale` modules and their dependencies are no longer imported by default. The
marshal module has been improved to load compiled Python code faster. (Contributed by Antoine Pitrou, Christian Heimes and Victor Stinner in issue 19219, issue 19218, issue 19209, issue 19205 and issue 9548.)

- **bz2.BZ2File** is now as fast or faster than the Python2 version for most cases. **lzma.LZMAFile** has also been optimized. (Contributed by Serhiy Storchaka and Nadeem Vawda in issue 16034.)

- **random.getrandbits()** is 20%-40% faster for small integers (the most common use case). (Contributed by Serhiy Storchaka in issue 16674.)

- By taking advantage of the new storage format for strings, pickling of strings is now significantly faster. (Contributed by Victor Stinner and Antoine Pitrou in issue 15596.)

- A performance issue in `io.FileIO.readall()` has been solved. This particularly affects Windows, and significantly speeds up the case of piping significant amounts of data through `subprocess`. (Contributed by Richard Oudkerk in issue 15758.)

- **html.escape()** is now 10x faster. (Contributed by Matt Bryant in issue 18020.)

- On Windows, the native `VirtualAlloc` is now used instead of the CRT `malloc` in `obmalloc`. Artificial benchmarks show about a 3% memory savings.

- **os.urandom()** now uses a lazily-opened persistent file descriptor so as to avoid using many file descriptors when run in parallel from multiple threads. (Contributed by Antoine Pitrou in issue 18756.)
Deprecated

This section covers various APIs and other features that have been deprecated in Python 3.4, and will be removed in Python 3.5 or later. In most (but not all) cases, using the deprecated APIs will produce a DeprecationWarning when the interpreter is run with deprecation warnings enabled (for example, by using -Wd).

Deprecations in the Python API

- As mentioned in PEP 451: A ModuleSpec Type for the Import System, a number of importlib methods and functions are deprecated: `importlib.find_loader()` is replaced by `importlib.util.find_spec()`, `importlib.machinery.PathFinder.find_module()` is replaced by `importlib.machinery.PathFinder.find_spec()`, `importlib.abc.MetaPathFinder.find_module()` is replaced by `importlib.abc.MetaPathFinder.find_spec()`, `importlib.abc.PathEntryFinder.find_loader()` and `find_module()` are replaced by `importlib.abc.PathEntryFinder.find_spec()`; all of the `xxxLoader ABC load_module methods` (`importlib.abc.Loader.load_module()`, `importlib.abc.InspectLoader.load_module()`, `importlib.abc.FileLoader.load_module()`, `importlib.abc.SourceLoader.load_module()`) should no longer be implemented, instead loaders should implement an `exec_module` method (`importlib.abc.Loader.exec_module()`,
importlib.abc.InspectLoader.exec_module()
importlib.abc.SourceLoader.exec_module()) and let the import system take care of the rest; and
importlib.abc.Loader.module_repr(),
importlib.util.module_for_loader(),
importlib.util.set_loader(), and
importlib.util.set_package() are no longer needed because their functions are now handled automatically by the import system.

- The imp module is pending deprecation. To keep compatibility with Python 2/3 code bases, the module’s removal is currently not scheduled.
- The formatter module is pending deprecation and is slated for removal in Python 3.6.
- MD5 as the default digestmod for the hmac.new() function is deprecated. Python 3.6 will require an explicit digest name or constructor as digestmod argument.
- The internal Netrc class in the ftplib module has been documented as deprecated in its docstring for quite some time. It now emits a DeprecationWarning and will be removed completely in Python 3.5.
- The undocumented endtime argument to subprocess.Popen.wait() should not have been exposed and is hopefully not in use; it is deprecated and will mostly likely be removed in Python 3.5.
- The strict argument of HTMLParser is deprecated.
- The plistlib readPlist(), writePlist(), readPlistFromBytes(), and writePlistToBytes() functions are deprecated in favor of the corresponding new functions load(), dump(), loads(), and dumps(). Data() is deprecated in favor of just using the bytes constructor.
- The sysconfig key SO is deprecated, it has been replaced by EXT_SUFFIX.
• The U mode accepted by various open functions is deprecated. In Python3 it does not do anything useful, and should be replaced by appropriate uses of `io.TextIOWrapper` (if needed) and its `newline` argument.

• The `parser` argument of `xml.etree.ElementTree.iterparse()` has been deprecated, as has the `html` argument of `XMLParser()`. To prepare for the removal of the latter, all arguments to `XMLParser` should be passed by keyword.

**Deprecated Features**

• Running IDLE with the `-n` flag (no subprocess) is deprecated. However, the feature will not be removed until issue 18823 is resolved.

• The site module adding a “site-python” directory to sys.path, if it exists, is deprecated (issue 19375).
Removed

Operating Systems No Longer Supported

Support for the following operating systems has been removed from the source and build tools:

- OS/2 (issue 16135).
- Windows 2000 (changeset e52df05b496a).
- Windows systems where COMSPEC points to command.com (issue 14470).
- VMS (issue 16136).

API and Feature Removals

The following obsolete and previously deprecated APIs and features have been removed:

- The unmaintained Misc/TextMate and Misc/vim directories have been removed (see the devguide for suggestions on what to use instead).
- The S0 makefile macro is removed (it was replaced by the SHLIB_SUFFIX and EXT_SUFFIX macros) (issue 16754).
- The PyThreadState.tick_counter field has been removed; its value has been meaningless since Python 3.2, when the “new GIL” was introduced (issue 19199).
- PyLoader and PyPycLoader have been removed from importlib. (Contributed by Taras Lyapun in issue 15641.)
- The strict argument to HTTPConnection and HTTPSConnection has been removed. HTTP 0.9-style “Simple Responses” are no longer supported.
- The deprecated urllib.request.Request getter and setter
methods add_data, has_data, get_data, get_type, get_host, get_selector, set_proxy, get_origin_req_host, and is_unverifiable have been removed (use direct attribute access instead).

- Support for loading the deprecated TYPE_INT64 has been removed from marshall. (Contributed by Dan Riti in issue 15480.)
- inspect.Signature: positional-only parameters are now required to have a valid name.
- object.__format__() no longer accepts non-empty format strings, it now raises a TypeError instead. Using a non-empty string has been deprecated since Python 3.2. This change has been made to prevent a situation where previously working (but incorrect) code would start failing if an object gained a __format__ method, which means that your code may now raise a TypeError if you are using an 's' format code with objects that do not have a __format__ method that handles it. See issue 7994 for background.
- difflib.SequenceMatcher.isbjunk() and difflib.SequenceMatcher.isbpopular() were deprecated in 3.2, and have now been removed: use x in sm.bjunk and x in sm.bpopular, where sm is a SequenceMatcher object (issue 13248).

Code Cleanups

- The unused and undocumented internal Scanner class has been removed from the pydoc module.
- The private and effectively unused _gestalt module has been removed, along with the private platform functions _mac_ver_lookup, _mac_ver_gstalt, and _bcd2str, which would only have ever been called on badly broken OSX systems (see issue 18393).
• The hardcoded copies of certain `stat` constants that were included in the `tarfile` module namespace have been removed.
Porting to Python 3.4

This section lists previously described changes and other bugfixes that may require changes to your code.

Changes in ‘python’ Command Behavior

- In a posix shell, setting the PATH environment variable to an empty value is equivalent to not setting it at all. However, setting PYTHONPATH to an empty value was not equivalent to not setting it at all: setting PYTHONPATH to an empty value was equivalent to setting it to ., which leads to confusion when reasoning by analogy to how PATH works. The behavior now conforms to the posix convention for PATH.
- The [X refs, Y blocks] output of a debug (--with-pydebug) build of the CPython interpreter is now off by default. It can be re-enabled using the -X showrefcount option. (Contributed by Ezio Melotti in issue 17323.)
- The python command and most stdlib scripts (as well as argparse) now output --version information to stdout instead of stderr (for issue list see Other Improvements above).

Changes in the Python API

- The ABCs defined in importlib.abc now either raise the appropriate exception or return a default value instead of raising NotImplemented Error blindly. This will only affect code calling super() and falling through all the way to the ABCs. For compatibility, catch both NotImplemented Error or the appropriate exception as needed.
- The module type now initializes the __package__ and
__loader__ attributes to None by default. To determine if these attributes were set in a backwards-compatible fashion, use e.g. `getattr(module, '__loader__', None) is not None` (issue 17115).

- `importlib.util.module_for_loader()` now sets __loader__ and __package__ unconditionally to properly support reloading. If this is not desired then you will need to set these attributes manually. You can use `importlib.util.module_to_load()` for module management.

- Import now resets relevant attributes (e.g. __name__, __loader__, __package__, __file__, __cached__) unconditionally when reloading. Note that this restores a pre-3.3 behavior in that it means a module is re-found when re-loaded (issue 19413).

- Frozen packages no longer set __path__ to a list containing the package name, they now set it to an empty list. The previous behavior could cause the import system to do the wrong thing on submodule imports if there was also a directory with the same name as the frozen package. The correct way to determine if a module is a package or not is to use `hasattr(module, '__path__')` (issue 18065).

- Frozen modules no longer define a __file__ attribute. It's semantically incorrect for frozen modules to set the attribute as they are not loaded from any explicit location. If you must know that a module comes from frozen code then you can see if the module's __spec__.location is set to 'frozen', check if the loader is a subclass of `importlib.machinery.FrozenImporter`, or if Python 2 compatibility is necessary you can use `imp.is_frozen()`.

- `py_compile.compile()` now raises `FileExistsError` if the file path it would write to is a symlink or a non-regular file. This is to act as a warning that import will overwrite those files with a
regular file regardless of what type of file path they were originally.

- `importlib.abc.SourceLoader.get_source()` no longer raises `ImportError` when the source code being loaded triggers a `SyntaxError` or `UnicodeDecodeError`. As `ImportError` is meant to be raised only when source code cannot be found but it should, it was felt to be over-reaching/overloading of that meaning when the source code is found but improperly structured. If you were catching `ImportError` before and wish to continue to ignore syntax or decoding issues, catch all three exceptions now.

- `functools.update_wrapper()` and `functools.wraps()` now correctly set the `__wrapped__` attribute to the function being wrapped, even if that function also had its `__wrapped__` attribute set. This means `__wrapped__` attributes now correctly link a stack of decorated functions rather than every `__wrapped__` attribute in the chain referring to the innermost function. Introspection libraries that assumed the previous behaviour was intentional can use `inspect.unwrap()` to access the first function in the chain that has no `__wrapped__` attribute.

- `inspect.getfullargspec()` has been reimplemented on top of `inspect.signature()` and hence handles a much wider variety of callable objects than it did in the past. It is expected that additional built-in and extension module callables will gain signature metadata over the course of the Python 3.4 series. Code that assumes that `inspect.getfullargspec()` will fail on non-Python callables may need to be adjusted accordingly.

- `importlib.machinery.PathFinder` now passes on the current working directory to objects in `sys.path_hooks` for the empty string. This results in `sys.path_importer_cache` never containing `''`, thus iterating through `sys.path_importer_cache` based on `sys.path` will not find all keys. A module's `__file__` when imported in the current working directory will also now have an absolute path, including when using `-m` with the interpreter (except for
__main__.__file__ when a script has been executed directly using a relative path) (Contributed by Brett Cannon in issue 18416). is specified on the command-line) (issue 18416).

- The removal of the strict argument to HTTPConnection and HTTPSConnection changes the meaning of the remaining arguments if you are specifying them positionally rather than by keyword. If you've been paying attention to deprecation warnings your code should already be specifying any additional arguments via keywords.

- Strings between from __future__ import ... statements now always raise a SyntaxError. Previously if there was no leading docstring, an interstitial string would sometimes be ignored. This brings CPython into compliance with the language spec; Jython and PyPy already were. (issue 17434).

- ssl.SSLSocket.getpeercert() and ssl.SSLSocket.do_handshake() now raise an OSError with ENOTCONN when the SSLSocket is not connected, instead of the previous behavior of raising an AttributeError. In addition, getpeercert() will raise a ValueError if the handshake has not yet been done.

- base64.b32decode() now raises a binascii.Error when the input string contains non-b32-alphabet characters, instead of a TypeError. This particular TypeError was missed when the other TypeErrors were converted. (Contributed by Serhiy Storchaka in issue 18011.) Note: this change was also inadvertently applied in Python 3.3.3.

- The file attribute is now automatically closed when the creating cgi.FieldStorage instance is garbage collected. If you were pulling the file object out separately from the cgi.FieldStorage instance and not keeping the instance alive, then you should either store the entire cgi.FieldStorage instance or read the contents of the file before the cgi.FieldStorage instance is garbage collected.
- Calling read or write on a closed SSL socket now raises an informative `ValueError` rather than the previous more mysterious `AttributeError` (issue 9177).
- `slice.indices()` no longer produces an `OverflowError` for huge values. As a consequence of this fix, `slice.indices()` now raises a `ValueError` if given a negative length; previously it returned nonsense values (issue 14794).
- The `complex` constructor, unlike the `cmath` functions, was incorrectly accepting `float` values if an object's `__complex__` special method returned one. This now raises a `TypeError`. (issue 16290.)
- The `int` constructor in 3.2 and 3.3 erroneously accepts `float` values for the `base` parameter. It is unlikely anyone was doing this, but if so, it will now raise a `TypeError` (issue 16772).
- Defaults for keyword-only arguments are now evaluated after defaults for regular keyword arguments, instead of before. Hopefully no one wrote any code that depends on the previous buggy behavior (issue 16967).
- Stale thread states are now cleared after `fork()`. This may cause some system resources to be released that previously were incorrectly kept perpetually alive (for example, database connections kept in thread-local storage). (issue 17094.)
- Parameter names in `__annotations__` dict are now mangled properly, similarly to `__kwdefaults__`. (Contributed by Yury Selivanov in issue 20625.)
- `hashlib.hash.name` now always returns the identifier in lower case. Previously some built-in hashes had uppercase names, but now that it is a formal public interface the naming has been made consistent (issue 18532).
- Because `unittest.TestSuite` now drops references to tests after they are run, test harnesses that re-use a `TestSuite` to re-run a set of tests may fail. Test suites should not be re-used in this fashion since it means state is retained between test runs,
breaking the test isolation that `unittest` is designed to provide. However, if the lack of isolation is considered acceptable, the old behavior can be restored by creating a `TestSuite` subclass that defines a `__removeTestAtIndex` method that does nothing (see `TestSuite.__iter__()`)(issue 11798).

- `unittest` now uses `argparse` for command line parsing. There are certain invalid command forms that used to work that are no longer allowed; in theory this should not cause backward compatibility issues since the disallowed command forms didn’t make any sense and are unlikely to be in use.

- The `re.split()`, `re.findall()`, and `re.sub()` functions, and the `group()` and `groups()` methods of match objects now always return a `bytes` object when the string to be matched is a `bytes-like object`. Previously the return type matched the input type, so if your code was depending on the return value being, say, a `bytearray`, you will need to change your code.

- `audioop` functions now raise an error immediately if passed string input, instead of failing randomly later on (issue 16685).

- The new `convert_charrefs` argument to `HTMLParser` currently defaults to False for backward compatibility, but will eventually be changed to default to True. It is recommended that you add this keyword, with the appropriate value, to any `HTMLParser` calls in your code (issue 13633).

- Since the `digestmod` argument to the `hmac.new()` function will in the future have no default, all calls to `hmac.new()` should be changed to explicitly specify a `digestmod` (issue 17276).

- Calling `sysconfig.get_config_var()` with the SO key, or looking SO up in the results of a call to `sysconfig.get_config_vars()` is deprecated. This key should be replaced by EXT_SUFFIX or SHLIB_SUFFIX, depending on the context (issue 19555).

- Any calls to open functions that specify U should be modified. U is ineffective in Python3 and will eventually raise an error if used.
Depending on the function, the equivalent of its old Python2 behavior can be achieved using either a `newline` argument, or if necessary by wrapping the stream in `TextIOWrapper` to use its `newline` argument (issue 15204).

- If you use `pyvenv` in a script and desire that pip `not` be installed, you must add `--without-pip` to your command invocation.

- The default behavior of `json.dump()` and `json.dumps()` when an indent is specified has changed: it no longer produces trailing spaces after the item separating commas at the ends of lines. This will matter only if you have tests that are doing white-space-sensitive comparisons of such output (issue 16333).

- `doctest` now looks for doctests in extension module `__doc__` strings, so if your doctest test discovery includes extension modules that have things that look like doctests in them you may see test failures you've never seen before when running your tests (issue 3158).

- The `collections.abc` module has been slightly refactored as part of the Python startup improvements. As a consequence of this, it is no longer the case that importing `collections` automatically imports `collections.abc`. If your program depended on the (undocumented) implicit import, you will need to add an explicit import `collections.abc` (issue 20784).

### Changes in the C API

- `PyEval_EvalFrameEx()`, `PyObject_Repr()`, and `PyObject_Str()`, along with some other internal C APIs, now include a debugging assertion that ensures they are not used in situations where they may silently discard a currently active exception. In cases where discarding the active exception is expected and desired (for example, because it has already been saved locally with `PyErr_Fetch()` or is being deliberately replaced with a different exception), an explicit `PyErr_Clear()`
call will be needed to avoid triggering the assertion when invoking these operations (directly or indirectly) and running against a version of Python that is compiled with assertions enabled.

- **PyErr_SetImportError()** now sets **TypeError** when its **msg** argument is not set. Previously only NULL was returned with no exception set.

- The result of the **PyOS_ReadlineFunctionPointer** callback must now be a string allocated by **PyMem_RawMalloc()** or **PyMem_RawRealloc()**, or **NULL** if an error occurred, instead of a string allocated by **PyMem_Malloc()** or **PyMem_Realloc()** (issue 16742)

- **PyThread_set_key_value()** now always set the value. In Python 3.3, the function did nothing if the key already exists (if the current value is a non-NULL pointer).

- The **f_tstate** (thread state) field of the **PyFrameObject** structure has been removed to fix a bug: see issue 14432 for the rationale.
Changed in 3.4.3

PEP 476: Enabling certificate verification by default for stdlib http clients

http.client and modules which use it, such as urllib.request and xmlrpc.client, will now verify that the server presents a certificate which is signed by a CA in the platform trust store and whose hostname matches the hostname being requested by default, significantly improving security for many applications.

For applications which require the old previous behavior, they can pass an alternate context:

```python
import urllib.request
import ssl

# This disables all verification
context = ssl._create_unverified_context()

# This allows using a specific certificate for the host to be in the trust store
context = ssl.create_default_context(cafile="/path/to/file.crt")

urllib.request.urlopen("https://invalid-cert", context)
```
What’s New In Python 3.3

This article explains the new features in Python 3.3, compared to 3.2. Python 3.3 was released on September 29, 2012. For full details, see the changelog.

See also: PEP 398 - Python 3.3 Release Schedule
Summary – Release highlights

New syntax features:

- New `yield from` expression for generator delegation.
- The `u'unicode'` syntax is accepted again for `str` objects.

New library modules:

- `faulthandler` (helps debugging low-level crashes)
- `ipaddress` (high-level objects representing IP addresses and masks)
- `lzma` (compress data using the XZ / LZMA algorithm)
- `unittest.mock` (replace parts of your system under test with mock objects)
- `venv` (Python virtual environments, as in the popular virtualenv package)

New built-in features:

- Reworked I/O exception hierarchy.

Implementation improvements:

- Rewritten `import machinery` based on `importlib`.
- More compact `unicode strings`.
- More compact `attribute dictionaries`.

Significantly Improved Library Modules:

- C Accelerator for the `decimal` module.
- Better unicode handling in the `email` module (provisional).

Security improvements:
• Hash randomization is switched on by default.

Please read on for a comprehensive list of user-facing changes.
PEP 405: Virtual Environments

Virtual environments help create separate Python setups while sharing a system-wide base install, for ease of maintenance. Virtual environments have their own set of private site packages (i.e. locally-installed libraries), and are optionally segregated from the system-wide site packages. Their concept and implementation are inspired by the popular virtualenv third-party package, but benefit from tighter integration with the interpreter core.

This PEP adds the venv module for programmatic access, and the pyvenv script for command-line access and administration. The Python interpreter checks for a pyvenv.cfg, file whose existence signals the base of a virtual environment’s directory tree.

See also:

PEP 405 - Python Virtual Environments
    PEP written by Carl Meyer; implementation by Carl Meyer and Vinay Sajip
PEP 420: Implicit Namespace Packages

Native support for package directories that don't require __init__.py marker files and can automatically span multiple path segments (inspired by various third party approaches to namespace packages, as described in PEP 420)

See also:

PEP 420 - Implicit Namespace Packages
   PEP written by Eric V. Smith; implementation by Eric V. Smith and Barry Warsaw
PEP 3118: New memoryview implementation and buffer protocol documentation

The implementation of PEP 3118 has been significantly improved.

The new memoryview implementation comprehensively fixes all ownership and lifetime issues of dynamically allocated fields in the Py_buffer struct that led to multiple crash reports. Additionally, several functions that crashed or returned incorrect results for non-contiguous or multi-dimensional input have been fixed.

The memoryview object now has a PEP-3118 compliant getbufferproc() that checks the consumer’s request type. Many new features have been added, most of them work in full generality for non-contiguous arrays and arrays with suboffsets.

The documentation has been updated, clearly spelling out responsibilities for both exporters and consumers. Buffer request flags are grouped into basic and compound flags. The memory layout of non-contiguous and multi-dimensional NumPy-style arrays is explained.

Features

- All native single character format specifiers in struct module syntax (optionally prefixed with ‘@’) are now supported.
- With some restrictions, the cast() method allows changing of format and shape of C-contiguous arrays.
- Multi-dimensional list representations are supported for any array type.
- Multi-dimensional comparisons are supported for any array type.
- One-dimensional memoryviews of hashable (read-only) types with formats B, b or c are now hashable. (Contributed by Antoine Pitrou in issue 13411.)
- Arbitrary slicing of any 1-D arrays type is supported. For example, it is now possible to reverse a memoryview in O(1) by using a negative step.

**API changes**

- The maximum number of dimensions is officially limited to 64.
- The representation of empty shape, strides and suboffsets is now an empty tuple instead of None.
- Accessing a memoryview element with format ‘B’ (unsigned bytes) now returns an integer (in accordance with the struct module syntax). For returning a bytes object the view must be cast to ‘c’ first.
- memoryview comparisons now use the logical structure of the operands and compare all array elements by value. All format strings in struct module syntax are supported. Views with unrecognised format strings are still permitted, but will always compare as unequal, regardless of view contents.
- For further changes see Build and C API Changes and Porting C code.

(Contributed by Stefan Krah in issue 10181.)

**See also:**  [PEP 3118](https://www.python.org/dev/peps/pep-03118/) - Revising the Buffer Protocol
PEP 393: Flexible String Representation

The Unicode string type is changed to support multiple internal representations, depending on the character with the largest Unicode ordinal (1, 2, or 4 bytes) in the represented string. This allows a space-efficient representation in common cases, but gives access to full UCS-4 on all systems. For compatibility with existing APIs, several representations may exist in parallel; over time, this compatibility should be phased out.

On the Python side, there should be no downside to this change.

On the C API side, PEP 393 is fully backward compatible. The legacy API should remain available at least five years. Applications using the legacy API will not fully benefit of the memory reduction, or - worse - may use a bit more memory, because Python may have to maintain two versions of each string (in the legacy format and in the new efficient storage).

Functionality

Changes introduced by PEP 393 are the following:

- Python now always supports the full range of Unicode code points, including non-BMP ones (i.e. from U+0000 to U+10FFFF). The distinction between narrow and wide builds no longer exists and Python now behaves like a wide build, even under Windows.
- With the death of narrow builds, the problems specific to narrow builds have also been fixed, for example:
  - `len()` now always returns 1 for non-BMP characters, so `len('\U0010FFFF') == 1`;
  - surrogate pairs are not recombined in string literals, so
'\uDBFF\uDFFF' != '\U0010FFFF';
• indexing or slicing non-BMP characters returns the expected value, so '\U0010FFFF'[0] now returns '\U0010FFFF' and not '\uDFFF';
• all other functions in the standard library now correctly handle non-BMP code points.
• The value of `sys.maxunicode` is now always 1114111 (0x10FFFF in hexadecimal). The `PyUnicode_GetMax()` function still returns either 0xFFFF or 0x10FFFF for backward compatibility, and it should not be used with the new Unicode API (see issue 13054).
• The `.configure` flag `--with-wide-unicode` has been removed.

Performance and resource usage

The storage of Unicode strings now depends on the highest code point in the string:

• pure ASCII and Latin1 strings (U+0000-U+00FF) use 1 byte per code point;
• BMP strings (U+0000-U+FFFF) use 2 bytes per code point;
• non-BMP strings (U+10000-U+10FFFF) use 4 bytes per code point.

The net effect is that for most applications, memory usage of string storage should decrease significantly - especially compared to former wide unicode builds - as, in many cases, strings will be pure ASCII even in international contexts (because many strings store non-human language data, such as XML fragments, HTTP headers, JSON-encoded data, etc.). We also hope that it will, for the same reasons, increase CPU cache efficiency on non-trivial applications. The memory usage of Python 3.3 is two to three times smaller than Python 3.2, and
a little bit better than Python 2.7, on a Django benchmark (see the PEP for details).

See also:

**PEP 393 - Flexible String Representation**

PEP written by Martin von Löwis; implementation by Torsten Becker and Martin von Löwis.
PEP 397: Python Launcher for Windows

The Python 3.3 Windows installer now includes a py launcher application that can be used to launch Python applications in a version independent fashion.

This launcher is invoked implicitly when double-clicking *.py files. If only a single Python version is installed on the system, that version will be used to run the file. If multiple versions are installed, the most recent version is used by default, but this can be overridden by including a Unix-style “shebang line” in the Python script.

The launcher can also be used explicitly from the command line as the py application. Running py follows the same version selection rules as implicitly launching scripts, but a more specific version can be selected by passing appropriate arguments (such as -3 to request Python 3 when Python 2 is also installed, or -2.6 to specifically request an earlier Python version when a more recent version is installed).

In addition to the launcher, the Windows installer now includes an option to add the newly installed Python to the system PATH. (Contributed by Brian Curtin in issue 3561.)

See also:

PEP 397 - Python Launcher for Windows
PEP written by Mark Hammond and Martin v. Löwis; implementation by Vinay Sajip.

Launcher documentation: Python Launcher for Windows

Installer PATH modification: Finding the Python executable
PEP 3151: Reworking the OS and IO exception hierarchy

The hierarchy of exceptions raised by operating system errors is now both simplified and finer-grained.

You don't have to worry anymore about choosing the appropriate exception type between OSError, IOError, EnvironmentError, WindowsError, mmap.error, socket.error or select.error. All these exception types are now only one: OSError. The other names are kept as aliases for compatibility reasons.

Also, it is now easier to catch a specific error condition. Instead of inspecting the errno attribute (or args[0]) for a particular constant from the errno module, you can catch the adequate OSError subclass. The available subclasses are the following:

- BlockingIOError
- ChildProcessError
- ConnectionError
- FileExistsError
- FileNotFoundError
- InterruptedError
- IsADirectoryError
- NotADirectoryError
- PermissionError
- ProcessLookupError
- TimeoutError

And the ConnectionError itself has finer-grained subclasses:
- BrokenPipeError
- ConnectionAbortedError
- ConnectionRefusedError
- ConnectionResetError

Thanks to the new exceptions, common usages of the `errno` can now be avoided. For example, the following code written for Python 3.2:

```python
from errno import ENOENT, EACCES, EPERM

try:
    with open("document.txt") as f:
        content = f.read()
except IOError as err:
    if err.errno == ENOENT:
        print("document.txt file is missing")
    elif err.errno in (EACCES, EPERM):
        print("You are not allowed to read document.
    else:
        raise
```

can now be written without the `errno` import and without manual inspection of exception attributes:

```python
try:
    with open("document.txt") as f:
        content = f.read()
except FileNotFoundError:
    print("document.txt file is missing")
except PermissionError:
    print("You are not allowed to read document.txt")
```

See also:
PEP 3151 - Reworking the OS and IO Exception Hierarchy

PEP written and implemented by Antoine Pitrou
PEP 380: Syntax for Delegating to a Subgenerator

PEP 380 adds the `yield from` expression, allowing a `generator` to delegate part of its operations to another generator. This allows a section of code containing `yield` to be factored out and placed in another generator. Additionally, the subgenerator is allowed to return with a value, and the value is made available to the delegating generator.

While designed primarily for use in delegating to a subgenerator, the `yield from` expression actually allows delegation to arbitrary subiterators.

For simple iterators, `yield from iterable` is essentially just a shortened form of `for item in iterable: yield item`:

```python
>>> def g(x):
    ...     yield from range(x, 0, -1)
    ...     yield from range(x)
    ...
>>> list(g(5))
[5, 4, 3, 2, 1, 0, 1, 2, 3, 4]
```

However, unlike an ordinary loop, `yield from` allows subgenerators to receive sent and thrown values directly from the calling scope, and return a final value to the outer generator:

```python
>>> def accumulate():
    ...     tally = 0
    ...     while 1:
    ...         next = yield
```
if next is None:
    return tally
    tally += next
    #
    def gather_tallies(tallies):
        while 1:
            tally = yield from accumulate()
            tallies.append(tally)
    
    tallies = []
    acc = gather_tallies(tallies)
    next(acc) # Ensure the accumulator is ready to accept values
    for i in range(4):
        acc.send(i)
    #
    # Finish the first tally
    acc.send(None) # Finish the first tally
    for i in range(5):
        acc.send(i)
    #
    acc.send(None) # Finish the second tally
    tallies
    
[6, 10]
PEP 409: Suppressing exception context

PEP 409 introduces new syntax that allows the display of the chained exception context to be disabled. This allows cleaner error messages in applications that convert between exception types:

```python
>>> class D:
...     def __init__(self, extra):
...         self._extra_attributes = extra
...     def __getattr__(self, attr):
...         try:
...             return self._extra_attributes[attr]
...         except KeyError:
...             raise AttributeError(attr) from None
... >>> D({}).x
```

Without the `from None` suffix to suppress the cause, the original exception would be displayed by default:

```python
>>> class C:
...     def __init__(self, extra):
...         self._extra_attributes = extra
...     def __getattr__(self, attr):
...         try:
...             return self._extra_attributes[attr]
...         except KeyError:
...             raise AttributeError(attr)
... >>> C({}).x
```
No debugging capability is lost, as the original exception context remains available if needed (for example, if an intervening library has incorrectly suppressed valuable underlying details):

```python
>>> try:
...     D({}).x
...     except AttributeError as exc:
...         print(repr(exc.__context__))
...     KeyError('x',)
```

See also:

**PEP 409 - Suppressing exception context**

PEP written by Ethan Furman; implemented by Ethan Furman and Nick Coghlan.
PEP 414: Explicit Unicode literals

To ease the transition from Python 2 for Unicode aware Python applications that make heavy use of Unicode literals, Python 3.3 once again supports the “u” prefix for string literals. This prefix has no semantic significance in Python 3, it is provided solely to reduce the number of purely mechanical changes in migrating to Python 3, making it easier for developers to focus on the more significant semantic changes (such as the stricter default separation of binary and text data).

See also:

**PEP 414 - Explicit Unicode literals**
PEP written by Armin Ronacher.
PEP 3155: Qualified name for classes and functions

Functions and class objects have a new __qualname__ attribute representing the "path" from the module top-level to their definition. For global functions and classes, this is the same as __name__. For other functions and classes, it provides better information about where they were actually defined, and how they might be accessible from the global scope.

Example with (non-bound) methods:

```python
>>> class C:
...     def meth(self):
...         pass
>>> C.meth.__name__
'meth'
>>> C.meth.__qualname__
'C.meth'
```

Example with nested classes:

```python
>>> class C:
...     class D:
...         def meth(self):
...             pass
...     ...
>>> C.D.__name__
'D'
>>> C.D.__qualname__
'C.D'
>>> C.D.meth.__name__
'meth'
>>> C.D.meth.__qualname__
```
Example with nested functions:

```python
>>> def outer():
...     def inner():
...         pass
...     return inner
...
>>> outer().__name__
'inner'
>>> outer().__qualname__
'outer.<locals>.inner'
```

The string representation of those objects is also changed to include the new, more precise information:

```python
>>> str(C.D)
"<class '__main__.C.D'>"
>>> str(C.D.meth)
'<function C.D.meth at 0x7f46b9fe31e0>'
```

See also:

**PEP 3155 - Qualified name for classes and functions**

PEP written and implemented by Antoine Pitrou.
PEP 412: Key-Sharing Dictionary

Dictionaries used for the storage of objects’ attributes are now able to share part of their internal storage between each other (namely, the part which stores the keys and their respective hashes). This reduces the memory consumption of programs creating many instances of non-built-in types.

See also:

PEP 412 - Key-Sharing Dictionary
  PEP written and implemented by Mark Shannon.
PEP 362: Function Signature Object

A new function `inspect.signature()` makes introspection of python callables easy and straightforward. A broad range of callables is supported: python functions, decorated or not, classes, and `functools.partial()` objects. New classes `inspect.Signature`, `inspect.Parameter` and `inspect.BoundArguments` hold information about the call signatures, such as, annotations, default values, parameters kinds, and bound arguments, which considerably simplifies writing decorators and any code that validates or amends calling signatures or arguments.

See also:

**PEP 362: - Function Signature Object**

PEP written by Brett Cannon, Yury Selivanov, Larry Hastings, Jiwon Seo; implemented by Yury Selivanov.
PEP 421: Adding sys.implementation

A new attribute on the `sys` module exposes details specific to the implementation of the currently running interpreter. The initial set of attributes on `sys.implementation` are `name`, `version`, `hexversion`, and `cache_tag`.

The intention of `sys.implementation` is to consolidate into one namespace the implementation-specific data used by the standard library. This allows different Python implementations to share a single standard library code base much more easily. In its initial state, `sys.implementation` holds only a small portion of the implementation-specific data. Over time that ratio will shift in order to make the standard library more portable.

One example of improved standard library portability is `cache_tag`. As of Python 3.3, `sys.implementation.cache_tag` is used by `importlib` to support PEP 3147 compliance. Any Python implementation that uses `importlib` for its built-in import system may use `cache_tag` to control the caching behavior for modules.

**SimpleNamespace**

The implementation of `sys.implementation` also introduces a new type to Python: `types.SimpleNamespace`. In contrast to a mapping-based namespace, like `dict`, `SimpleNamespace` is attribute-based, like `object`. However, unlike `object`, `SimpleNamespace` instances are writable. This means that you can add, remove, and modify the namespace through normal attribute access.
See also:

**PEP 421** - Adding `sys.implementation`

PEP written and implemented by Eric Snow.
Using importlib as the Implementation of Import

issue 2377 - Replace __import__ w/ importlib.__import__  issue 13959
- Re-implement parts of imp in pure Python  issue 14605 - Make import machinery explicit  issue 14646 - Require loaders set __loader__ and __package__

The __import__() function is now powered by importlib.__import__(). This work leads to the completion of “phase 2” of PEP 302. There are multiple benefits to this change. First, it has allowed for more of the machinery powering import to be exposed instead of being implicit and hidden within the C code. It also provides a single implementation for all Python VMs supporting Python 3.3 to use, helping to end any VM-specific deviations in import semantics. And finally it eases the maintenance of import, allowing for future growth to occur.

For the common user, there should be no visible change in semantics. For those whose code currently manipulates import or calls import programmatically, the code changes that might possibly be required are covered in the Porting Python code section of this document.

New APIs

One of the large benefits of this work is the exposure of what goes into making the import statement work. That means the various importers that were once implicit are now fully exposed as part of the importlib package.

The abstract base classes defined in importlib.abc have been
expanded to properly delineate between meta path finders and path entry finders by introducing `importlib.abc.MetaPathFinder` and `importlib.abc.PathEntryFinder`, respectively. The old ABC of `importlib.abc.Finder` is now only provided for backwards-compatibility and does not enforce any method requirements.

In terms of finders, `importlib.machinery.FileFinder` exposes the mechanism used to search for source and bytecode files of a module. Previously this class was an implicit member of `sys.path_hooks`.

For loaders, the new abstract base class `importlib.abc.FileLoader` helps write a loader that uses the file system as the storage mechanism for a module's code. The loader for source files (`importlib.machinery.SourceFileLoader`), sourceless bytecode files (`importlib.machinery.SourcelessFileLoader`), and extension modules (`importlib.machinery.ExtensionFileLoader`) are now available for direct use.

`ImportError` now has name and path attributes which are set when there is relevant data to provide. The message for failed imports will also provide the full name of the module now instead of just the tail end of the module's name.

The `importlib.invalidate_caches()` function will now call the method with the same name on all finders cached in `sys.path_importer_cache` to help clean up any stored state as necessary.

Visible Changes
For potential required changes to code, see the Porting Python code section.

Beyond the expanse of what importlib now exposes, there are other visible changes to import. The biggest is that sys.meta_path and sys.path_hooks now store all of the meta path finders and path entry hooks used by import. Previously the finders were implicit and hidden within the C code of import instead of being directly exposed. This means that one can now easily remove or change the order of the various finders to fit one’s needs.

Another change is that all modules have a __loader__ attribute, storing the loader used to create the module. PEP 302 has been updated to make this attribute mandatory for loaders to implement, so in the future once 3rd-party loaders have been updated people will be able to rely on the existence of the attribute. Until such time, though, import is setting the module post-load.

Loaders are also now expected to set the __package__ attribute from PEP 366. Once again, import itself is already setting this on all loaders from importlib and import itself is setting the attribute post-load.

None is now inserted into sys.path_importer_cache when no finder can be found on sys.path_hooks. Since imp.NullImporter is not directly exposed on sys.path_hooks it could no longer be relied upon to always be available to use as a value representing no finder found.

All other changes relate to semantic changes which should be taken into consideration when updating code for Python 3.3, and thus should be read about in the Porting Python code section of this document.
(Implementation by Brett Cannon)
Other Language Changes

Some smaller changes made to the core Python language are:

- Added support for Unicode name aliases and named sequences. Both `unicodedata.lookup()` and '\N{...}' now resolve name aliases, and `unicodedata.lookup()` resolves named sequences too.

  (Contributed by Ezio Melotti in issue 12753.)

- Unicode database updated to UCD version 6.1.0

- Equality comparisons on `range()` objects now return a result reflecting the equality of the underlying sequences generated by those range objects. (issue 13201)

- The `count()`, `find()`, `rfind()`, `index()` and `rindex()` methods of `bytes` and `bytearray` objects now accept an integer between 0 and 255 as their first argument.

  (Contributed by Petri Lehtinen in issue 12170.)

- The `rjust()`, `ljust()`, and `center()` methods of `bytes` and `bytearray` now accept a `bytearray` for the fill argument.

  (Contributed by Petri Lehtinen in issue 12380.)

- New methods have been added to `list` and `bytearray`: `copy()` and `clear()` (issue 10516). Consequently, `MutableSequence` now also defines a `clear()` method (issue 11388).

- Raw bytes literals can now be written `rb"..."` as well as
br"...".

(Contributed by Antoine Pitrou in issue 13748.)

- `dict.setdefault()` now does only one lookup for the given key, making it atomic when used with built-in types.

  (Contributed by Filip Gruszczyński in issue 13521.)

- The error messages produced when a function call does not match the function signature have been significantly improved.

  (Contributed by Benjamin Peterson.)
A Finer-Grained Import Lock

Previous versions of CPython have always relied on a global import lock. This led to unexpected annoyances, such as deadlocks when importing a module would trigger code execution in a different thread as a side-effect. Clumsy workarounds were sometimes employed, such as the `PyImport_ImportModuleNoBlock()` C API function.

In Python 3.3, importing a module takes a per-module lock. This correctly serializes importation of a given module from multiple threads (preventing the exposure of incompletely initialized modules), while eliminating the aforementioned annoyances.

(Contributed by Antoine Pitrou in issue 9260.)
Built-in functions and types

- `open()` gets a new `opener` parameter: the underlying file descriptor for the file object is then obtained by calling `opener` with `(file, flags)`. It can be used to use custom flags like `os.O_CLOEXEC` for example. The 'x' mode was added: open for exclusive creation, failing if the file already exists.
- `print()`: added the `flush` keyword argument. If the `flush` keyword argument is true, the stream is forcibly flushed.
- `hash()`: hash randomization is enabled by default, see `object.__hash__()` and `PYTHONHASHSEED`.
- The `str` type gets a new `casefold()` method: return a casefolded copy of the string, casefolded strings may be used for caseless matching. For example, `'ß'.casefold()` returns `'ss'`.
- The sequence documentation has been substantially rewritten to better explain the binary/text sequence distinction and to provide specific documentation sections for the individual built-in sequence types (issue 4966).
New Modules

faulthandler

This new debug module *faulthandler* contains functions to dump Python tracebacks explicitly, on a fault (a crash like a segmentation fault), after a timeout, or on a user signal. Call *faulthandler.enable()* to install fault handlers for the SIGSEGV, SIGFPE, SIGABRT, SIGBUS, and SIGILL signals. You can also enable them at startup by setting the PYTHONFAULTHANDLER environment variable or by using `-X faulthandler` command line option.

Example of a segmentation fault on Linux:

```
$ python -q -X faulthandler
>>> import ctypes
>>> ctypes.string_at(0)
Fatal Python error: segmentation fault

Current thread 0x00007fb899f39700:
  File "/home/python/cpython/Lib/ctypes/__init__.py", line 486 in string_at
  File "<stdin>", line 1 in <module>
Segmentation fault
```

ipaddress

The new *ipaddress* module provides tools for creating and manipulating objects representing IPv4 and IPv6 addresses, networks and interfaces (i.e. an IP address associated with a specific IP subnet).

(Contributed by Google and Peter Moody in PEP 3144.)
Izma

The newly-added `lzma` module provides data compression and decompression using the LZMA algorithm, including support for the `.xz` and `.lzma` file formats.

(Contributed by Nadeem Vawda and Per Øyvind Karlsen in issue 6715.)
Improved Modules

abc

Improved support for abstract base classes containing descriptors composed with abstract methods. The recommended approach to declaring abstract descriptors is now to provide `__isabstractmethod__` as a dynamically updated property. The built-in descriptors have been updated accordingly.

- `abc.abstractproperty` has been deprecated, use `property` with `abc.abstractmethod()` instead.
- `abc.abstractclassmethod` has been deprecated, use `classmethod` with `abc.abstractmethod()` instead.
- `abc.abstractstaticmethod` has been deprecated, use `staticmethod` with `abc.abstractmethod()` instead.

(Contributed by Darren Dale in issue 11610.)

`abc.ABCMeta.register()` now returns the registered subclass, which means it can now be used as a class decorator (issue 10868).

array

The `array` module supports the long long type using q and Q type codes.

(Contributed by Oren Tirosh and Hirokazu Yamamoto in issue 1172711.)

base64
ASCII-only Unicode strings are now accepted by the decoding functions of the base64 modern interface. For example, base64.b64decode('YWJj') returns b'abc'. (Contributed by Catalin Iacob in issue 13641.)

binascii

In addition to the binary objects they normally accept, the a2b_ functions now all also accept ASCII-only strings as input. (Contributed by Antoine Pitrou in issue 13637.)

bz2

The bz2 module has been rewritten from scratch. In the process, several new features have been added:

- New bz2.open() function: open a bzip2-compressed file in binary or text mode.

- bz2.BZ2File can now read from and write to arbitrary file-like objects, by means of its constructor’s fileobj argument.

  (Contributed by Nadeem Vawda in issue 5863.)

- bz2.BZ2File and bz2.decompress() can now decompress multi-stream inputs (such as those produced by the pbzip2 tool). bz2.BZ2File can now also be used to create this type of file, using the 'a' (append) mode.

  (Contributed by Nir Aides in issue 1625.)

- bz2.BZ2File now implements all of the io.BufferedIOBase
API, except for the detach() and truncate() methods.

codecs

The mbcs codec has been rewritten to handle correctly replace and ignore error handlers on all Windows versions. The mbcs codec now supports all error handlers, instead of only replace to encode and ignore to decode.

A new Windows-only codec has been added: cp65001 (issue 13216). It is the Windows code page 65001 (Windows UTF-8, CP_UTF8). For example, it is used by sys.stdout if the console output code page is set to cp65001 (e.g., using chcp 65001 command).

Multibyte CJK decoders now resynchronize faster. They only ignore the first byte of an invalid byte sequence. For example, b'\xff\n'.decode('gb2312', 'replace') now returns a \n after the replacement character.

(issue 12016)

Incremental CJK codec encoders are no longer reset at each call to their encode() methods. For example:

```
$ ./python -q
>>> import codecs
>>> encoder = codecs.getincrementalencoder('hz')('strict')
>>> b''.join(encoder.encode(x) for x in '\u52ff\u65bd\u65bc\u4eba. Bye.')
```

This example gives b'~{Np~}~{J}~{16~}~{HK~}~{!#~} Bye.' with older Python versions.
The unicode_internal codec has been deprecated.

collections

Addition of a new ChainMap class to allow treating a number of mappings as a single unit. (Written by Raymond Hettinger for issue 11089, made public in issue 11297.)

The abstract base classes have been moved in a new collections.abc module, to better differentiate between the abstract and the concrete collections classes. Aliases for ABCs are still present in the collections module to preserve existing imports. (issue 11085)

The Counter class now supports the unary + and - operators, as well as the in-place operators +=, -=, |=, and &=. (Contributed by Raymond Hettinger in issue 13121.)

contextlib

ExitStack now provides a solid foundation for programmatic manipulation of context managers and similar cleanup functionality. Unlike the previous contextlib.nested API (which was deprecated and removed), the new API is designed to work correctly regardless of whether context managers acquire their resources in their __init__ method (for example, file objects) or in their __enter__ method (for example, synchronisation objects from the threading module).

(issue 13585)
**crypt**

Addition of salt and modular crypt format (hashing method) and the `mksalt()` function to the `crypt` module.

(issue 10924)

**curses**

- If the `curses` module is linked to the ncursesw library, use Unicode functions when Unicode strings or characters are passed (e.g. `waddwstr()`), and bytes functions otherwise (e.g. `waddstr()`).
- Use the locale encoding instead of utf-8 to encode Unicode strings.
- `curses.window` has a new `curses.window.encoding` attribute.
- The `curses.window` class has a new `get_wch()` method to get a wide character.
- The `curses` module has a new `unget_wch()` function to push a wide character so the next `get_wch()` will return it.

(Contributed by Iñigo Serna in issue 6755.)

**datetime**

- Equality comparisons between naive and aware `datetime` instances now return `False` instead of raising `TypeError` (issue 15006).
- New `datetime.datetime.timestamp()` method: Return POSIX timestamp corresponding to the `datetime` instance.
- The `datetime.datetime.strftime()` method supports
formatting years older than 1000.
- The `datetime.datetime.astimezone()` method can now be called without arguments to convert datetime instance to the system timezone.

**decimal**

**issue 7652** - integrate fast native decimal arithmetic.

C-module and libmpdec written by Stefan Krah.

The new C version of the decimal module integrates the high speed libmpdec library for arbitrary precision correctly-rounded decimal floating point arithmetic. libmpdec conforms to IBM's General Decimal Arithmetic Specification.

Performance gains range from 10x for database applications to 100x for numerically intensive applications. These numbers are expected gains for standard precisions used in decimal floating point arithmetic. Since the precision is user configurable, the exact figures may vary. For example, in integer bignum arithmetic the differences can be significantly higher.

The following table is meant as an illustration. Benchmarks are available at [http://www.bytereef.org/mpdecimal/quickstart.html](http://www.bytereef.org/mpdecimal/quickstart.html).

<table>
<thead>
<tr>
<th></th>
<th>decimal.py</th>
<th>_decimal</th>
<th>speedup</th>
</tr>
</thead>
<tbody>
<tr>
<td>pi</td>
<td>42.02s</td>
<td>0.345s</td>
<td>120x</td>
</tr>
<tr>
<td>telco</td>
<td>172.19s</td>
<td>5.68s</td>
<td>30x</td>
</tr>
<tr>
<td>psycopg</td>
<td>3.57s</td>
<td>0.29s</td>
<td>12x</td>
</tr>
</tbody>
</table>

Features
• The **FloatOperation** signal optionally enables stricter semantics for mixing floats and Decimals.

• If Python is compiled without threads, the C version automatically disables the expensive thread local context machinery. In this case, the variable **HAVE_THREADS** is set to False.

**API changes**

• The C module has the following context limits, depending on the machine architecture:

```
<table>
<thead>
<tr>
<th></th>
<th>32-bit</th>
<th>64-bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX_PREC</td>
<td>4250000000</td>
<td>999999999999999999</td>
</tr>
<tr>
<td>MAX_EMAX</td>
<td>4250000000</td>
<td>999999999999999999</td>
</tr>
<tr>
<td>MIN_EMIN</td>
<td>-4250000000</td>
<td>-999999999999999999</td>
</tr>
</tbody>
</table>
```

• In the context templates (**DefaultContext**, **BasicContext** and **ExtendedContext**) the magnitude of Emax and Emin has changed to 999999.

• The **Decimal** constructor in decimal.py does not observe the context limits and converts values with arbitrary exponents or precision exactly. Since the C version has internal limits, the following scheme is used: If possible, values are converted exactly, otherwise **InvalidOperation** is raised and the result is NaN. In the latter case it is always possible to use **create_decimal()** in order to obtain a rounded or inexact value.

• The power function in decimal.py is always correctly-rounded. In the C version, it is defined in terms of the correctly-rounded
\texttt{exp()} and \texttt{ln()} functions, but the final result is only “almost always correctly rounded”.

- In the C version, the context dictionary containing the signals is a \texttt{MutableMapping}. For speed reasons, flags and traps always refer to the same \texttt{MutableMapping} that the context was initialized with. If a new signal dictionary is assigned, flags and traps are updated with the new values, but they do not refer to the RHS dictionary.

- Pickling a \texttt{Context} produces a different output in order to have a common interchange format for the Python and C versions.

- The order of arguments in the \texttt{Context} constructor has been changed to match the order displayed by \texttt{repr()}.

- The \texttt{watchexp} parameter in the \texttt{quantize()} method is deprecated.

\textbf{email}

\textbf{Policy Framework}

The email package now has a \texttt{policy} framework. A \texttt{Policy} is an object with several methods and properties that control how the email package behaves. The primary policy for Python 3.3 is the \texttt{Compat32} policy, which provides backward compatibility with the email package in Python 3.2. A policy can be specified when an email message is parsed by a \texttt{parser}, or when a \texttt{Message} object is created, or when an email is serialized using a \texttt{generator}. Unless overridden, a policy passed to a parser is inherited by all the Message object and sub-objects created by the parser. By default a generator will use the
policy of the Message object it is serializing. The default policy is `compat32`.

The minimum set of controls implemented by all policy objects are:

<table>
<thead>
<tr>
<th>Control</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>max_line_length</code></td>
<td>The maximum length, excluding the linesep character(s), individual lines may have when a Message is serialized. Defaults to 78.</td>
</tr>
<tr>
<td><code>linesep</code></td>
<td>The character used to separate individual lines when a Message is serialized. Defaults to <code>\n</code>.</td>
</tr>
<tr>
<td><code>cte_type</code></td>
<td>7bit or 8bit. 8bit applies only to a Bytes generator, and means that non-ASCII may be used where allowed by the protocol (or where it exists in the original input).</td>
</tr>
<tr>
<td><code>raise_on_defect</code></td>
<td>Causes a parser to raise error when defects are encountered instead of adding them to the Message object's defects list.</td>
</tr>
</tbody>
</table>

A new policy instance, with new settings, is created using the `clone()` method of policy objects. `clone` takes any of the above controls as keyword arguments. Any control not specified in the call retains its default value. Thus you can create a policy that uses `\r\n` linesep characters like this:

```python
mypolicy = compat32.clone(linesep='\r\n')
```

Policies can be used to make the generation of messages in the format needed by your application simpler. Instead of having to remember to specify `linesep='\r\n'` in all the places you call a generator, you can specify it once, when you set the policy used by the parser or the Message, whichever your program uses to create
Message objects. On the other hand, if you need to generate messages in multiple forms, you can still specify the parameters in the appropriate generator call. Or you can have custom policy instances for your different cases, and pass those in when you create the generator.

Provisional Policy with New Header API

While the policy framework is worthwhile all by itself, the main motivation for introducing it is to allow the creation of new policies that implement new features for the email package in a way that maintains backward compatibility for those who do not use the new policies. Because the new policies introduce a new API, we are releasing them in Python 3.3 as a provisional policy. Backwards incompatible changes (up to and including removal of the code) may occur if deemed necessary by the core developers.

The new policies are instances of `EmailPolicy`, and add the following additional controls:

<table>
<thead>
<tr>
<th>refold_source</th>
<th>Controls whether or not headers parsed by a parser are refolded by the generator. It can be none, long, or all. The default is long, which means that source headers with a line longer than max_line_length get refolded. none means no line get refolded, and all means that all lines get refolded.</th>
</tr>
</thead>
<tbody>
<tr>
<td>header_factory</td>
<td>A callable that take a name and value and produces a custom header object.</td>
</tr>
</tbody>
</table>

The header_factory is the key to the new features provided by the new policies. When one of the new policies is used, any header retrieved from a Message object is an object produced by the
header_factory, and any time you set a header on a Message it becomes an object produced by header_factory. All such header objects have a name attribute equal to the header name. Address and Date headers have additional attributes that give you access to the parsed data of the header. This means you can now do things like this:

```python
>>> m = Message(policy=SMTP)
>>> m['To'] = 'Éric <foo@example.com>'
>>> m['to']
'Éric <foo@example.com>'
>>> m['to'].addresses
(Address(display_name='Éric', username='foo', domain='example.com'),)
>>> m['to'].addresses[0].username
'foo'
>>> m['to'].addresses[0].display_name
'Éric'
>>> m['Date'] = email.utils.localtime()
>>> m['Date'].datetime
datetime.datetime(2012, 5, 25, 21, 39, 24, 465484, tzinfo=datetime.timezone(datetime.timedelta(-1, 72000), 'EDT'))
>>> m['Date']
'Fri, 25 May 2012 21:44:27 -0400'
>>> print(m)
To: =?utf-8?q?=C3=89ric?= <foo@example.com>
Date: Fri, 25 May 2012 21:44:27 -0400
```

You will note that the unicode display name is automatically encoded as utf-8 when the message is serialized, but that when the header is accessed directly, you get the unicode version. This eliminates any need to deal with the `email.header.decode_header()` or `make_header()` functions.

You can also create addresses from parts:

```python
>>> m['cc'] = [Group('pals', [Address('Bob', 'bob',<BLANKLINE>```
Decoding to unicode is done automatically:

```
>>> m2 = message_from_string(str(m))
>>> m2['to']
Éric <foo@example.com>'
```

When you parse a message, you can use the addresses and groups attributes of the header objects to access the groups and individual addresses:

```
>>> m2['cc'].addresses
(Address(display_name='Bob', username='bob', domain='example.com'),
 Address(display_name='Sally', username='sally', domain='example.com'),
 Address(display_name='Bonzo', username='bonz', domain='laugh.com'))
>>> m2['cc'].groups
(Group(display_name='pals', addresses=(Address(display_name='Bob', username='bob', domain='example.com'),
 Address(display_name='Sally', username='sally', domain='example.com'),)),
 Group(display_name=None, addresses=(Address(display_name='Bonzo', username='bonz', domain='laugh.com'),)))
```

In summary, if you use one of the new policies, header manipulation works the way it ought to: your application works with unicode strings, and the email package transparently encodes and decodes the unicode to and from the RFC standard Content Transfer Encodings.

**Other API Changes**

New BytesHeaderParser, added to the parser module to complement HeaderParser and complete the Bytes API.

New utility functions:
• **format_datetime()**: given a `datetime`, produce a string formatted for use in an email header.
• **parsedate_to_datetime()**: given a date string from an email header, convert it into an aware `datetime`, or a naive `datetime` if the offset is `-0000`.
• **localtime()**: With no argument, returns the current local time as an aware `datetime` using the local `timezone`. Given an aware `datetime`, converts it into an aware `datetime` using the local `timezone`.

**ftplib**

• **ftplib.FTP** now accepts a source_address keyword argument to specify the (host, port) to use as the source address in the bind call when creating the outgoing socket. (Contributed by Giampaolo Rodolà in issue 8594.)
• The **FTP_TLS** class now provides a new `ccc()` function to revert control channel back to plaintext. This can be useful to take advantage of firewalls that know how to handle NAT with non-secure FTP without opening fixed ports. (Contributed by Giampaolo Rodolà in issue 12139.)
• Added **ftplib.FTP.mlsd()** method which provides a parsable directory listing format and deprecates **ftplib.FTP.nlst()** and **ftplib.FTP.dir()**. (Contributed by Giampaolo Rodolà in issue 11072.)

**functools**

The **functools.lru_cache()** decorator now accepts a typed keyword argument (that defaults to `False` to ensure that it caches values of different types that compare equal in separate cache slots. (Contributed by Raymond Hettinger in issue 13227.)
It is now possible to register callbacks invoked by the garbage collector before and after collection using the new `callbacks` list.

A new `compare_digest()` function has been added to prevent side channel attacks on digests through timing analysis. (Contributed by Nick Coghlan and Christian Heimes in issue 15061.)

`http.server.BaseHTTPRequestHandler` now buffers the headers and writes them all at once when `end_headers()` is called. A new method `flush_headers()` can be used to directly manage when the accumulated headers are sent. (Contributed by Andrew Schaaf in issue 3709.)

`http.server` now produces valid HTML 4.01 strict output. (Contributed by Ezio Melotti in issue 13295.)

`http.client.HTTPResponse` now has a `readinto()` method, which means it can be used as an `io.RawIOWBase` class. (Contributed by John Kuhn in issue 13464.)

`html.parser.HTMLParser` is now able to parse broken markup without raising errors, therefore the `strict` argument of the constructor
and the HTMLParseError exception are now deprecated. The ability to parse broken markup is the result of a number of bug fixes that are also available on the latest bug fix releases of Python 2.7/3.2. (Contributed by Ezio Melotti in issue 15114, and issue 14538, issue 13993, issue 13960, issue 13358, issue 1745761, issue 755670, issue 13357, issue 12629, issue 1200313, issue 670664, issue 13273, issue 12888, issue 7311.)

A new html5 dictionary that maps HTML5 named character references to the equivalent Unicode character(s) (e.g. html5['gt;'] == '>') has been added to the html.entities module. The dictionary is now also used by HTMLParser. (Contributed by Ezio Melotti in issue 11113 and issue 15156.)

imaplib

The IMAP4_SSL constructor now accepts an SSLContext parameter to control parameters of the secure channel. (Contributed by Sijin Joseph in issue 8808.)

inspect

A new getclosurevars() function has been added. This function reports the current binding of all names referenced from the function body and where those names were resolved, making it easier to verify correct internal state when testing code that relies on stateful closures. (Contributed by Meador Inge and Nick Coghlan in issue 13062.)

A new getgeneratorlocals() function has been added. This function reports the current binding of local variables in the generator's
stack frame, making it easier to verify correct internal state when testing generators.

(Contributed by Meador Inge in issue 15153.)

**io**

The `open()` function has a new 'x' mode that can be used to exclusively create a new file, and raise a `FileExistsError` if the file already exists. It is based on the C11 ‘x’ mode to fopen().

(Contributed by David Townshend in issue 12760.)

The constructor of the `TextIOWrapper` class has a new `write_through` optional argument. If `write_through` is True, calls to `write()` are guaranteed not to be buffered: any data written on the `TextIOWrapper` object is immediately handled to its underlying binary buffer.

**itertools**

`accumulate()` now takes an optional `func` argument for providing a user-supplied binary function.

**logging**

The `basicConfig()` function now supports an optional `handlers` argument taking an iterable of handlers to be added to the root logger.

A class level attribute `append_nul` has been added to `SysLogHandler` to allow control of the appending of the NUL (\000)
byte to syslog records, since for some daemons it is required while for others it is passed through to the log.

**math**

The `math` module has a new function, `log2()`, which returns the base-2 logarithm of `x`.

(Written by Mark Dickinson in issue 11888.)

**mmap**

The `read()` method is now more compatible with other file-like objects: if the argument is omitted or specified as `None`, it returns the bytes from the current file position to the end of the mapping. (Contributed by Petri Lehtinen in issue 12021.)

**multiprocessing**

The new `multiprocessing.connection.wait()` function allows to poll multiple objects (such as connections, sockets and pipes) with a timeout. (Contributed by Richard Oudkerk in issue 12328.)

`multiprocessing.Connection` objects can now be transferred over multiprocessing connections. (Contributed by Richard Oudkerk in issue 4892.)

`multiprocessing.Process` now accepts a daemon keyword argument to override the default behavior of inheriting the daemon flag from the parent process (issue 6064).

New attribute `multiprocessing.Process.sentinel` allows a
program to wait on multiple Process objects at one time using the appropriate OS primitives (for example, select on posix systems).

New methods multiprocessing.pool.Pool.starmap() and starmap_async() provide itertools.starmap() equivalents to the existing multiprocessing.pool.Pool.map() and map_async() functions. (Contributed by Hynek Schlawack in issue 12708.)

nntplib

The nntplib.NNTP class now supports the context management protocol to unconditionally consume socket.error exceptions and to close the NNTP connection when done:

```python
>>> from nntplib import NNTP
>>> with NNTP('news.gmane.org') as n:
...     n.group('gmane.comp.python.committers')
... ('211 1755 1 1755 gmane.comp.python.committers', 1755)
```

(Contributed by Giampaolo Rodolà in issue 9795.)

OS

- The os module has a new pipe2() function that makes it possible to create a pipe with O_CLOEXEC or O_NONBLOCK flags set atomically. This is especially useful to avoid race conditions in multi-threaded programs.
- The **os** module has a new `sendfile()` function which provides an efficient “zero-copy” way for copying data from one file (or socket) descriptor to another. The phrase “zero-copy” refers to the fact that all of the copying of data between the two descriptors is done entirely by the kernel, with no copying of data into userspace buffers. `sendfile()` can be used to efficiently copy data from a file on disk to a network socket, e.g. for downloading a file.

  (Patch submitted by Ross Lagerwall and Giampaolo Rodolà in [issue 10882](https://www.python.org).)

- To avoid race conditions like symlink attacks and issues with temporary files and directories, it is more reliable (and also faster) to manipulate file descriptors instead of file names. Python 3.3 enhances existing functions and introduces new functions to work on file descriptors ([issue 4761](https://www.python.org), [issue 10755](https://www.python.org) and [issue 14626](https://www.python.org)).

  - The **os** module has a new `fwalk()` function similar to `walk()` except that it also yields file descriptors referring to the directories visited. This is especially useful to avoid symlink races.
  - The following functions get new optional `dir_fd` (paths relative to directory descriptors) and/or `follow_symlinks` (not following symlinks): `access()`, `chflags()`, `chmod()`, `chown()`, `link()`, `lstat()`, `mkdir()`, `mkfifo()`, `mknod()`, `open()`, `readlink()`, `remove()`, `rename()`, `replace()`, `rmdir()`, `stat()`, `symlink()`, `unlink()`, `utime()`.
  Platform support for using these parameters can be checked via the sets `os.supports_dir_fd` and `os.supports_follows_symlinks`.
  - The following functions now support a file descriptor for their path argument: `chdir()`, `chmod()`, `chown()`, `execve()`, `listdir()`, `pathconf()`, `exists()`, `stat()`,...
statvfs(), utime(). Platform support for this can be checked via the os.supports_fd set.

- `access()` accepts an effective_ids keyword argument to turn on using the effective uid/gid rather than the real uid/gid in the access check. Platform support for this can be checked via the supports_effective_ids set.

- The `os` module has two new functions: `getpriority()` and `setpriority()`. They can be used to get or set process niceness/priority in a fashion similar to `os.nice()` but extended to all processes instead of just the current one.
  
  (Patch submitted by Giampaolo Rodolà in issue 10784.)

- The new `os.replace()` function allows cross-platform renaming of a file with overwriting the destination. With `os.rename()`, an existing destination file is overwritten under POSIX, but raises an error under Windows. (Contributed by Antoine Pitrou in issue 8828.)

- The stat family of functions (`stat()`, `fstat()`, and `lstat()`) now support reading a file's timestamps with nanosecond precision. Symmetrically, `utime()` can now write file timestamps with nanosecond precision. (Contributed by Larry Hastings in issue 14127.)

- The new `os.get_terminal_size()` function queries the size of the terminal attached to a file descriptor. See also `shutil.get_terminal_size()`. (Contributed by Zbigniew Jędrzejewski-Szmek in issue 13609.)

- New functions to support Linux extended attributes (issue 12720): `getxattr()`, `listxattr()`, `removexattr()`, `setxattr()`.
New interface to the scheduler. These functions control how a process is allocated CPU time by the operating system. New functions:

- `sched_get_priority_max()`
- `sched_get_priority_min()`
- `sched_getaffinity()`
- `sched_getparam()`
- `sched_getscheduler()`
- `sched_rr_get_interval()`
- `sched_setaffinity()`
- `sched_setparam()`
- `sched_setscheduler()`
- `sched_yield()`

New functions to control the file system:

- `posix_fadvise()`: Announces an intention to access data in a specific pattern thus allowing the kernel to make optimizations.
- `posix_fallocate()`: Ensures that enough disk space is allocated for a file.
- `sync()`: Force write of everything to disk.

Additional new posix functions:

- `lockf()`: Apply, test or remove a POSIX lock on an open file descriptor.
- `pread()`: Read from a file descriptor at an offset, the file offset remains unchanged.
- `pwrite()`: Write to a file descriptor from an offset, leaving the file offset unchanged.
- `readv()`: Read from a file descriptor into a number of writable buffers.
- `truncate()`: Truncate the file corresponding to `path`, so that it is at most `length` bytes in size.
- `waitid()`: Wait for the completion of one or more child processes.
- `writev()`: Write the contents of `buffers` to a file descriptor, where `buffers` is an arbitrary sequence of buffers.
- `getgrouplist()` (issue 9344): Return list of group ids that specified user belongs to.

`times()` and `uname()`: Return type changed from a tuple to a
tuple-like object with named attributes.

- Some platforms now support additional constants for the `lseek()` function, such as `os.SEEK_HOLE` and `os.SEEK_DATA`.
- New constants `RTLD_LAZY`, `RTLD_NOW`, `RTLD_GLOBAL`, `RTLD_LOCAL`, `RTLD_NODELETE`, `RTLD_NOLOAD`, and `RTLD_DEEPBIND` are available on platforms that support them. These are for use with the `sys.setdlopenflags()` function, and supersede the similar constants defined in `ctypes` and `DLFCN`. (Contributed by Victor Stinner in issue 13226.)
- `os.symlink()` now accepts (and ignores) the `target_is_directory` keyword argument on non-Windows platforms, to ease cross-platform support.

**pdb**

Tab-completion is now available not only for command names, but also their arguments. For example, for the `break` command, function and file names are completed.

(Contributed by Georg Brandl in issue 14210)

**pickle**

`pickle.Pickler` objects now have an optional `dispatch_table` attribute allowing to set per-pickler reduction functions.

(Contributed by Richard Oudkerk in issue 14166.)

**pydoc**

The Tk GUI and the `serve()` function have been removed from the `pydoc` module: `pydoc -g` and `serve()` have been deprecated in
Python 3.2.

re

str regular expressions now support \u and \U escapes.

(Contributed by Serhiy Storchaka in issue 3665.)

sched

- run() now accepts a blocking parameter which when set to False makes the method execute the scheduled events due to expire soonest (if any) and then return immediately. This is useful in case you want to use the scheduler in non-blocking applications. (Contributed by Giampaolo Rodolà in issue 13449.)
- scheduler class can now be safely used in multi-threaded environments. (Contributed by Josiah Carlson and Giampaolo Rodolà in issue 8684.)
- timefunc and delayfunc parameters of scheduler class constructor are now optional and defaults to time.time() and time.sleep() respectively. (Contributed by Chris Clark in issue 13245.)
- enter() and enterabs() argument parameter is now optional. (Contributed by Chris Clark in issue 13245.)
- enter() and enterabs() now accept a kwargs parameter. (Contributed by Chris Clark in issue 13245.)

select

Solaris and derivative platforms have a new class select.devpoll for high performance asynchronous sockets via /dev/poll. (Contributed by Jesús Cea Avión in issue 6397.)
shlex

The previously undocumented helper function `quote` from the `pipes` modules has been moved to the `shlex` module and documented. `quote()` properly escapes all characters in a string that might be otherwise given special meaning by the shell.

shutil

- New functions:
  - `disk_usage()`: provides total, used and free disk space statistics. (Contributed by Giampaolo Rodolà in issue 12442.)
  - `chown()`: allows one to change user and/or group of the given path also specifying the user/group names and not only their numeric ids. (Contributed by Sandro Tosi in issue 12191.)
  - `shutil.get_terminal_size()`: returns the size of the terminal window to which the interpreter is attached. (Contributed by Zbigniew Jędrzejewski-Szmek in issue 13609.)
- `copy2()` and `copystat()` now preserve file timestamps with nanosecond precision on platforms that support it. They also preserve file “extended attributes” on Linux. (Contributed by Larry Hastings in issue 14127 and issue 15238.)
- Several functions now take an optional `symlinks` argument: when that parameter is true, symlinks aren’t dereferenced and the operation instead acts on the symlink itself (or creates one, if relevant). (Contributed by Hynek Schlawack in issue 12715.)
- When copying files to a different file system, `move()` now handles symlinks the way the posix `mv` command does, recreating the symlink rather than copying the target file contents. (Contributed by Jonathan Niehof in issue 9993.) `move()` now also returns the
dst argument as its result.

- `rmtree()` is now resistant to symlink attacks on platforms which support the new `dir_fd` parameter in `os.open()` and `os.unlink()`. (Contributed by Martin von Löwis and Hynek Schlawack in issue 4489.)

**signal**

- The `signal` module has new functions:
  - `pthread_sigmask()`: fetch and/or change the signal mask of the calling thread (Contributed by Jean-Paul Calderone in issue 8407);
  - `pthread_kill()`: send a signal to a thread;
  - `sigpending()`: examine pending functions;
  - `sigwait()`: wait a signal;
  - `sigwaitinfo()`: wait for a signal, returning detailed information about it;
  - `sigtimedwait()`: like `sigwaitinfo()` but with a timeout.
- The signal handler writes the signal number as a single byte instead of a nul byte into the wakeup file descriptor. So it is possible to wait more than one signal and know which signals were raised.
- `signal.signal()` and `signal.siginterrupt()` raise an OSError, instead of a RuntimeError: OSError has an errno attribute.

**smtpd**

The `smtpd` module now supports RFC 5321 (extended SMTP) and RFC 1870 (size extension). Per the standard, these extensions are enabled if and only if the client initiates the session with an EHLO command.
smtplib

The SMTP, SMTP_SSL, and LMTP classes now accept a source_address keyword argument to specify the (host, port) to use as the source address in the bind call when creating the outgoing socket. (Contributed by Paulo Scardine in issue 11281.)

SMTP now supports the context management protocol, allowing an SMTP instance to be used in a with statement. (Contributed by Giampaolo Rodolà in issue 11289.)

The SMTP_SSL constructor and the starttls() method now accept an SSLContext parameter to control parameters of the secure channel. (Contributed by Kasun Herath in issue 8809.)

socket

- The socket class now exposes additional methods to process ancillary data when supported by the underlying platform:
  - sendmsg()
  - recvmsg()
  - recvmsg_into()

  (Contributed by David Watson in issue 6560, based on an earlier patch by Heiko Wundram)

- The socket class now supports the PF_CAN protocol family

(Contributed by Matthias Fuchs, updated by Tiago Gonçalves in issue 10141.)


- The `socket` class now supports the PF_SYSTEM protocol family on OS X. (Contributed by Michael Goderbauer in issue 13777.)

- New function `sethostname()` allows the hostname to be set on unix systems if the calling process has sufficient privileges. (Contributed by Ross Lagerwall in issue 10866.)

socketserver

`BaseServer` now has an overridable method `service_actions()` that is called by the `serve_forever()` method in the service loop. `ForkingMixIn` now uses this to clean up zombie child processes. (Contributed by Justin Warkentin in issue 11109.)

sqlite3

New `sqlite3.Connection` method `set_trace_callback()` can be used to capture a trace of all sql commands processed by sqlite. (Contributed by Torsten Landschoff in issue 11688.)

ssl
- The `ssl` module has two new random generation functions:
  - `RAND_bytes()`: generate cryptographically strong pseudo-random bytes.
  - `RAND_pseudo_bytes()`: generate pseudo-random bytes.
  (Contributed by Victor Stinner in issue 12049.)

- The `ssl` module now exposes a finer-grained exception hierarchy in order to make it easier to inspect the various kinds of errors. (Contributed by Antoine Pitrou in issue 11183.)

- `load_cert_chain()` now accepts a `password` argument to be used if the private key is encrypted. (Contributed by Adam Simpkins in issue 12803.)

- Diffie-Hellman key exchange, both regular and Elliptic Curve-based, is now supported through the `load_dh_params()` and `set_ecdh_curve()` methods. (Contributed by Antoine Pitrou in issue 13626 and issue 13627.)

- SSL sockets have a new `get_channel_binding()` method allowing the implementation of certain authentication mechanisms such as SCRAM-SHA-1-PLUS. (Contributed by Jacek Konieczny in issue 12551.)

- You can query the SSL compression algorithm used by an SSL socket, thanks to its new `compression()` method. The new attribute `OP_NO_COMPRESSION` can be used to disable compression. (Contributed by Antoine Pitrou in issue 13634.)

- Support has been added for the Next Protocol Negotiation extension using the `ssl.SSLContext.set_npn_protocols()`
method. (Contributed by Colin Marc in issue 14204.)

- SSL errors can now be introspected more easily thanks to `library` and `reason` attributes. (Contributed by Antoine Pitrou in issue 14837.)

- The `get_server_certificate()` function now supports IPv6. (Contributed by Charles-François Natali in issue 11811.)

- New attribute `OP_CIPHER_SERVER_PREFERENCE` allows setting SSLv3 server sockets to use the server’s cipher ordering preference rather than the client's (issue 13635).

**stat**

The undocumented `tarfile.filemode` function has been moved to `stat.filemode()`. It can be used to convert a file’s mode to a string of the form ‘-rwxrwxrwx’.

(Contributed by Giampaolo Rodolà in issue 14807.)

**struct**

The `struct` module now supports `ssize_t` and `size_t` via the new codes `n` and `N`, respectively. (Contributed by Antoine Pitrou in issue 3163.)

**subprocess**

Command strings can now be bytes objects on posix platforms. (Contributed by Victor Stinner in issue 8513.)
A new constant `DEVNULL` allows suppressing output in a platform-independent fashion. (Contributed by Ross Lagerwall in issue 5870.)

**sys**

The `sys` module has a new `thread_info struct sequence` holding informations about the thread implementation (issue 11223).

**tarfile**

`tarfile` now supports lzma encoding via the `lzma` module. (Contributed by Lars Gustäbel in issue 5689.)

**tempfile**

`tempfile.SpooledTemporaryFile's truncate()` method now accepts a size parameter. (Contributed by Ryan Kelly in issue 9957.)

**textwrap**

The `textwrap` module has a new `indent()` that makes it straightforward to add a common prefix to selected lines in a block of text (issue 13857).

**threading**

`threading.Condition`, `threading.Semaphore`, `threading.BoundedSemaphore`, `threading.Event`, and `threading.Timer`, all of which used to be factory functions returning a class instance, are now classes and may be subclassed.
The `threading.Thread` constructor now accepts a daemon keyword argument to override the default behavior of inheriting the daemon flag value from the parent thread (issue 6064).

The formerly private function `_thread.get_ident` is now available as the public function `threading.get_ident()`. This eliminates several cases of direct access to the `_thread` module in the stdlib. Third party code that used `_thread.get_ident` should likewise be changed to use the new public interface.

**time**

The [PEP 418](https://www.python.org/dev/peps/pep-0418/) added new functions to the `time` module:

- `get_clock_info()`: Get information on a clock.
- `monotonic()`: Monotonic clock (cannot go backward), not affected by system clock updates.
- `perf_counter()`: Performance counter with the highest available resolution to measure a short duration.
- `process_time()`: Sum of the system and user CPU time of the current process.

Other new functions:

- `clock_gettime()`, `clock_getres()` and `clock_settime()` functions with `CLOCK_XXX` constants. (Contributed by Victor Stinner in issue 10278.)

To improve cross platform consistency, `sleep()` now raises a `ValueError` when passed a negative sleep value. Previously this was an error on posix, but produced an infinite sleep on Windows.
types

Add a new `types.MappingProxyType` class: Read-only proxy of a mapping. (issue 14386)

The new functions `types.new_class()` and `types.prepare_class()` provide support for PEP 3115 compliant dynamic type creation. (issue 14588)

unittest

`assertRaises()`, `assertRaisesRegex()`, `assertWarns()`, and `assertWarnsRegex()` now accept a keyword argument `msg` when used as context managers. (Contributed by Ezio Melotti and Winston Ewert in issue 10775.)

`unittest.TestCase.run()` now returns the `TestResult` object.

urllib

The `Request` class, now accepts a `method` argument used by `get_method()` to determine what HTTP method should be used. For example, this will send a 'HEAD' request:

```python
>>> urlopen(Request('https://www.python.org', method='HEAD'))
```

(issue 1673007)

webbrowser
The `webbrowser` module supports more “browsers”: Google Chrome (named `chrome`, `chromium`, `chrome-browser` or `chromium-browser` depending on the version and operating system), and the generic launchers `xdg-open`, from the FreeDesktop.org project, and `gvfs-open`, which is the default URI handler for GNOME 3. (The former contributed by Arnaud Calmettes in issue 13620, the latter by Matthias Klose in issue 14493.)

`xml.etree.ElementTree`

The `xml.etree.ElementTree` module now imports its C accelerator by default; there is no longer a need to explicitly import `xml.etree.cElementTree` (this module stays for backwards compatibility, but is now deprecated). In addition, the `iter` family of methods of `Element` has been optimized (rewritten in C). The module’s documentation has also been greatly improved with added examples and a more detailed reference.

`zlib`

New attribute `zlib.Decompress.eof` makes it possible to distinguish between a properly-formed compressed stream and an incomplete or truncated one. (Contributed by Nadeem Vawda in issue 12646.)

New attribute `zlib.ZLIB_RUNTIME_VERSION` reports the version string of the underlying zlib library that is loaded at runtime. (Contributed by Torsten Landschoff in issue 12306.)
Optimizations

Major performance enhancements have been added:

- Thanks to PEP 393, some operations on Unicode strings have been optimized:
  - the memory footprint is divided by 2 to 4 depending on the text
  - encode an ASCII string to UTF-8 doesn’t need to encode characters anymore, the UTF-8 representation is shared with the ASCII representation
  - the UTF-8 encoder has been optimized
  - repeating a single ASCII letter and getting a substring of an ASCII string is 4 times faster
- UTF-8 is now 2x to 4x faster. UTF-16 encoding is now up to 10x faster.

(Contributed by Serhiy Storchaka, issue 14624, issue 14738 and issue 15026.)
Build and C API Changes

Changes to Python’s build process and to the C API include:

- **New PEP 3118** related function:
  - `PyMemoryView_FromMemory()`
- **PEP 393** added new Unicode types, macros and functions:
  - **High-level API:**
    - `PyUnicode_CopyCharacters()`
    - `PyUnicode_FindChar()`
    - `PyUnicode_GetLength()`, `PyUnicode_GET_LENGTH`
    - `PyUnicode_New()`
    - `PyUnicode_Substring()`
    - `PyUnicode_ReadChar()`, `PyUnicode_WriteChar()`
  - **Low-level API:**
    - `Py_UCS1`, `Py_UCS2`, `Py_UCS4` types
    - `PyASCIIObject` and `PyCompactUnicodeObject` structures
    - `PyUnicode_READY`
    - `PyUnicode_FromKindAndData()`
    - `PyUnicode_AsUCS4()`, `PyUnicode_AsUCS4Copy()`
    - `PyUnicode_DATA`, `PyUnicode_1BYTE_DATA`, `PyUnicode_2BYTE_DATA`, `PyUnicode_4BYTE_DATA`
    - `PyUnicode_KIND` with `PyUnicode.Kind` enum: `PyUnicode_WCHAR_KIND`, `PyUnicode_1BYTE_KIND`, `PyUnicode_2BYTE_KIND`, `PyUnicode_4BYTE_KIND`
    - `PyUnicode_READ`, `PyUnicode_READ_CHAR`, `PyUnicode_WRITE`
    - `PyUnicode_MAX_CHAR_VALUE`
- **`PyArg_ParseTuple`** now accepts a `bytearray` for the `c` format (issue 12380).
Deprecated

Unsupported Operating Systems

OS/2 and VMS are no longer supported due to the lack of a maintainer.

Windows 2000 and Windows platforms which set COMSPEC to command.com are no longer supported due to maintenance burden.

OSF support, which was deprecated in 3.2, has been completely removed.

Deprecated Python modules, functions and methods

- Passing a non-empty string to object.__format__() is deprecated, and will produce a TypeError in Python 3.4 (issue 9856).
- The unicode_internal codec has been deprecated because of the PEP 393, use UTF-8, UTF-16 (utf-16-le or utf-16-be), or UTF-32 (utf-32-le or utf-32-be)
- ftplib.FTP.nlst() and ftplib.FTP.dir(): use ftplib.FTP.mlsd()
- platform.popen(): use the subprocess module. Check especially the Replacing Older Functions with the subprocess Module section (issue 11377).
- issue 13374: The Windows bytes API has been deprecated in the os module. Use Unicode filenames, instead of bytes filenames, to not depend on the ANSI code page anymore and to support any filename.
- issue 13988: The xml.etree.cElementTree module is
deprecated. The accelerator is used automatically whenever available.

- The behaviour of `time.clock()` depends on the platform: use the new `time.perf_counter()` or `time.process_time()` function instead, depending on your requirements, to have a well defined behaviour.
- The `os.stat_float_times()` function is deprecated.
- `abc` module:
  - `abc.abstractproperty` has been deprecated, use `property` with `abc.abstractmethod()` instead.
  - `abc.abstractclassmethod` has been deprecated, use `classmethod` with `abc.abstractmethod()` instead.
  - `abc.abstractstaticmethod` has been deprecated, use `staticmethod` with `abc.abstractmethod()` instead.
- `importlib` package:
  - `importlib.abc.SourceLoader.path_mtime()` is now deprecated in favour of `importlib.abc.SourceLoader.path_stats()` as bytecode files now store both the modification time and size of the source file the bytecode file was compiled from.

### Deprecated functions and types of the C API

The `Py_UNICODE` has been deprecated by PEP 393 and will be removed in Python 4. All functions using this type are deprecated:

- Unicode functions and methods using `Py_UNICODE` and `Py_UNICODE*` types:
  - `PyUnicode_FromUnicode`: use `PyUnicode_FromWideChar()` or `PyUnicode_FromKindAndData()`
- `PyUnicode_AS_UNICODE`, `PyUnicode_AsUnicode()`, `PyUnicode_AsUnicodeAndSize()`: use `PyUnicode_AsWideCharString()`.
- `PyUnicode_GET_DATA_SIZE`: use `PyUnicode_GET_LENGTH(str) * PyUnicode_KIND(str)` (only work on ready strings).
- `PyUnicode_AsUnicodeCopy()`: use `PyUnicode_AsUCS4Copy()` or `PyUnicode_AsWideCharString()`.
- `PyUnicode_GetMax()`.

Functions and macros manipulating Py_UNICODE* strings:

- `Py_UNICODE_strlen`: use `PyUnicode_GetLength()` or `PyUnicode_GET_LENGTH`.
- `Py_UNICODE_strcat`: use `PyUnicode_CopyCharacters()` or `PyUnicode_FromFormat()`.
- `Py_UNICODE_strcpy, Py_UNICODE_strncpy, Py_UNICODE_COPY`: use `PyUnicode_CopyCharacters()` or `PyUnicode_Substring()`.
- `Py_UNICODE_strcmp`: use `PyUnicode_Compare()`.
- `Py_UNICODE_strncmp`: use `PyUnicode_Tailmatch()`.
- `Py_UNICODE_strchr, Py_UNICODE_strrchr`: use `PyUnicode_FindChar()`.
- `Py_UNICODE.FILL`: use `PyUnicode_Fill()`.
- `Py_UNICODE.MATCH`.

Encoders:
- `PyUnicode_Encode()`: use `PyUnicode_AsEncodedObject()``
- `PyUnicode_EncodeUTF7()`
- `PyUnicode_EncodeUTF8()`: use `PyUnicode_AsUTF8()` or `PyUnicode_AsUTF8String()`
- `PyUnicode_EncodeUTF32()`
- `PyUnicode_EncodeUTF16()`
- `PyUnicode_EncodeUnicodeEscape():` use `PyUnicode_AsUnicodeEscapeString()`
- `PyUnicode_EncodeRawUnicodeEscape():` use `PyUnicode_AsRawUnicodeEscapeString()`
- `PyUnicode_EncodeLatin1():` use `PyUnicode_AsLatin1String()`
- `PyUnicode_EncodeASCII():` use `PyUnicode_AsASCIIString()`
- `PyUnicode_EncodeCharmap()`
- `PyUnicode_TranslateCharmap()`
- `PyUnicode_EncodeMBCS():` use `PyUnicode_AsMBCSString()` or `PyUnicode_EncodeCodePage()` (with CP_ACP code_page)
- `PyUnicode_EncodeDecimal()`, `PyUnicode_TransformDecimalToASCII()`

**Deprecated features**

The `array` module's 'u' format code is now deprecated and will be removed in Python 4 together with the rest of the (`Py_UNICODE`) API.
Porting to Python 3.3

This section lists previously described changes and other bugfixes that may require changes to your code.

Porting Python code

- Hash randomization is enabled by default. Set the $\texttt{PYTHONHASHSEED}$ environment variable to 0 to disable hash randomization. See also the $\texttt{object.__hash__()}$ method.
- **issue 12326**: On Linux, sys.platform doesn’t contain the major version anymore. It is now always ‘linux’, instead of ‘linux2’ or ‘linux3’ depending on the Linux version used to build Python. Replace `sys.platform == 'linux2'` with `sys.platform.startswith('linux')`, or directly `sys.platform == 'linux'` if you don’t need to support older Python versions.
- **issue 13847, issue 14180**: `time` and `datetime`: `OverflowError` is now raised instead of `ValueError` if a timestamp is out of range. `OSError` is now raised if C functions `gmtime()` or `localtime()` failed.
- The default finders used by import now utilize a cache of what is contained within a specific directory. If you create a Python source file or sourceless bytecode file, make sure to call `importlib.invalidate_caches()` to clear out the cache for the finders to notice the new file.
- `ImportError` now uses the full name of the module that was attempted to be imported. Doctests that check ImportErrors’ message will need to be updated to use the full name of the module instead of just the tail of the name.
- The `index` argument to `__import__()` now defaults to 0 instead of -1 and no longer support negative values. It was an oversight when PEP 328 was implemented that the default value remained
-1. If you need to continue to perform a relative import followed by an absolute import, then perform the relative import using an index of 1, followed by another import using an index of 0. It is preferred, though, that you use `importlib.import_module()` rather than call `__import__()` directly.

- `__import__()` no longer allows one to use an index value other than 0 for top-level modules. E.g. `__import__('sys', level=1)` is now an error.

- Because `sys.meta_path` and `sys.path_hooks` now have finders on them by default, you will most likely want to use `list.insert()` instead of `list.append()` to add to those lists.

- Because `None` is now inserted into `sys.path_importer_cache`, if you are clearing out entries in the dictionary of paths that do not have a finder, you will need to remove keys paired with values of `None` and `imp.NullImporter` to be backwards-compatible. This will lead to extra overhead on older versions of Python that re-insert `None` into `sys.path_importer_cache` where it represents the use of implicit finders, but semantically it should not change anything.

- `importlib.abc.Finder` no longer specifies a `find_module()` abstract method that must be implemented. If you were relying on subclasses to implement that method, make sure to check for the method’s existence first. You will probably want to check for `find_loader()` first, though, in the case of working with path entry finders.

- `pkgutil` has been converted to use `importlib` internally. This eliminates many edge cases where the old behaviour of the PEP 302 import emulation failed to match the behaviour of the real import system. The import emulation itself is still present, but is now deprecated. The `pkgutil.iter_importers()` and `pkgutil.walk_packages()` functions special case the standard import hooks so they are still supported even though
they do not provide the non-standard `iter_modules()` method.

- A longstanding RFC-compliance bug (issue 1079) in the parsing done by `email.header.decode_header()` has been fixed. Code that uses the standard idiom to convert encoded headers into unicode (str(make_header(decode_header(h)))) will see no change, but code that looks at the individual tuples returned by decode_header will see that whitespace that precedes or follows ASCII sections is now included in the ASCII section. Code that builds headers using make_header should also continue to work without change, since make_header continues to add whitespace between ASCII and non-ASCII sections if it is not already present in the input strings.

- `email.utils.formataddr()` now does the correct content transfer encoding when passed non-ASCII display names. Any code that depended on the previous buggy behavior that preserved the non-ASCII unicode in the formatted output string will need to be changed (issue 1690608).

- `poplib.POP3.quit()` may now raise protocol errors like all other `poplib` methods. Code that assumes quit does not raise `poplib.error_proto` errors may need to be changed if errors on quit are encountered by a particular application (issue 11291).

- The strict argument to `email.parser.Parser`, deprecated since Python 2.4, has finally been removed.

- The deprecated method `unittest.TestCase.assertSameElements` has been removed.

- The deprecated variable `time.accept2dyear` has been removed.

- The deprecated `Context._clamp` attribute has been removed from the `decimal` module. It was previously replaced by the public attribute `clamp`. (See issue 8540.)

- The undocumented internal helper class `SSLFakeFile` has been
removed from `smtplib`, since its functionality has long been provided directly by `socket.socket.makefile()`.

- Passing a negative value to `time.sleep()` on Windows now raises an error instead of sleeping forever. It has always raised an error on posix.
- The `ast.__version__` constant has been removed. If you need to make decisions affected by the AST version, use `sys.version_info` to make the decision.
- Code that used to work around the fact that the `threading` module used factory functions by subclassing the private classes will need to change to subclass the now-public classes.
- The undocumented debugging machinery in the threading module has been removed, simplifying the code. This should have no effect on production code, but is mentioned here in case any application debug frameworks were interacting with it ([issue 13550](https://github.com/python/cpython/issues/13550)).

### Porting C code

- In the course of changes to the buffer API the undocumented `smalltable` member of the `Py_buffer` structure has been removed and the layout of the `PyMemoryViewObject` has changed.

  All extensions relying on the relevant parts in `memoryobject.h` or `object.h` must be rebuilt.

- Due to [PEP 393](https://www.python.org/dev/peps/pep-0393/), the `Py_UNICODE` type and all functions using this type are deprecated (but will stay available for at least five years). If you were using low-level Unicode APIs to construct and access unicode objects and you want to benefit of the memory footprint reduction provided by PEP 393, you have to convert your
code to the new *Unicode API*.

However, if you only have been using high-level functions such as `PyUnicode_Concat()`, `PyUnicode_Join()` or `PyUnicode_FromFormat()`, your code will automatically take advantage of the new unicode representations.

- `PyImport_GetMagicNumber()` now returns `-1` upon failure.

- As a negative value for the `level` argument to `__import__()` is no longer valid, the same now holds for `PyImport_ImportModuleLevel()`. This also means that the value of `level` used by `PyImport_ImportModuleEx()` is now `0` instead of `-1`.

**Building C extensions**

- The range of possible file names for C extensions has been narrowed. Very rarely used spellings have been suppressed: under POSIX, files named `xxxmodule.so`, `xxxmodule.abi3.so` and `xxxmodule.cpython-*3.so` are no longer recognized as implementing the `xxx` module. If you had been generating such files, you have to switch to the other spellings (i.e., remove the module string from the file names).

  (implemented in issue 14040.)

**Command Line Switch Changes**

- The `-Q` command-line flag and related artifacts have been removed. Code checking `sys.flags.division_warning` will need updating.
When **python** is started with `-S`, `import site` will no longer add site-specific paths to the module search paths. In previous versions, it did.

(issue 10998, contributed by Éric Araujo.)

(issue 11591, contributed by Carl Meyer with editions by Éric Araujo.)
What’s New In Python 3.2

Author: Raymond Hettinger

This article explains the new features in Python 3.2 as compared to 3.1. It focuses on a few highlights and gives a few examples. For full details, see the Misc/NEWS file.

See also: PEP 392 - Python 3.2 Release Schedule
In the past, extension modules built for one Python version were often not usable with other Python versions. Particularly on Windows, every feature release of Python required rebuilding all extension modules that one wanted to use. This requirement was the result of the free access to Python interpreter internals that extension modules could use.

With Python 3.2, an alternative approach becomes available: extension modules which restrict themselves to a limited API (by defining `Py_LIMITED_API`) cannot use many of the internals, but are constrained to a set of API functions that are promised to be stable for several releases. As a consequence, extension modules built for 3.2 in that mode will also work with 3.3, 3.4, and so on. Extension modules that make use of details of memory structures can still be built, but will need to be recompiled for every feature release.

See also:

PEP 384 - Defining a Stable ABI

PEP written by Martin von Löwis.
PEP 389: Argparse Command Line Parsing Module

A new module for command line parsing, `argparse`, was introduced to overcome the limitations of `optparse` which did not provide support for positional arguments (not just options), subcommands, required options and other common patterns of specifying and validating options.

This module has already had widespread success in the community as a third-party module. Being more fully featured than its predecessor, the `argparse` module is now the preferred module for command-line processing. The older module is still being kept available because of the substantial amount of legacy code that depends on it.

Here’s an annotated example parser showing features like limiting results to a set of choices, specifying a `metavar` in the help screen, validating that one or more positional arguments is present, and making a required option:

```python
import argparse
parser = argparse.ArgumentParser(
    description = 'Manage servers',
    epilog = 'Tested on Solaris and Linux')
parser.add_argument('action',
    choices = ['deploy', 'start', 'stop'],
    help = 'action on each target')
parser.add_argument('targets',
    metavar = 'HOSTNAME',
    nargs = '+',
    help = 'url for target machines')
parser.add_argument('-u', '--user',
    required = True,
```
Example of calling the parser on a command string:

```python
>>> cmd = 'deploy sneezy.example.com sleepy.example.com
>>> result = parser.parse_args(cmd.split())
>>> result.action
'deploy'
>>> result.targets
['sneezy.example.com', 'sleepy.example.com']
>>> result.user
'skycaptain'
```

Example of the parser's automatically generated help:

```python
>>> parser.parse_args('-h'.split())
usage: manage_cloud.py [-h] -u USER
   {deploy,start,stop} HOSTNAME
Manage servers

positional arguments:
   {deploy,start,stop} action on each target
   HOSTNAME url for target machines

optional arguments:
   -h, --help show this help message and exit
   -u USER, --user USER login as user

Tested on Solaris and Linux
```

An especially nice `argparse` feature is the ability to define subparsers, each with their own argument patterns and help displays:
import argparse
parser = argparse.ArgumentParser(prog='HELM')
subparsers = parser.add_subparsers()

parser_l = subparsers.add_parser('launch', help='Launch Control')
    # first subgroup
parser_l.add_argument('-m', '--missiles', action='store_true')
parser_l.add_argument('-t', '--torpedos', action='store_true')

parser_m = subparsers.add_parser('move', help='Move Vessel',
    aliases=('steer', 'turn'))
    # second subgroup
parser_m.add_argument('-c', '--course', type=int, required=True)
parser_m.add_argument('-s', '--speed', type=int, default=0)

$ ./helm.py --help
$ ./helm.py launch --help
$ ./helm.py launch --missiles
$ ./helm.py steer --course 180 --speed 5

See also:

**PEP 389** - New Command Line Parsing Module
   PEP written by Steven Bethard.

Upgrading `optparse` code for details on the differences from `optparse`. 
PEP 391: Dictionary Based Configuration for Logging

The `logging` module provided two kinds of configuration, one style with function calls for each option or another style driven by an external file saved in a ConfigParser format. Those options did not provide the flexibility to create configurations from JSON or YAML files, nor did they support incremental configuration, which is needed for specifying logger options from a command line.

To support a more flexible style, the module now offers `logging.config.dictConfig()` for specifying logging configuration with plain Python dictionaries. The configuration options include formatters, handlers, filters, and loggers. Here’s a working example of a configuration dictionary:

```json
{
    "version": 1,
    "formatters": {
        "brief": {
            "format": "%(levelname)-8s: %(name)-15s: %(message)s"
        },
        "full": {
            "format": "%(asctime)s %(name)-15s %(levelname)-8s %(message)s"
        }
    },
    "handlers": {
        "console": {
            "class": "logging.StreamHandler",
            "formatter": "brief",
            "level": "INFO",
            "stream": "ext://sys.stdout"
        },
        "console_priority": {
            "class": "logging.StreamHandler",
            "formatter": "full",
            "level": "ERROR",
            "stream": "ext://sys.stderr"
        }
    },
    "root": {
        "level": "DEBUG",
        "handlers": ["console",
```
If that dictionary is stored in a file called conf.json, it can be loaded and called with code like this:

```python
>>> import json, logging.config
>>> with open('conf.json') as f:
    conf = json.load(f)
>>> logging.config.dictConfig(conf)
>>> logging.info("Transaction completed normally")
INFO : root : Transaction completed normally
>>> logging.critical("Abnormal termination")
2011-02-17 11:14:36,694 root CRITICAL Abnormal termination
```

See also:

**PEP 391 - Dictionary Based Configuration for Logging**

PEP written by Vinay Sajip.
PEP 3148: The concurrent.futures module

Code for creating and managing concurrency is being collected in a new top-level namespace, `concurrent`. Its first member is a `futures` package which provides a uniform high-level interface for managing threads and processes.

The design for `concurrent.futures` was inspired by the `java.util.concurrent` package. In that model, a running call and its result are represented by a `Future` object that abstracts features common to threads, processes, and remote procedure calls. That object supports status checks (running or done), timeouts, cancellations, adding callbacks, and access to results or exceptions.

The primary offering of the new module is a pair of executor classes for launching and managing calls. The goal of the executors is to make it easier to use existing tools for making parallel calls. They save the effort needed to setup a pool of resources, launch the calls, create a results queue, add time-out handling, and limit the total number of threads, processes, or remote procedure calls.

Ideally, each application should share a single executor across multiple components so that process and thread limits can be centrally managed. This solves the design challenge that arises when each component has its own competing strategy for resource management.

Both classes share a common interface with three methods: `submit()` for scheduling a callable and returning a `Future` object; `map()` for scheduling many asynchronous calls at a time, and `shutdown()` for freeing resources. The class is a `context manager`
and can be used in a `with` statement to assure that resources are automatically released when currently pending futures are done executing.

A simple of example of `ThreadPoolExecutor` is a launch of four parallel threads for copying files:

```python
import concurrent.futures, shutil
with concurrent.futures.ThreadPoolExecutor(max_workers=4) as e:
    e.submit(shutil.copy, 'src1.txt', 'dest1.txt')
    e.submit(shutil.copy, 'src2.txt', 'dest2.txt')
    e.submit(shutil.copy, 'src3.txt', 'dest3.txt')
    e.submit(shutil.copy, 'src3.txt', 'dest4.txt')
```

See also:

**PEP 3148 - Futures – Execute Computations Asynchronously**

PEP written by Brian Quinlan.

**Code for Threaded Parallel URL reads**, an example using threads to fetch multiple web pages in parallel.

**Code for computing prime numbers in parallel**, an example demonstrating `ProcessPoolExecutor`. 
PEP 3147: PYC Repository Directories

Python’s scheme for caching bytecode in .pyc files did not work well in environments with multiple Python interpreters. If one interpreter encountered a cached file created by another interpreter, it would recompile the source and overwrite the cached file, thus losing the benefits of caching.

The issue of “pyc fights” has become more pronounced as it has become commonplace for Linux distributions to ship with multiple versions of Python. These conflicts also arise with CPython alternatives such as Unladen Swallow.

To solve this problem, Python’s import machinery has been extended to use distinct filenames for each interpreter. Instead of Python 3.2 and Python 3.3 and Unladen Swallow each competing for a file called “mymodule.pyc”, they will now look for “mymodule.cpython-32.pyc”, “mymodule.cpython-33.pyc”, and “mymodule.unladen10.pyc”. And to prevent all of these new files from cluttering source directories, the pyc files are now collected in a “__pycache__” directory stored under the package directory.

Aside from the filenames and target directories, the new scheme has a few aspects that are visible to the programmer:

- Imported modules now have a __cached__ attribute which stores the name of the actual file that was imported:

```python
>>> import collections
>>> collections.__cached__
'c:/py32/lib/__pycache__/collections.cpython-32.pyc'
```
• The tag that is unique to each interpreter is accessible from the `imp` module:

```python
>>> import imp
>>> imp.get_tag()
'cpython-32'
```

• Scripts that try to deduce source filename from the imported file now need to be smarter. It is no longer sufficient to simply strip the “c” from a ”.pyc” filename. Instead, use the new functions in the `imp` module:

```python
>>> imp.source_from_cache('c:/py32/lib/__pycache__/collections.cpython-32.pyc', 'c:/py32/lib/collections.py')
>>> imp.cache_from_source('c:/py32/lib/collections.py', 'c:/py32/lib/__pycache__/collections.cpython-32.pyc')
```

• The `py_compile` and `compileall` modules have been updated to reflect the new naming convention and target directory. The command-line invocation of `compileall` has new options: `-i` for specifying a list of files and directories to compile and `-b` which causes bytecode files to be written to their legacy location rather than `__pycache__`.

• The `importlib.abc` module has been updated with new abstract base classes for loading bytecode files. The obsolete ABCs, `PyLoader` and `PyPycLoader`, have been deprecated (instructions on how to stay Python 3.1 compatible are included with the documentation).

See also:

**PEP 3147 - PYC Repository Directories**
PEP written by Barry Warsaw.
PEP 3149: ABI Version Tagged .so Files

The PYC repository directory allows multiple bytecode cache files to be co-located. This PEP implements a similar mechanism for shared object files by giving them a common directory and distinct names for each version.

The common directory is “pyshared” and the file names are made distinct by identifying the Python implementation (such as CPython, PyPy, Jython, etc.), the major and minor version numbers, and optional build flags (such as “d” for debug, “m” for pymalloc, “u” for wide-unicode). For an arbitrary package “foo”, you may see these files when the distribution package is installed:

```
/usr/share/pyshared/foo.cpython-32m.so
/usr/share/pyshared/foo.cpython-33md.so
```

In Python itself, the tags are accessible from functions in the `sysconfig` module:

```
>>> import sysconfig
>>> sysconfig.get_config_var('SOABI')  # find the version tag
'cpython-32mu'
>>> sysconfig.get_config_var('EXT_SUFFIX') # find the filename extension
'.cpython-32mu.so'
```

See also:

**PEP 3149 - ABI Version Tagged .so Files**
PEP written by Barry Warsaw.
PEP 3333: Python Web Server Gateway Interface v1.0.1

This informational PEP clarifies how bytes/text issues are to be handled by the WSGI protocol. The challenge is that string handling in Python 3 is most conveniently handled with the `str` type even though the HTTP protocol is itself bytes oriented.

The PEP differentiates so-called `native strings` that are used for request/response headers and metadata versus `byte strings` which are used for the bodies of requests and responses.

The `native strings` are always of type `str` but are restricted to code points between $U+0000$ through $U+00FF$ which are translatable to bytes using `Latin-1` encoding. These strings are used for the keys and values in the environment dictionary and for response headers and statuses in the `start_response()` function. They must follow `RFC 2616` with respect to encoding. That is, they must either be `ISO-8859-1` characters or use `RFC 2047` MIME encoding.

For developers porting WSGI applications from Python 2, here are the salient points:

- If the app already used strings for headers in Python 2, no change is needed.
- If instead, the app encoded output headers or decoded input headers, then the headers will need to be re-encoded to Latin-1. For example, an output header encoded in utf-8 was using `h.encode('utf-8')` now needs to convert from bytes to native strings using `h.encode('utf-8').decode('latin-1')`.
- Values yielded by an application or sent using the `write()` method must be byte strings. The `start_response()` function
and environ must use native strings. The two cannot be mixed.

For server implementers writing CGI-to-WSGI pathways or other CGI-style protocols, the users must to be able access the environment using native strings even though the underlying platform may have a different convention. To bridge this gap, the wsgiref module has a new function, wsgiref.handlers.read_environ() for transcoding CGI variables from os.environ into native strings and returning a new dictionary.

See also:

PEP 3333 - Python Web Server Gateway Interface v1.0.1
PEP written by Phillip Eby.
Other Language Changes

Some smaller changes made to the core Python language are:

- String formatting for `format()` and `str.format()` gained new capabilities for the format character #. Previously, for integers in binary, octal, or hexadecimal, it caused the output to be prefixed with ‘0b’, ‘0o’, or ‘0x’ respectively. Now it can also handle floats, complex, and Decimal, causing the output to always have a decimal point even when no digits follow it.

  ```python
  >>> format(20, '#o')
  '0o24'
  >>> format(12.34, '#5.0f')
  '  12.'
  ```

  (Suggested by Mark Dickinson and implemented by Eric Smith in issue 7094.)

- There is also a new `str.format_map()` method that extends the capabilities of the existing `str.format()` method by accepting arbitrary mapping objects. This new method makes it possible to use string formatting with any of Python’s many dictionary-like objects such as `defaultdict`, `Shelf`, `ConfigParser`, or `dbm`. It is also useful with custom `dict` subclasses that normalize keys before look-up or that supply a `__missing__()` method for unknown keys:

  ```python
  >>> import shelve
  >>> d = shelve.open('tmp.shl')
  >>> 'The {project_name} status is {status} as of {date}'
  'The testing project status is green as of February 15, 2011'
  ```
>>> class LowerCasedDict(dict):
    def __getitem__(self, key):
        return dict.__getitem__(self, key.lower())
>>>lcd = LowerCasedDict(part='widgets', quantity='There are {QUANTITY} {Part} in stock'.format_map(vars(lcd)))
'There are 10 widgets in stock'

>>> class PlaceholderDict(dict):
    def __missing__(self, key):
        return '<{}>'.format(key)

>>> 'Hello {name}, welcome to {location}'.format_map(PlaceholderDict(name='<name>', location='<location>'))
'Hello <name>, welcome to <location>'

(Suggested by Raymond Hettinger and implemented by Eric Smith in issue 6081.)

- The interpreter can now be started with a quiet option, -q, to prevent the copyright and version information from being displayed in the interactive mode. The option can be introspected using the sys.flags attribute:

```bash
$ python -q
>>> sys.flags
sys.flags(debug=0, division_warning=0, inspect=0, optimize=0, dont_write_bytecode=0, no_user_site=0, ignore_environment=0, verbose=0, bytes_warning=0, quiet=1)
```

(Contributed by Marcin Wojdyr in issue 1772833).

- The hasattr() function works by calling getattribute() and detecting whether an exception is raised. This technique allows it to detect methods created dynamically by __getattribute__() or __getattribute__() which would otherwise be absent from
the class dictionary. Formerly, `hasattr` would catch any exception, possibly masking genuine errors. Now, `hasattr` has been tightened to only catch `AttributeError` and let other exceptions pass through:

```python
>>> class A:
    @property
def f(self):
    return 1 // 0

>>> a = A()
>>> hasattr(a, 'f')
Traceback (most recent call last):
  ... AttributeError: integer division or modulo by zero
```

(Discovered by Yury Selivanov and fixed by Benjamin Peterson; [issue 9666](https://bugs.python.org/issue9666).)

- The `str()` of a float or complex number is now the same as its `repr()`. Previously, the `str()` form was shorter but that just caused confusion and is no longer needed now that the shortest possible `repr()` is displayed by default:

```python
>>> import math
>>> repr(math.pi)
'3.141592653589793'
>>> str(math.pi)
'3.141592653589793'
```

(Proposed and implemented by Mark Dickinson; [issue 9337](https://bugs.python.org/issue9337).)

- `memoryview` objects now have a `release()` method and they also now support the context management protocol. This allows
timely release of any resources that were acquired when requesting a buffer from the original object.

```python
>>> with memoryview(b'abcdefgh') as v:
    print(v.tolist())
[97, 98, 99, 100, 101, 102, 103, 104]
```

(Added by Antoine Pitrou; issue 9757.)

- Previously it was illegal to delete a name from the local namespace if it occurs as a free variable in a nested block:

```python
def outer(x):
    def inner():
        return x
    inner()
    del x
```

This is now allowed. Remember that the target of an `except` clause is cleared, so this code which used to work with Python 2.6, raised a `SyntaxError` with Python 3.1 and now works again:

```python
def f():
    def print_error():
        print(e)
    try:
        something
    except Exception as e:
        print_error()
        # implicit "del e" here
```

(See issue 4617.)

- The internal `structsequence` tool now creates subclasses of
tuple. This means that C structures like those returned by os.stat(), time.gmtime(), and sys.version_info now work like a named tuple and now work with functions and methods that expect a tuple as an argument. This is a big step forward in making the C structures as flexible as their pure Python counterparts:

```python
>>> isinstance(sys.version_info, tuple)
True
>>> 'Version %d.%d.%d %s(%d)' % sys.version_info
'Version 3.2.0 final(0)'
```

(Suggested by Arfrever Frehtes Taifersar Arahesis and implemented by Benjamin Peterson in issue 8413.)

- Warnings are now easier to control using the PYTHONWARNINGS environment variable as an alternative to using -W at the command line:

```bash
$ export PYTHONWARNINGS='ignore::RuntimeWarning::,once::UnicodeWarning::'
```

(Suggested by Barry Warsaw and implemented by Philip Jenvey in issue 7301.)

- A new warning category, ResourceWarning, has been added. It is emitted when potential issues with resource consumption or cleanup are detected. It is silenced by default in normal release builds but can be enabled through the means provided by the warnings module, or on the command line.

  A ResourceWarning is issued at interpreter shutdown if the gc.garbage list isn’t empty, and if gc.DEBUG_UNCOLLECTABLE
is set, all uncollectable objects are printed. This is meant to make the
programmer aware that their code contains object finalization
issues.

A `ResourceWarning` is also issued when a file object is
destroyed without having been explicitly closed. While the
deallocator for such object ensures it closes the underlying
operating system resource (usually, a file descriptor), the delay in
deallocating the object could produce various issues, especially
under Windows. Here is an example of enabling the warning from
the command line:

```
$ python -q -Wdefault
>>> f = open("foo", "wb")
>>> del f
__main__:1: ResourceWarning: unclosed file <_io.BufferedWriter

(Added by Antoine Pitrou and Georg Brandl in issue 10093 and
issue 477863.)

- `range` objects now support `index` and `count` methods. This is part
  of an effort to make more objects fully implement the
  collections.Sequence abstract base class. As a result, the
  language will have a more uniform API. In addition, `range` objects
  now support slicing and negative indices, even with values larger
  than `sys.maxsize`. This makes `range` more interoperable with
  lists:

```
>>> range(0, 100, 2).count(10)
1
>>> range(0, 100, 2).index(10)
5
>>> range(0, 100, 2)[5]
range(0, 100, 2)[0:5]
range(0, 10, 2)

(Contributed by Daniel Stutzbach in issue 9213, by Alexander Belopolsky in issue 2690, and by Nick Coghlan in issue 10889.)

- The callable() built-in function from Py2.x was resurrected. It provides a concise, readable alternative to using an abstract base class in an expression like isinstance(x, collections.Callable):

```python
>>> callable(max)
True
>>> callable(20)
False
```

(See issue 10518.)

- Python's import mechanism can now load modules installed in directories with non-ASCII characters in the path name. This solved an aggravating problem with home directories for users with non-ASCII characters in their usernames.

(Required extensive work by Victor Stinner in issue 9425.)
New, Improved, and Deprecated Modules

Python's standard library has undergone significant maintenance efforts and quality improvements.

The biggest news for Python 3.2 is that the `email` package, `mailbox` module, and `nntplib` modules now work correctly with the bytes/text model in Python 3. For the first time, there is correct handling of messages with mixed encodings.

Throughout the standard library, there has been more careful attention to encodings and text versus bytes issues. In particular, interactions with the operating system are now better able to exchange non-ASCII data using the Windows MBCS encoding, locale-aware encodings, or UTF-8.

Another significant win is the addition of substantially better support for SSL connections and security certificates.

In addition, more classes now implement a `context manager` to support convenient and reliable resource clean-up using a `with` statement.

email

The usability of the `email` package in Python 3 has been mostly fixed by the extensive efforts of R. David Murray. The problem was that emails are typically read and stored in the form of `bytes` rather than `str` text, and they may contain multiple encodings within a single email. So, the email package had to be extended to parse and generate email messages in bytes format.
New functions `message_from_bytes()` and `message_from_binary_file()`, and new classes `BytesFeedParser` and `BytesParser` allow binary message data to be parsed into model objects.

Given bytes input to the model, `get_payload()` will by default decode a message body that has a `Content-Transfer-Encoding` of `8bit` using the charset specified in the MIME headers and return the resulting string.

Given bytes input to the model, `Generator` will convert message bodies that have a `Content-Transfer-Encoding` of `8bit` to instead have a `7bit Content-Transfer-Encoding`.

Headers with unencoded non-ASCII bytes are deemed to be `RFC 2047`-encoded using the `unknown-8bit` character set.

A new class `BytesGenerator` produces bytes as output, preserving any unchanged non-ASCII data that was present in the input used to build the model, including message bodies with a `Content-Transfer-Encoding` of `8bit`.

The `smtplib` SMTP class now accepts a byte string for the `msg` argument to the `sendmail()` method, and a new method, `send_message()` accepts a `Message` object and can optionally obtain the `from_addr` and `to_addrs` addresses directly from the object.

(Proposed and implemented by R. David Murray, issue 4661 and issue 10321.)

elementtree
The `xml.etree.ElementTree` package and its `xml.etree.cElementTree` counterpart have been updated to version 1.3.

Several new and useful functions and methods have been added:

- `xml.etree.ElementTree.fromstringlist()` which builds an XML document from a sequence of fragments
- `xml.etree.ElementTree.register_namespace()` for registering a global namespace prefix
- `xml.etree.ElementTree.tostringlist()` for string representation including all sublists
- `xml.etree.ElementTree.Element.extend()` for appending a sequence of zero or more elements
- `xml.etree.ElementTree.Element.iterfind()` searches an element and subelements
- `xml.etree.ElementTree.Element.itertext()` creates a text iterator over an element and its subelements
- `xml.etree.ElementTree.TreeBuilder.end()` closes the current element
- `xml.etree.ElementTree.TreeBuilder.doctype()` handles a doctype declaration

Two methods have been deprecated:

- `xml.etree.ElementTree.getchildren()` use `list(elem)` instead.
- `xml.etree.ElementTree.getiterator()` use `Element.iter` instead.

For details of the update, see [Introducing ElementTree](#) on Fredrik Lundh’s website.

(Contributed by Florent Xicluna and Fredrik Lundh, issue 6472.)
functools

- The **functools** module includes a new decorator for caching function calls. **functools.lru_cache()** can save repeated queries to an external resource whenever the results are expected to be the same.

For example, adding a caching decorator to a database query function can save database accesses for popular searches:

```python
>>> import functools
c
>>> @functools.lru_cache(maxsize=300)
>>> def get_phone_number(name):
    c = conn.cursor()
    c.execute('SELECT phonenumber FROM phonelist WHERE name=?', (name,))
    return c.fetchone()[0]

>>> for name in user_requests:
    get_phone_number(name)       # cached lookup
```

To help with choosing an effective cache size, the wrapped function is instrumented for tracking cache statistics:

```python
>>> get_phone_number.cache_info()
CacheInfo(hits=4805, misses=980, maxsize=300, currsize=300)
```

If the phonelist table gets updated, the outdated contents of the cache can be cleared with:

```python
>>> get_phone_number.cache_clear()
```
(Contributed by Raymond Hettinger and incorporating design ideas from Jim Baker, Miki Tebeka, and Nick Coghlan; see recipe 498245, recipe 577479, issue 10586, and issue 10593.)

- The `functools.wraps()` decorator now adds a `__wrapped__` attribute pointing to the original callable function. This allows wrapped functions to be introspected. It also copies `__annotations__` if defined. And now it also gracefully skips over missing attributes such as `__doc__` which might not be defined for the wrapped callable.

In the above example, the cache can be removed by recovering the original function:

```python
>>> get_phone_number = get_phone_number.__wrapped__
```

(By Nick Coghlan and Terrence Cole; issue 9567, issue 3445, and issue 8814.)

- To help write classes with rich comparison methods, a new decorator `functools.total_ordering()` will use existing equality and inequality methods to fill in the remaining methods.

For example, supplying `__eq__` and `__lt__` will enable `total_ordering()` to fill-in `__le__`, `__gt__` and `__ge__`:

```python
@total_ordering
class Student:
    def __eq__(self, other):
        return ((self.lastname.lower(), self.firstname),
                (other.lastname.lower(), other.firstname))
    def __lt__(self, other):
        return ((self.lastname.lower(), self.firstname),
                (other.lastname.lower(), other.firstname))
```
With the `total_ordering` decorator, the remaining comparison methods are filled in automatically.

(Contributed by Raymond Hettinger.)

- To aid in porting programs from Python 2, the `functools.cmp_to_key()` function converts an old-style comparison function to modern key function:

```python
>>> # locale-aware sort order
>>> sorted(iterable, key=cmp_to_key(locale.strcoll))
```

For sorting examples and a brief sorting tutorial, see the Sorting HowTo tutorial.

(Contributed by Raymond Hettinger.)

`itertools`

- The `itertools` module has a new `accumulate()` function modeled on APL's `scan` operator and Numpy's `accumulate` function:

```python
>>> from itertools import accumulate
>>> list(accumulate([8, 2, 50]))
[8, 10, 60]
```

```python
>>> prob_dist = [0.1, 0.4, 0.2, 0.3]
>>> list(accumulate(prob_dist))  # cumulative
[0.1, 0.5, 0.7, 1.0]
```
For an example using `accumulate()`, see the examples for the random module.

(Contributed by Raymond Hettinger and incorporating design suggestions from Mark Dickinson.)

collections

- The `collections.Counter` class now has two forms of in-place subtraction, the existing `-=` operator for saturating subtraction and the new `subtract()` method for regular subtraction. The former is suitable for multisets which only have positive counts, and the latter is more suitable for use cases that allow negative counts:

  ```python
  >>> tally = Counter(dogs=5, cat=3)
  >>> tally -= Counter(dogs=2, cats=8)  # saturating subtraction
  >>> tally
  Counter({'dogs': 3})
  >>> tally = Counter(dogs=5, cats=3)
  >>> tally.subtract(dogs=2, cats=8)  # regular subtraction
  >>> tally
  Counter({'dogs': 3, 'cats': -5})
  ```

  (Contributed by Raymond Hettinger.)

- The `collections.OrderedDict` class has a new method `move_to_end()` which takes an existing key and moves it to either the first or last position in the ordered sequence.

  The default is to move an item to the last position. This is
equivalent of renewing an entry with `od[k] = od.pop(k)`.

A fast move-to-end operation is useful for resequencing entries. For example, an ordered dictionary can be used to track order of access by aging entries from the oldest to the most recently accessed.

```python
>>> d = OrderedDict.fromkeys(['a', 'b', 'X', 'd'])
>>> list(d)
['a', 'b', 'X', 'd', 'e']
>>> d.move_to_end('X')
>>> list(d)
['a', 'b', 'd', 'e', 'X']
```

(Contributed by Raymond Hettinger.)

- The `collections.deque` class grew two new methods `count()` and `reverse()` that make them more substitutable for `list` objects:

```python
>>> d = deque('simsalabim')
>>> d.count('s')
2
>>> d.reverse()
>>> d
deque(['m', 'i', 'b', 'a', 'l', 'a', 's', 'm', 'i', 's'])
```

(Contributed by Raymond Hettinger.)

### threading

The `threading` module has a new `Barrier` synchronization class for making multiple threads wait until all of them have reached a
common barrier point. Barriers are useful for making sure that a task with multiple preconditions does not run until all of the predecessor tasks are complete.

Barriers can work with an arbitrary number of threads. This is a generalization of a Rendezvous which is defined for only two threads.

Implemented as a two-phase cyclic barrier, Barrier objects are suitable for use in loops. The separate filling and draining phases assure that all threads get released (drained) before any one of them can loop back and re-enter the barrier. The barrier fully resets after each cycle.

Example of using barriers:

```python
from threading import Barrier, Thread

def get_votes(site):
    ballots = conduct_election(site)
    all_polls_closed.wait()  # do not count until all polls are closed
    totals = summarize(ballots)
    publish(site, totals)

all_polls_closed = Barrier(len(sites))
for site in sites:
    Thread(target=get_votes, args=(site,)).start()
```

In this example, the barrier enforces a rule that votes cannot be counted at any polling site until all polls are closed. Notice how a solution with a barrier is similar to one with threading.Thread.join(), but the threads stay alive and continue to do work (summarizing ballots) after the barrier point is crossed.
If any of the predecessor tasks can hang or be delayed, a barrier can be created with an optional `timeout` parameter. Then if the timeout period elapses before all the predecessor tasks reach the barrier point, all waiting threads are released and a `BrokenBarrierError` exception is raised:

```python
def get_votes(site):
    ballots = conduct_election(site)
    try:
        all_polls_closed.wait(timeout = midnight - t
    except BrokenBarrierError:
        lockbox = seal_ballots(ballots)
        queue.put(lockbox)
    else:
        totals = summarize(ballots)
        publish(site, totals)
```

In this example, the barrier enforces a more robust rule. If some election sites do not finish before midnight, the barrier times-out and the ballots are sealed and deposited in a queue for later handling.

See Barrier Synchronization Patterns for more examples of how barriers can be used in parallel computing. Also, there is a simple but thorough explanation of barriers in The Little Book of Semaphores, section 3.6.

(Contributed by Kristján Valur Jónsson with an API review by Jeffrey Yasskin in issue 8777.)

datetime and time

- The `datetime` module has a new type `timezone` that implements the `tzinfo` interface by returning a fixed UTC offset
and timezone name. This makes it easier to create timezone-aware datetime objects:

```python
>>> from datetime import datetime, timezone
>>> datetime.now(timezone.utc)
datetime(2010, 12, 8, 21, 4, 2, 923754, tzinfo=datetime.timezone.utc)
>>> datetime.strptime("01/01/2000 12:00 +0000", "%m/%d/%Y %H:%M %z")
datetime.datetime(2000, 1, 1, 12, 0, tzinfo=datetime.timezone.utc)
```

- Also, `timedelta` objects can now be multiplied by `float` and divided by `float` and `int` objects. And `timedelta` objects can now divide one another.

- The `datetime.date.strftime()` method is no longer restricted to years after 1900. The new supported year range is from 1000 to 9999 inclusive.

- Whenever a two-digit year is used in a time tuple, the interpretation has been governed by `time.accept2dyear`. The default is `True` which means that for a two-digit year, the century is guessed according to the POSIX rules governing the `%y` `strptime` format.

Starting with Py3.2, use of the century guessing heuristic will emit a `DeprecationWarning`. Instead, it is recommended that `time.accept2dyear` be set to `False` so that large date ranges can be used without guesswork:

```python
>>> import time, warnings
>>> warnings.resetwarnings()  # remove the deprecation warning
```
Several functions now have significantly expanded date ranges. When `time.accept2dyear` is false, the `time.asctime()` function will accept any year that fits in a C `int`, while the `time.mktime()` and `time.strftime()` functions will accept the full range supported by the corresponding operating system functions.

(Contributed by Alexander Belopolsky and Victor Stinner in issue 1289118, issue 5094, issue 6641, issue 2706, issue 1777412, issue 8013, and issue 10827.)

**math**

The `math` module has been updated with six new functions inspired by the C99 standard.

The `isfinite()` function provides a reliable and fast way to detect special values. It returns `True` for regular numbers and `False` for `Nan` or `Infinity`:

```python
>>> [isfinite(x) for x in (123, 4.56, float('Nan'), [True, True, False, False])]
```
The `expm1()` function computes $e^{x}-1$ for small values of $x$ without incurring the loss of precision that usually accompanies the subtraction of nearly equal quantities:

```python
>>> expm1(0.013671875)  # more accurate way to compute e**x-1 for a small x
0.013765762467652909
```

The `erf()` function computes a probability integral or Gaussian error function. The complementary error function, `erfc()`, is $1 - \text{erf}(x)$:

```python
>>> erf(1.0/sqrt(2.0))  # portion of normal distribution
0.682689492137086
>>> erfc(1.0/sqrt(2.0))  # portion of normal distribution
0.31731050786291404
>>> erf(1.0/sqrt(2.0)) + erfc(1.0/sqrt(2.0))
1.0
```

The `gamma()` function is a continuous extension of the factorial function. See [http://en.wikipedia.org/wiki/Gamma_function](http://en.wikipedia.org/wiki/Gamma_function) for details. Because the function is related to factorials, it grows large even for small values of $x$, so there is also a `lgamma()` function for computing the natural logarithm of the gamma function:

```python
>>> gamma(7.0)  # six factorial
720.0
>>> lgamma(801.0)  # log(800 factorial)
4551.950730698041
```

(Contributed by Mark Dickinson.)
The *abc* module now supports *abstractclassmethod()* and *abstractstaticmethod()*.

These tools make it possible to define an *abstract base class* that requires a particular *classmethod()* or *staticmethod()* to be implemented:

```python
class Temperature(metaclass=abc.ABCMeta):
    @abc.abstractclassmethod
    def from_fahrenheit(cls, t):
        ...
    @abc.abstractclassmethod
    def from_celsius(cls, t):
        ...
```

(Patch submitted by Daniel Urban; issue 5867.)

**iO**

The *io.BytesIO* has a new method, *getbuffer()*, which provides functionality similar to *memoryview()*. It creates an editable view of the data without making a copy. The buffer's random access and support for slice notation are well-suited to in-place editing:

```python
>>> REC_LEN, LOC_START, LOC_LEN = 34, 7, 11

>>> def change_location(buffer, record_number, location):
    start = record_number * REC_LEN + LOC_START
    buffer[start:start+LOC_LEN] = location

>>> import io

>>> byte_stream = io.BytesIO(b'G3805    storeroom    Main chassis    ')
```
buffer = byte_stream.getbuffer()
change_location(buffer, 1, b'warehouse ')
change_location(buffer, 0, b'showroom ')
print(byte_stream.getvalue())

(Contributed by Antoine Pitrou in issue 5506.)

reprlib

When writing a __repr__() method for a custom container, it is easy to forget to handle the case where a member refers back to the container itself. Python’s built-in objects such as list and set handle self-reference by displaying "..." in the recursive part of the representation string.

To help write such __repr__() methods, the reprlib module has a new decorator, recursive_repr(), for detecting recursive calls to __repr__() and substituting a placeholder string instead:

```python
class MyList(list):
    @recursive_repr()
    def __repr__(self):
        return '<' + '|'.join(map(repr, self)) + '>

m = MyList('abc')
m.append(m)
m.append('x')
print(m)
```
logging

In addition to dictionary-based configuration described above, the `logging` package has many other improvements.

The logging documentation has been augmented by a basic tutorial, an advanced tutorial, and a cookbook of logging recipes. These documents are the fastest way to learn about logging.

The `logging.basicConfig()` set-up function gained a `style` argument to support three different types of string formatting. It defaults to “%” for traditional %-formatting, can be set to “{” for the new `str.format()` style, or can be set to “$” for the shell-style formatting provided by `string.Template`. The following three configurations are equivalent:

```python
>>> from logging import basicConfig
>>> basicConfig(style='%', format='%(name)s -> %(levelname)s: %(message)s')
>>> basicConfig(style='{', format='{name} -> {levelname} {message}')
>>> basicConfig(style='$', format='$name -> $levelname: $message')
```

If no configuration is set-up before a logging event occurs, there is now a default configuration using a `StreamHandler` directed to `sys.stderr` for events of WARNING level or higher. Formerly, an event occurring before a configuration was set-up would either raise an exception or silently drop the event depending on the value of `logging.raiseExceptions`. The new default handler is stored in
logging.lastResort.

The use of filters has been simplified. Instead of creating a Filter object, the predicate can be any Python callable that returns True or False.

There were a number of other improvements that add flexibility and simplify configuration. See the module documentation for a full listing of changes in Python 3.2.

CSV

The csv module now supports a new dialect, unix_dialect, which applies quoting for all fields and a traditional Unix style with '\n' as the line terminator. The registered dialect name is unix.

The csv.DictWriter has a new method, writeheader() for writing-out an initial row to document the field names:

```python
>>> import csv, sys
>>> w = csv.DictWriter(sys.stdout, ['name', 'dept'],
                     "name","dept"
>>> w.writeheader()
"name","dept"
>>> w.writerows([
                {'name': 'tom', 'dept': 'accounting'},
                {'name': 'susan', 'dept': 'Salesl'}])
"tom","accounting"
"susan","sales"
```

(New dialect suggested by Jay Talbot in issue 5975, and the new method suggested by Ed Abraham in issue 1537721.)

contextlib
There is a new and slightly mind-blowing tool `ContextDecorator` that is helpful for creating a context manager that does double duty as a function decorator.

As a convenience, this new functionality is used by `contextmanager()` so that no extra effort is needed to support both roles.

The basic idea is that both context managers and function decorators can be used for pre-action and post-action wrappers. Context managers wrap a group of statements using a `with` statement, and function decorators wrap a group of statements enclosed in a function. So, occasionally there is a need to write a pre-action or post-action wrapper that can be used in either role.

For example, it is sometimes useful to wrap functions or groups of statements with a logger that can track the time of entry and time of exit. Rather than writing both a function decorator and a context manager for the task, the `contextmanager()` provides both capabilities in a single definition:

```python
from contextlib import contextmanager
import logging

logging.basicConfig(level=logging.INFO)

@contextmanager
def track_entry_and_exit(name):
    logging.info('Entering: {}' .format(name))
    yield
    logging.info('Exiting: {}' .format(name))
```

Formerly, this would have only been usable as a context manager:
with track_entry_and_exit('widget loader'):
    print('Some time consuming activity goes here')
load_widget()

Now, it can be used as a decorator as well:

@track_entry_and_exit('widget loader')
def activity():
    print('Some time consuming activity goes here')
load_widget()

Trying to fulfill two roles at once places some limitations on the technique. Context managers normally have the flexibility to return an argument usable by a with statement, but there is no parallel for function decorators.

In the above example, there is not a clean way for the track_entry_and_exit context manager to return a logging instance for use in the body of enclosed statements.

(Contributed by Michael Foord in issue 9110.)

decimal and fractions

Mark Dickinson crafted an elegant and efficient scheme for assuring that different numeric datatypes will have the same hash value whenever their actual values are equal (issue 8188):

```
assert hash(Fraction(3, 2)) == hash(1.5) == \
    hash(Decimal("1.5")) == hash(complex(1.5, 0))
```

Some of the hashing details are exposed through a new attribute, sys.hash_info, which describes the bit width of the hash value, the
prime modulus, the hash values for \textit{infinity} and \textit{nan}, and the multiplier used for the imaginary part of a number:

```python
>>> sys.hash_info
sys.hash_info(width=64, modulus=2305843009213693951,
```

An early decision to limit the inter-operability of various numeric types has been relaxed. It is still unsupported (and ill-advised) to have implicit mixing in arithmetic expressions such as `Decimal('1.1') + float('1.1')` because the latter loses information in the process of constructing the binary float. However, since existing floating point value can be converted losslessly to either a decimal or rational representation, it makes sense to add them to the constructor and to support mixed-type comparisons.

- The \texttt{decimal.Decimal} constructor now accepts \texttt{float} objects directly so there in no longer a need to use the \texttt{from_float()} method (issue 8257).
- Mixed type comparisons are now fully supported so that \texttt{Decimal} objects can be directly compared with \texttt{float} and \texttt{fractions.Fraction} (issue 2531 and issue 8188).

Similar changes were made to \texttt{fractions.Fraction} so that the \texttt{from_float()} and \texttt{from_decimal()} methods are no longer needed (issue 8294):

```python
>>> Decimal(1.1)
Decimal('1.100000000000000088817841970012523233890535897931168')

>>> Fraction(1.1)
Fraction(2476979795053773, 2251799813685248)
```

Another useful change for the \texttt{decimal} module is that the
Context.clamp attribute is now public. This is useful in creating contexts that correspond to the decimal interchange formats specified in IEEE 754 (see issue 8540).

(Contributed by Mark Dickinson and Raymond Hettinger.)

**ftp**

The `ftplib.FTP` class now supports the context management protocol to unconditionally consume `socket.error` exceptions and to close the FTP connection when done:

```python
>>> from ftplib import FTP
>>> with FTP("ftp1.at.proftpd.org") as ftp:
    ftp.login()
    ftp.dir()

'230 Anonymous login ok, restrictions apply.'
dr-xr-xr-x 9 ftp ftp 154 May 6 10:18..
dr-xr-xr-x 5 ftp ftp 4096 May 6 10:18 CentOS
dr-xr-xr-x 3 ftp ftp 18 Jul 10 2008 Fedora
```

Other file-like objects such as `mmap.mmap` and `fileinput.input()` also grew auto-closing context managers:

```python
with fileinput.input(files=("log1.txt", "log2.txt"))
    for line in f:
        process(line)
```

(Contributed by Tarek Ziadé and Giampaolo Rodolà in issue 4972, and by Georg Brandl in issue 8046 and issue 1286.)
The **FTP_TLS** class now accepts a *context* parameter, which is a
**ssl.SSLContext** object allowing bundling SSL configuration options,
certificates and private keys into a single (potentially long-lived)
structure.

(Contributed by Giampaolo Rodolà; [issue 8806](#).)

**popen**

The **os.popen()** and **subprocess.Popen()** functions now support
*with* statements for auto-closing of the file descriptors.

(Contributed by Antoine Pitrou and Brian Curtin in [issue 7461](#) and
[issue 10554](#).)

**select**

The **select** module now exposes a new, constant attribute,
**PIPE_BUF**, which gives the minimum number of bytes which are
guaranteed not to block when **select.select()** says a pipe is
ready for writing.

```
>>> import select
>>> select.PIPE_BUF
512
```

(Available on Unix systems. Patch by Sébastien Sablé in [issue 9862](#))

**gzip and zipfile**

**gzip.GzipFile** now implements the **io.BufferedIOBase abstract base class** (except for **truncate()**). It also has a **peek()** method
and supports unseekable as well as zero-padded file objects.

The `gzip` module also gains the `compress()` and `decompress()` functions for easier in-memory compression and decompression. Keep in mind that text needs to be encoded as `bytes` before compressing and decompressing:

```python
>>> s = 'Three shall be the number thou shalt count,'
>>> s += 'and the number of the counting shall be the
>>> b = s.encode()  # convert
>>> len(b)
89
>>> c = gzip.compress(b)
>>> len(c)
77
>>> gzip.decompress(c).decode()[42]  # decompress and convert to text
'Three shall be the number thou shalt count,'
```

(Contributed by Anand B. Pillai in issue 3488; and by Antoine Pitrou, Nir Aides and Brian Curtin in issue 9962, issue 1675951, issue 7471 and issue 2846.)

Also, the `zipfile.ZipExtFile` class was reworked internally to represent files stored inside an archive. The new implementation is significantly faster and can be wrapped in an `io.BufferedReader` object for more speedups. It also solves an issue where interleaved calls to `read` and `readline` gave the wrong results.

(Patch submitted by Nir Aides in issue 7610.)

tarfile

The `TarFile` class can now be used as a context manager. In
addition, its `add()` method has a new option, `filter`, that controls which files are added to the archive and allows the file metadata to be edited.

The new `filter` option replaces the older, less flexible `exclude` parameter which is now deprecated. If specified, the optional `filter` parameter needs to be a `keyword argument`. The user-supplied filter function accepts a `TarInfo` object and returns an updated `TarInfo` object, or if it wants the file to be excluded, the function can return `None`:

```python
>>> import tarfile, glob

>>> def myfilter(tarinfo):
    if tarinfo.isfile():  # only save
        tarinfo.uname = 'monty'  # redact the
    return tarinfo

>>> with tarfile.open(name='myarchive.tar.gz', mode=
    for filename in glob.glob('*.txt'):
        tf.add(filename, filter=myfilter)

tf.list()
```

```
-rw-r--r--  monty/501  902 2011-01-26 17:59:11 annotations.txt
-rw-r--r--  monty/501 123 2011-01-26 17:59:11 general_questions.txt
-rw-r--r--  monty/501 3514 2011-01-26 17:59:11 prion.txt
-rw-r--r--  monty/501 124 2011-01-26 17:59:11 py_todo.txt
-rw-r--r--  monty/501 1399 2011-01-26 17:59:11 semaphore_notes.txt
```

(Proposed by Tarek Ziadé and implemented by Lars Gustäbel in issue 6856.)

**hashlib**

The `hashlib` module has two new constant attributes listing the
hashing algorithms guaranteed to be present in all implementations and those available on the current implementation:

```python
>>> import hashlib

>>> hashlib.algorithms_guaranteed
{'sha1', 'sha224', 'sha384', 'sha256', 'sha512', 'md5'}

>>> hashlib.algorithms_available
{'md2', 'SHA256', 'SHA512', 'dsaWithSHA', 'mdc2', 'SHA1', 'MDC2', 'SHA', 'SHA384', 'ecdsa-with-SHA1', 'md4', 'md5', 'sha1', 'DSA-SHA', 'dsaEncryption', 'DSA', 'RIPEMD160', 'sha', 'MD5', 'sha224', 'sha256', 'ripemd160'}

(Suggested by Carl Chenet in issue 7418.)
```

**ast**

The *ast* module has a wonderful a general-purpose tool for safely evaluating expression strings using the Python literal syntax. The *ast.literal_eval()* function serves as a secure alternative to the builtin *eval()* function which is easily abused. Python 3.2 adds *bytes* and *set* literals to the list of supported types: strings, bytes, numbers, tuples, lists, dicts, sets, booleans, and None.

```python
>>> from ast import literal_eval

>>> request = "{'req': 3, 'func': 'pow', 'args': (2, 0.5)}, 'func': 'pow'

>>> literal_eval(request)
{'args': (2, 0.5), 'req': 3, 'func': 'pow'}

>>> request = "os.system('do something harmful')"

>>> literal_eval(request)
Traceback (most recent call last):
```
OS

Different operating systems use various encodings for filenames and environment variables. The `os` module provides two new functions, `fsencode()` and `fsdecode()`, for encoding and decoding filenames:

```
>>> filename = 'Sehenswürdigkeiten'
>>> os.fsencode(filename)
'b\'Sehensw\xc3\xbcrdigkeiten\'
```

Some operating systems allow direct access to encoded bytes in the environment. If so, the `os.supports_bytes_environ` constant will be true.

For direct access to encoded environment variables (if available), use the new `os.getenvb()` function or use `os.environb` which is a bytes version of `os.environ`.

(Contributed by Victor Stinner.)

shutil

The `shutil.copytree()` function has two new options:

- `ignore_dangling_symlinks`: when `symlinks=False` so that the function copies a file pointed to by a symlink, not the symlink
itself. This option will silence the error raised if the file doesn't exist.

- *copy_function*: is a callable that will be used to copy files. `shutil.copy2()` is used by default.

(Contributed by Tarek Ziadé.)

In addition, the `shutil` module now supports *archiving operations* for zipfiles, uncompressed tarfiles, gzipped tarfiles, and bzipped tarfiles. And there are functions for registering additional archiving file formats (such as xz compressed tarfiles or custom formats).

The principal functions are `make_archive()` and `unpack_archive()`. By default, both operate on the current directory (which can be set by `os.chdir()` and on any sub-directories. The archive filename needs to be specified with a full pathname. The archiving step is non-destructive (the original files are left unchanged).

```python
>>> import shutil, pprint

>>> os.chdir('mydata')
>>> f = shutil.make_archive('/var/backup/mydata', 'zip')

>>> f
'/var/backup/mydata.zip'
>>> os.chdir('tmp')
>>> shutil.unpack_archive('/var/backup/mydata.zip')

>>> pprint.pprint(shutil.get_archive_formats())
[('bztar', "bzip2'ed tar-file"), ('gztar', "gzip'ed tar-file"), ('tar', 'uncompressed tar file'), ('zip', 'ZIP file')]
```
shutil.

```python
>>> shutil.register_archive_format(
    name = 'xz',
    function = xz.compress,
    extra_args = [('level', 8)],
    description = 'xz compression'
)
```

(Contributed by Tarek Ziadé.)

sqlite3

The `sqlite3` module was updated to `pysqlite` version 2.6.0. It has two new capabilities.

- The `sqlite3.Connection.in_transit` attribute is true if there is an active transaction for uncommitted changes.
- The `sqlite3.Connection.enable_load_extension()` and `sqlite3.Connection.load_extension()` methods allows you to load SQLite extensions from ".so" files. One well-known extension is the fulltext-search extension distributed with SQLite.

(Contributed by R. David Murray and Shashwat Anand; issue 8845.)

html

A new `html` module was introduced with only a single function, `escape()`, which is used for escaping reserved characters from HTML markup:

```python
>>> import html
>>> html.escape('x > 2 && x < 7')
'x &gt; 2 &amp;&amp; x &lt; 7'
```
socket

The `socket` module has two new improvements.

- Socket objects now have a `detach()` method which puts the socket into closed state without actually closing the underlying file descriptor. The latter can then be reused for other purposes. (Added by Antoine Pitrou; issue 8524.)
- `socket.create_connection()` now supports the context management protocol to unconditionally consume `socket.error` exceptions and to close the socket when done. (Contributed by Giampaolo Rodolà; issue 9794.)

ssl

The `ssl` module added a number of features to satisfy common requirements for secure (encrypted, authenticated) internet connections:

- A new class, `SSLContext`, serves as a container for persistent SSL data, such as protocol settings, certificates, private keys, and various other options. It includes a `wrap_socket()` for creating an SSL socket from an SSL context.
- A new function, `ssl.match_hostname()`, supports server identity verification for higher-level protocols by implementing the rules of HTTPS (from RFC 2818) which are also suitable for other protocols.
- The `ssl.wrap_socket()` constructor function now takes a `ciphers` argument. The `ciphers` string lists the allowed encryption algorithms using the format described in the OpenSSL documentation.
- When linked against recent versions of OpenSSL, the `ssl` module now supports the Server Name Indication extension to the
TLS protocol, allowing multiple “virtual hosts” using different certificates on a single IP port. This extension is only supported in client mode, and is activated by passing the `server_hostname` argument to `ssl.SSLContext.wrap_socket()`.

- Various options have been added to the `ssl` module, such as `OP_NO_SSLv2` which disables the insecure and obsolete SSLv2 protocol.
- The extension now loads all the OpenSSL ciphers and digest algorithms. If some SSL certificates cannot be verified, they are reported as an “unknown algorithm” error.
- The version of OpenSSL being used is now accessible using the module attributes `ssl.OPENSSL_VERSION` (a string), `ssl.OPENSSL_VERSION_INFO` (a 5-tuple), and `ssl.OPENSSL_VERSION_NUMBER` (an integer).

(Contributed by Antoine Pitrou in issue 8850, issue 1589, issue 8322, issue 5639, issue 4870, issue 8484, and issue 8321.)

**nntp**

The `nntplib` module has a revamped implementation with better bytes and text semantics as well as more practical APIs. These improvements break compatibility with the nntplib version in Python 3.1, which was partly dysfunctional in itself.

Support for secure connections through both implicit (using `nntplib.NNTP_SSL`) and explicit (using `nntplib.NNTP.starttls()`) TLS has also been added.

(Contributed by Antoine Pitrou in issue 9360 and Andrew Vant in issue 1926.)
certificates

http.client.HTTPSConnection, urllib.request.HTTPSHandler and urllib.request.urlopen() now take optional arguments to allow for server certificate checking against a set of Certificate Authorities, as recommended in public uses of HTTPS.

(Added by Antoine Pitrou, issue 9003.)

imaplib

Support for explicit TLS on standard IMAP4 connections has been added through the new imaplib.IMAP4.starttls method.

(Contributed by Lorenzo M. Catucci and Antoine Pitrou, issue 4471.)

http.client

There were a number of small API improvements in the http.client module. The old-style HTTP 0.9 simple responses are no longer supported and the strict parameter is deprecated in all classes.

The HTTPConnection and HTTPSConnection classes now have a source_address parameter for a (host, port) tuple indicating where the HTTP connection is made from.

Support for certificate checking and HTTPS virtual hosts were added to HTTPSConnection.

The request() method on connection objects allowed an optional
body argument so that a file object could be used to supply the content of the request. Conveniently, the body argument now also accepts an iterable object so long as it includes an explicit Content-Length header. This extended interface is much more flexible than before.

To establish an HTTPS connection through a proxy server, there is a new set_tunnel() method that sets the host and port for HTTP Connect tunneling.

To match the behavior of http.server, the HTTP client library now also encodes headers with ISO-8859-1 (Latin-1) encoding. It was already doing that for incoming headers, so now the behavior is consistent for both incoming and outgoing traffic. (See work by Armin Ronacher in issue 10980.)

unittest

The unittest module has a number of improvements supporting test discovery for packages, easier experimentation at the interactive prompt, new testcase methods, improved diagnostic messages for test failures, and better method names.

- The command-line call python -m unittest can now accept file paths instead of module names for running specific tests (issue 10620). The new test discovery can find tests within packages, locating any test importable from the top-level directory. The top-level directory can be specified with the -t option, a pattern for matching files with -p, and a directory to start discovery with -s:

```bash
$ python -m unittest discover -s my_proj_dir -p
```
Experimentation at the interactive prompt is now easier because the `unittest.case.TestCase` class can now be instantiated without arguments:

```python
>>> TestCase().assertEqual(pow(2, 3), 8)
```

The `unittest` module has two new methods, `assertWarns()` and `assertWarnsRegex()` to verify that a given warning type is triggered by the code under test:

```python
with self.assertWarns(DeprecationWarning):
    legacy_function('XYZ')
```

Another new method, `assertCountEqual()` is used to compare two iterables to determine if their element counts are equal (whether the same elements are present with the same number of occurrences regardless of order):

```python
def test_anagram(self):
    self.assertCountEqual('algorithm', 'logarithm')
```

A principal feature of the `unittest` module is an effort to produce meaningful diagnostics when a test fails. When possible, the failure is recorded along with a diff of the output. This is especially helpful for analyzing log files of failed test runs. However, since
diffs can sometime be voluminous, there is a new `maxDiff` attribute that sets maximum length of diffs displayed.

- In addition, the method names in the module have undergone a number of clean-ups.

For example, `assertRegex()` is the new name for `assertRegexpMatches()` which was misnamed because the test uses `re.search()`, not `re.match()`. Other methods using regular expressions are now named using short form “Regex” in preference to “Regexp” – this matches the names used in other unittest implementations, matches Python’s old name for the `re` module, and it has unambiguous camel-casing.

(Contributed by Raymond Hettinger and implemented by Ezio Melotti.)

- To improve consistency, some long-standing method aliases are being deprecated in favor of the preferred names:

<table>
<thead>
<tr>
<th>Old Name</th>
<th>Preferred Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>assert_()</code></td>
<td><code>assertTrue()</code></td>
</tr>
<tr>
<td><code>assertEquals()</code></td>
<td><code>assertEqual()</code></td>
</tr>
<tr>
<td><code>assertNotEquals()</code></td>
<td><code>assertNotEqual()</code></td>
</tr>
<tr>
<td><code>assertAlmostEquals()</code></td>
<td><code>assertAlmostEqual()</code></td>
</tr>
<tr>
<td><code>assertNotAlmostEquals()</code></td>
<td><code>assertNotAlmostEqual()</code></td>
</tr>
</tbody>
</table>

Likewise, the `TestCase.fail*` methods deprecated in Python 3.1 are expected to be removed in Python 3.3. Also see the `Deprecated aliases` section in the `unittest` documentation.
The `assertDictContainsSubset()` method was deprecated because it was misimplemented with the arguments in the wrong order. This created hard-to-debug optical illusions where tests like `testCase().assertDictContainsSubset({'a':1, 'b':2}, {'a':1})` would fail.

(Contributed by Raymond Hettinger.)

**random**

The integer methods in the `random` module now do a better job of producing uniform distributions. Previously, they computed selections with `int(n*random())` which had a slight bias whenever \( n \) was not a power of two. Now, multiple selections are made from a range up to the next power of two and a selection is kept only when it falls within the range \( 0 \leq x < n \). The functions and methods affected are `randrange()`, `randint()`, `choice()`, `shuffle()` and `sample()`.

(Contributed by Raymond Hettinger; issue 9025.)

**poplib**

`POP3_SSL` class now accepts a `context` parameter, which is a `ssl.SSLContext` object allowing bundling SSL configuration options, certificates and private keys into a single (potentially long-lived) structure.

(Contributed by Giampaolo Rodolà; issue 8807.)

**asyncore**
asyncore.dispatcher now provides a handle_accepted() method returning a (sock, addr) pair which is called when a connection has actually been established with a new remote endpoint. This is supposed to be used as a replacement for old handle_accept() and avoids the user to call accept() directly.

(Contributed by Giampaolo Rodolà; issue 6706.)

tempfile

The tempfile module has a new context manager, TemporaryDirectory which provides easy deterministic cleanup of temporary directories:

```python
with tempfile.TemporaryDirectory() as tmpdirname:
    print('created temporary dir:', tmpdirname)
```

(Contributed by Neil Schemenauer and Nick Coghlan; issue 5178.)

inspect

- The inspect module has a new function getgeneratorstate() to easily identify the current state of a generator-iterator:

```python
>>> from inspect import getgeneratorstate
>>> def gen():
...     yield 'demo'
>>> g = gen()
>>> getgeneratorstate(g)
'GEN_CREATED'
>>> next(g)
```
(Contributed by Rodolpho Eckhardt and Nick Coghlan, issue 10220.)

- To support lookups without the possibility of activating a dynamic attribute, the `inspect` module has a new function, `getattr_static()`. Unlike `hasattr()`, this is a true read-only search, guaranteed not to change state while it is searching:

```python
>>> class A:
    @property
    def f(self):
        print('Running')
        return 10

>>> a = A()
>>> getattr(a, 'f')
Running
10
>>> inspect.getattr_static(a, 'f')
<property object at 0x1022bd788>
```

(Contributed by Michael Foord.)

**pydoc**

The `pydoc` module now provides a much-improved Web server interface, as well as a new command-line option `-b` to automatically
open a browser window to display that server:

```bash
$ pydoc3.2 -b
```

(Contributed by Ron Adam; issue 2001.)

dis

The `dis` module gained two new functions for inspecting code, `code_info()` and `show_code()`. Both provide detailed code object information for the supplied function, method, source code string or code object. The former returns a string and the latter prints it:

```python
>>> import dis, random
>>> dis.show_code(random.choice)
Name:        choice
Filename:    /Library/Frameworks/Python.framework/Versions/3.2/lib/python3.2/random.py
Argument count:  2
Kw-only arguments:  0
Number of locals:  3
Stack size:           11
Flags: OPTIMIZED, NEWLOCALS, NOFREE
Constants:
    0: 'Choose a random element from a non-empty sequence'
    1: 'Cannot choose from an empty sequence'
Names:
    0: _randbelow
    1: len
    2: ValueError
    3: IndexError
Variable names:
    0: self
    1: seq
    2: i
```
In addition, the `dis()` function now accepts string arguments so that the common idiom `dis(compile(s, '', 'eval'))` can be shortened to `dis(s):

```python
>>> dis('3*x+1 if x%2==1 else x//2')
    0 LOAD_NAME              0 (x)
    3 LOAD_CONST            0 (2)
    6 BINARY_MODULO
    7 LOAD_CONST             1 (1)
   10 COMPARE_OP            2 (==)
   13 POP_JUMP_IF_FALSE      28
   16 LOAD_CONST             2 (3)
   19 LOAD_NAME              0 (x)
   22 BINARY_MULTIPLY
   23 LOAD_CONST             1 (1)
   26 BINARY_ADD
   27 RETURN_VALUE

>>> 28 LOAD_NAME              0 (x)
   31 LOAD_CONST             0 (2)
   34 BINARY_FLOOR_DIVIDE
   35 RETURN_VALUE
```

Taken together, these improvements make it easier to explore how CPython is implemented and to see for yourself what the language syntax does under-the-hood.

(Contributed by Nick Coghlan in issue 9147.)

**dbm**

All database modules now support the `get()` and `setdefault()` methods.

(Suggested by Ray Allen in issue 9523.)
ctypes

A new type, `ctypes.c_ssize_t` represents the C `ssize_t` datatype.

site

The `site` module has three new functions useful for reporting on the details of a given Python installation.

- `getsitepackages()` lists all global site-packages directories.
- `getuserbase()` reports on the user's base directory where data can be stored.
- `getusersitepackages()` reveals the user-specific site-packages directory path.

```python
>>> import site
>>> site.getsitepackages()
['/Library/Frameworks/Python.framework/Versions/3.2/lib/python3.2/site-packages',
 '/Library/Frameworks/Python.framework/Versions/3.2/lib/site-python',
 '/Library/Python/3.2/site-packages']
>>> site.getuserbase()
'/Users/raymondhettinger/Library/Python/3.2'
>>> site.getusersitepackages()
'/Users/raymondhettinger/Library/Python/3.2/lib/python/site-packages'
```

Conveniently, some of site's functionality is accessible directly from the command-line:

```bash
$ python -m site --user-base
/Users/raymondhettinger/.local
$ python -m site --user-site
/Users/raymondhettinger/.local/lib/python3.2/site-packages
```
(Contributed by Tarek Ziadé in issue 6693.)

sysconfig

The new `sysconfig` module makes it straightforward to discover installation paths and configuration variables that vary across platforms and installations.

The module offers access simple access functions for platform and version information:

- `get_platform()` returning values like `linux-i586` or `macosx-10.6-ppc`.
- `get_python_version()` returns a Python version string such as "3.2".

It also provides access to the paths and variables corresponding to one of seven named schemes used by `distutils`. Those include `posix_prefix`, `posix_home`, `posix_user`, `nt`, `nt_user`, `os2`, `os2_home`:

- `get_paths()` makes a dictionary containing installation paths for the current installation scheme.
- `get_config_vars()` returns a dictionary of platform specific variables.

There is also a convenient command-line interface:

```
C:\Python32>python -m sysconfig
Platform: "win32"
Python version: "3.2"
Current installation scheme: "nt"

Paths:
```
data = "C:\Python32"
include = "C:\Python32\Include"
platinclude = "C:\Python32\Include"
platlib = "C:\Python32\Lib\site-packages"
platstdlib = "C:\Python32\Lib"
purelib = "C:\Python32\Lib\site-packages"
scripts = "C:\Python32\Scripts"
stdlib = "C:\Python32\Lib"

Variables:
BINDIR = "C:\Python32"
BINLIBDEST = "C:\Python32\Lib"
EXE = ".exe"
INCLUDEPY = "C:\Python32\Include"
LIBDEST = "C:\Python32\Lib"
SO = ".pyd"
VERSION = "32"
abiflags = ""
base = "C:\Python32"
exec_prefix = "C:\Python32"
platbase = "C:\Python32"
prefix = "C:\Python32"
projectbase = "C:\Python32"
py_version = "3.2"
py_version_nodot = "32"
py_version_short = "3.2"
srcdir = "C:\Python32"
userbase = "C:\Documents and Settings\Raymond"

(Moved out of Distutils by Tarek Ziade.)

**pdb**

The **pdb** debugger module gained a number of usability improvements:
pdb.py now has a -c option that executes commands as given in a .pdbrc script file.
A .pdbrc script file can contain continue and next commands that continue debugging.
The Pdb class constructor now accepts a nosigint argument.
New commands: l(list), ll(long list) and source for listing source code.
New commands: display and undisplay for showing or hiding the value of an expression if it has changed.
New command: interact for starting an interactive interpreter containing the global and local names found in the current scope.
Breakpoints can be cleared by breakpoint number.

(Contributed by Georg Brandl, Antonio Cuni and Ilya Sandler.)

cfgparser

The configparser module was modified to improve usability and predictability of the default parser and its supported INI syntax. The old ConfigParser class was removed in favor of SafeConfigParser which has in turn been renamed to ConfigParser. Support for inline comments is now turned off by default and section or option duplicates are not allowed in a single configuration source.

Config parsers gained a new API based on the mapping protocol:

```python
>>> parser = ConfigParser()
>>> parser.read_string(""
[DEFAULT]
location = upper left
visible = yes
editable = no
color = blue
```
The new API is implemented on top of the classical API, so custom parser subclasses should be able to use it without modifications.

The INI file structure accepted by config parsers can now be customized. Users can specify alternative option/value delimiters and comment prefixes, change the name of the DEFAULT section or switch the interpolation syntax.

There is support for pluggable interpolation including an additional interpolation handler ExtendedInterpolation:

```python
>>> parser = ConfigParser(interpolation=ExtendedInterpolation)
>>> parser.read_dict({'buildout': {'directory': '/home/ambv/zope9',
                                  'custom': {'prefix': '/usr/local'}})
>>> parser.read_string(""
 [buildout]
```
A number of smaller features were also introduced, like support for specifying encoding in read operations, specifying fallback values for get-functions, or reading directly from dictionaries and strings.

(All changes contributed by Łukasz Langa.)

**urllib.parse**

A number of usability improvements were made for the **urllib.parse** module.
The `urlparse()` function now supports IPv6 addresses as described in RFC 2732:

```python
>>> import urllib.parse
ParseResult(scheme='http',
            path='/foo/',
            params='',
            query='',
            fragment='')
```

The `urldefrag()` function now returns a named tuple:

```python
>>> r = urllib.parse.urldefrag('http://python.org/about/#target')
>>> r
 DefragResult(url='http://python.org/about/', fragment='target')
>>> r[0]
 'http://python.org/about/'
>>> r.fragment
 'target'
```

And, the `urlencode()` function is now much more flexible, accepting either a string or bytes type for the `query` argument. If it is a string, then the `safe`, `encoding`, and `error` parameters are sent to `quote_plus()` for encoding:

```python
>>> urlparseurlencode([('type', 'telenovela'),
                       ('name', '¿Dónde Está Elisa?')],
                       encoding='latin-1')
'type=telenovela&name=%BFD%E3nde+Est%E1+Elisa%3F'
```
As detailed in Parsing ASCII Encoded Bytes, all the `urllib.parse` functions now accept ASCII-encoded byte strings as input, so long as they are not mixed with regular strings. If ASCII-encoded byte strings are given as parameters, the return types will also be an ASCII-encoded byte strings:

```python
>>> urllib.parse.urlparse(b'http://www.python.org:80/about/
ParseResultBytes(scheme=b'http', netloc=b'www.python.org:80',
    path=b'/about/', params=b'', query=)

(Work by Nick Coghlan, Dan Mahn, and Senthil Kumaran in issue 2987, issue 5468, and issue 9873.)

mailbox

Thanks to a concerted effort by R. David Murray, the `mailbox` module has been fixed for Python 3.2. The challenge was that mailbox had been originally designed with a text interface, but email messages are best represented with `bytes` because various parts of a message may have different encodings.

The solution harnessed the `email` package's binary support for parsing arbitrary email messages. In addition, the solution required a number of API changes.

As expected, the `add()` method for `mailbox.Mailbox` objects now accepts binary input.

`StringIO` and text file input are deprecated. Also, string input will fail early if non-ASCII characters are used. Previously it would fail when the email was processed in a later step.
There is also support for binary output. The `get_file()` method now returns a file in the binary mode (where it used to incorrectly set the file to text-mode). There is also a new `get_bytes()` method that returns a `bytes` representation of a message corresponding to a given `key`.

It is still possible to get non-binary output using the old API's `get_string()` method, but that approach is not very useful. Instead, it is best to extract messages from a `Message` object or to load them from binary input.

(Contributed by R. David Murray, with efforts from Steffen Daode Nurpmeso and an initial patch by Victor Stinner in issue 9124.)

**turtledemo**

The demonstration code for the `turtle` module was moved from the `Demo` directory to main library. It includes over a dozen sample scripts with lively displays. Being on `sys.path`, it can now be run directly from the command-line:

```
$ python -m turtledemo
```

(Moved from the Demo directory by Alexander Belopolsky in issue 10199.)
Multi-threading

- The mechanism for serializing execution of concurrently running Python threads (generally known as the **GIL** or **Global Interpreter Lock**) has been rewritten. Among the objectives were more predictable switching intervals and reduced overhead due to lock contention and the number of ensuing system calls. The notion of a “check interval” to allow thread switches has been abandoned and replaced by an absolute duration expressed in seconds. This parameter is tunable through `sys.setswitchinterval()`. It currently defaults to 5 milliseconds.

  Additional details about the implementation can be read from a [python-dev mailing-list message](https://mail.python.org/pipermail/python-dev/2005-February/) (however, “priority requests” as exposed in this message have not been kept for inclusion).

  (Contributed by Antoine Pitrou.)

- Regular and recursive locks now accept an optional `timeout` argument to their `acquire()` method. (Contributed by Antoine Pitrou; [issue 7316](https://bugs.python.org/issue7316).)

- Similarly, `threading.Semaphore.acquire()` also gained a `timeout` argument. (Contributed by Torsten Landschoff; [issue 850728](https://bugs.python.org/issue850728).)

- Regular and recursive lock acquisitions can now be interrupted by signals on platforms using Pthreads. This means that Python programs that deadlock while acquiring locks can be successfully killed by repeatedly sending SIGINT to the process (by pressing `Ctrl+C` in most shells). (Contributed by Reid Kleckner; [issue 8844](https://bugs.python.org/issue8844).)
Optimizations

A number of small performance enhancements have been added:

- Python's peephole optimizer now recognizes patterns such as `x in {1, 2, 3}` as being a test for membership in a set of constants. The optimizer recasts the `set` as a `frozenset` and stores the pre-built constant.

Now that the speed penalty is gone, it is practical to start writing membership tests using set-notation. This style is both semantically clear and operationally fast:

```python
extension = name.rpartition('.' )[2]
if extension in { 'xml', 'html', 'xhtml', 'css' }:
    handle(name)
```

(Patch and additional tests contributed by Dave Malcolm; issue 6690).

- Serializing and unserializing data using the `pickle` module is now several times faster.

  (Contributed by Alexandre Vassalotti, Antoine Pitrou and the Unladen Swallow team in issue 9410 and issue 3873.)

- The `Timsort algorithm` used in `list.sort()` and `sorted()` now runs faster and uses less memory when called with a `key function`. Previously, every element of a list was wrapped with a temporary object that remembered the key value associated with each element. Now, two arrays of keys and values are sorted in parallel. This saves the memory consumed by the sort wrappers,
and it saves time lost to delegating comparisons.

(Patch by Daniel Stutzbach in issue 9915.)

- JSON decoding performance is improved and memory consumption is reduced whenever the same string is repeated for multiple keys. Also, JSON encoding now uses the C speedups when the sort_keys argument is true.

  (Contributed by Antoine Pitrou in issue 7451 and by Raymond Hettinger and Antoine Pitrou in issue 10314.)

- Recursive locks (created with the `threading.RLock()` API) now benefit from a C implementation which makes them as fast as regular locks, and between 10x and 15x faster than their previous pure Python implementation.

  (Contributed by Antoine Pitrou; issue 3001.)

- The fast-search algorithm in stringlib is now used by the `split()`, `rsplit()`, `splitlines()` and `replace()` methods on `bytes`, `bytearray` and `str` objects. Likewise, the algorithm is also used by `rfind()`, `rindex()`, `rsplit()` and `rpartition()`.

  (Patch by Florent Xicluna in issue 7622 and issue 7462.)

- Integer to string conversions now work two “digits” at a time, reducing the number of division and modulo operations.

  (issue 6713 by Gawain Bolton, Mark Dickinson, and Victor Stinner.)

There were several other minor optimizations. Set differencing now
runs faster when one operand is much larger than the other (patch by Andress Bennetts in issue 8685). The `array.repeat()` method has a faster implementation (issue 1569291 by Alexander Belopolsky). The `BaseHTTPRequestHandler` has more efficient buffering (issue 3709 by Andrew Schaaf). The `operator.attrgetter()` function has been sped-up (issue 10160 by Christos Georgiou). And `ConfigParser` loads multi-line arguments a bit faster (issue 7113 by Łukasz Langa).
Unicode

Python has been updated to Unicode 6.0.0. The update to the standard adds over 2,000 new characters including emoji symbols which are important for mobile phones.

In addition, the updated standard has altered the character properties for two Kannada characters (U+0CF1, U+0CF2) and one New Tai Lue numeric character (U+19DA), making the former eligible for use in identifiers while disqualifying the latter. For more information, see Unicode Character Database Changes.
Codecs

Support was added for cp720 Arabic DOS encoding (issue 1616979).

MBCS encoding no longer ignores the error handler argument. In the default strict mode, it raises an `UnicodeDecodeError` when it encounters an undecodable byte sequence and an `UnicodeEncodeError` for an unencodable character.

The MBCS codec supports 'strict' and 'ignore' error handlers for decoding, and 'strict' and 'replace' for encoding.

To emulate Python3.1 MBCS encoding, select the 'ignore' handler for decoding and the 'replace' handler for encoding.

On Mac OS X, Python decodes command line arguments with 'utf-8' rather than the locale encoding.

By default, `tarfile` uses 'utf-8' encoding on Windows (instead of 'mbcs') and the 'surrogateescape' error handler on all operating systems.
Documentation

The documentation continues to be improved.

- A table of quick links has been added to the top of lengthy sections such as Built-in Functions. In the case of itertools, the links are accompanied by tables of cheatsheet-style summaries to provide an overview and memory jog without having to read all of the docs.

- In some cases, the pure Python source code can be a helpful adjunct to the documentation, so now many modules now feature quick links to the latest version of the source code. For example, the functools module documentation has a quick link at the top labeled:

  Source code Lib/functools.py.

  (Contributed by Raymond Hettinger; see rationale.)

- The docs now contain more examples and recipes. In particular, re module has an extensive section, Regular Expression Examples. Likewise, the itertools module continues to be updated with new Itertools Recipes.

- The datetime module now has an auxiliary implementation in pure Python. No functionality was changed. This just provides an easier-to-read alternate implementation.

  (Contributed by Alexander Belopolsky in issue 9528.)

- The unmaintained Demo directory has been removed. Some demos were integrated into the documentation, some were moved
to the Tools/demo directory, and others were removed altogether.

(Contributed by Georg Brandl in issue 7962.)
IDLE

- The format menu now has an option to clean source files by stripping trailing whitespace.

  (Contributed by Raymond Hettinger; issue 5150.)

- IDLE on Mac OS X now works with both Carbon AquaTk and Cocoa AquaTk.

  (Contributed by Kevin Walzer, Ned Deily, and Ronald Oussoren; issue 6075.)
In addition to the existing Subversion code repository at http://svn.python.org there is now a Mercurial repository at https://hg.python.org/.

After the 3.2 release, there are plans to switch to Mercurial as the primary repository. This distributed version control system should make it easier for members of the community to create and share external changesets. See PEP 385 for details.

To learn to use the new version control system, see the tutorial by Joel Spolsky or the Guide to Mercurial Workflows.
Build and C API Changes

Changes to Python’s build process and to the C API include:

- The idle, pydoc and 2to3 scripts are now installed with a version-specific suffix on make altinstall (issue 10679).

- The C functions that access the Unicode Database now accept and return characters from the full Unicode range, even on narrow unicode builds (Py_UNICODE_TOLOWER, Py_UNICODE_ISDECIMAL, and others). A visible difference in Python is that unicodedata.numeric() now returns the correct value for large code points, and repr() may consider more characters as printable.

  (Reported by Bupjoe Lee and fixed by Amaury Forgeot D'Arc; issue 5127.)

- Computed gotos are now enabled by default on supported compilers (which are detected by the configure script). They can still be disabled selectively by specifying --without-computed-gotos.

  (Contributed by Antoine Pitrou; issue 9203.)

- The option --with-wctype-functions was removed. The built-in unicode database is now used for all functions.

  (Contributed by Amaury Forgeot D'Arc; issue 9210.)

- Hash values are now values of a new type, Py_hash_t, which is defined to be the same size as a pointer. Previously they were of type long, which on some 64-bit operating systems is still only 32
bits long. As a result of this fix, `set` and `dict` can now hold more than $2^{**32}$ entries on builds with 64-bit pointers (previously, they could grow to that size but their performance degraded catastrophically).

(Suggested by Raymond Hettinger and implemented by Benjamin Peterson; issue 9778.)

- A new macro `Py_VA_COPY` copies the state of the variable argument list. It is equivalent to C99 `va_copy` but available on all Python platforms (issue 2443).

- A new C API function `PySys_SetArgvEx()` allows an embedded interpreter to set `sys.argv` without also modifying `sys.path` (issue 5753).

- `PyEval_CallObject` is now only available in macro form. The function declaration, which was kept for backwards compatibility reasons, is now removed – the macro was introduced in 1997 (issue 8276).

- There is a new function `PyLong_AsLongLongAndOverflow()` which is analogous to `PyLong_AsLongAndOverflow()`. They both serve to convert Python `int` into a native fixed-width type while providing detection of cases where the conversion won’t fit (issue 7767).

- The `PyUnicode_CompareWithASCIIString()` function now returns `not equal` if the Python string is `NUL` terminated.

- There is a new function `PyErr_NewExceptionWithDoc()` that is like `PyErr_NewException()` but allows a docstring to be specified. This lets C exceptions have the same self-documenting
capabilities as their pure Python counterparts (issue 7033).

- When compiled with the --with-valgrind option, the pymalloc allocator will be automatically disabled when running under Valgrind. This gives improved memory leak detection when running under Valgrind, while taking advantage of pymalloc at other times (issue 2422).

- Removed the 0? format from the PyArg_Parse functions. The format is no longer used and it had never been documented (issue 8837).

There were a number of other small changes to the C-API. See the Misc/NEWS file for a complete list.

Also, there were a number of updates to the Mac OS X build, see Mac/BuildScript/README.txt for details. For users running a 32/64-bit build, there is a known problem with the default Tcl/Tk on Mac OS X 10.6. Accordingly, we recommend installing an updated alternative such as ActiveState Tcl/Tk 8.5.9. See https://www.python.org/download/mac/tcltk/ for additional details.
Porting to Python 3.2

This section lists previously described changes and other bugfixes that may require changes to your code:

- The `configparser` module has a number of clean-ups. The major change is to replace the old ConfigParser class with long-standing preferred alternative SafeConfigParser. In addition there are a number of smaller incompatibilities:
  - The interpolation syntax is now validated on `get()` and `set()` operations. In the default interpolation scheme, only two tokens with percent signs are valid: `%(name)s` and `%%`, the latter being an escaped percent sign.
  - The `set()` and `add_section()` methods now verify that values are actual strings. Formerly, unsupported types could be introduced unintentionally.
  - Duplicate sections or options from a single source now raise either `DuplicateSectionError` or `DuplicateOptionError`. Formerly, duplicates would silently overwrite a previous entry.
  - Inline comments are now disabled by default so now the `;` character can be safely used in values.
  - Comments now can be indented. Consequently, for `;` or `#` to appear at the start of a line in multiline values, it has to be interpolated. This keeps comment prefix characters in values from being mistaken as comments.
  - `""` is now a valid value and is no longer automatically converted to an empty string. For empty strings, use "option =" in a line.
- The `ntplib` module was reworked extensively, meaning that its APIs are often incompatible with the 3.1 APIs.
- **bytearray** objects can no longer be used as filenames; instead, they should be converted to **bytes**.

- The `array.tostring()` and `array.fromstring()` have been renamed to `array.tobytes()` and `array.frombytes()` for clarity. The old names have been deprecated. (See issue 8990.)

- **PyArg_Parse**\*() functions:
  - “t#” format has been removed: use “s#” or “s\*” instead
  - “w” and “w#” formats has been removed: use “w\*” instead

- The PyCObject type, deprecated in 3.1, has been removed. To wrap opaque C pointers in Python objects, the PyCapsule API should be used instead; the new type has a well-defined interface for passing typing safety information and a less complicated signature for calling a destructor.

- The `sys.setfilesystemencoding()` function was removed because it had a flawed design.

- The `random.seed()` function and method now salt string seeds with an sha512 hash function. To access the previous version of seed in order to reproduce Python 3.1 sequences, set the `version` argument to 1, `random.seed(s, version=1)`.

- The previously deprecated `string.maketrans()` function has been removed in favor of the static methods `bytes.maketrans()` and `bytearray.maketrans()`. This change solves the confusion around which types were supported by the `string` module. Now, `str`, `bytes`, and `bytearray` each have their own **maketrans** and **translate** methods with intermediate translation tables of the appropriate type.
The previously deprecated `contextlib.nested()` function has been removed in favor of a plain `with` statement which can accept multiple context managers. The latter technique is faster (because it is built-in), and it does a better job finalizing multiple context managers when one of them raises an exception:

```python
with open('mylog.txt') as infile, open('a.out', 'w') as outfile:
    for line in infile:
        if '<critical>' in line:
            outfile.write(line)
```

(Contributed by Georg Brandl and Mattias Brändström; appspot issue 53094.)

`struct.pack()` now only allows bytes for the `s` string pack code. Formerly, it would accept text arguments and implicitly encode them to bytes using UTF-8. This was problematic because it made assumptions about the correct encoding and because a variable-length encoding can fail when writing to fixed length segment of a structure.

Code such as `struct.pack('<6sHHBBB', 'GIF87a', x, y)` should be rewritten to use bytes instead of text, `struct.pack('<6sHHBBB', b'GIF87a', x, y)`.

(Discovered by David Beazley and fixed by Victor Stinner; issue 10783.)


(Contributed by Georg Brandl; issue 5675.)
- The new, longer `str()` value on floats may break doctests which rely on the old output format.

- In `subprocess.Popen`, the default value for `close_fds` is now `True` under Unix; under Windows, it is `True` if the three standard streams are set to `None`, `False` otherwise. Previously, `close_fds` was always `False` by default, which produced difficult to solve bugs or race conditions when open file descriptors would leak into the child process.

- Support for legacy HTTP 0.9 has been removed from `urllib.request` and `http.client`. Such support is still present on the server side (in `http.server`).

  (Contributed by Antoine Pitrou, issue 10711.)

- SSL sockets in timeout mode now raise `socket.timeout` when a timeout occurs, rather than a generic `SSLError`.

  (Contributed by Antoine Pitrou, issue 10272.)

- The misleading functions `PyEval_AcquireLock()` and `PyEval_ReleaseLock()` have been officially deprecated. The thread-state aware APIs (such as `PyEval_SaveThread()` and `PyEval_RestoreThread()`) should be used instead.

- Due to security risks, `asyncore.handle_accept()` has been deprecated, and a new function, `asyncore.handle_accepted()`, was added to replace it.

  (Contributed by Giampaolo Rodola in issue 6706.)

- Due to the new GIL implementation, `PyEval_InitThreads()`
cannot be called before \texttt{Py\_Initialize()} anymore.
What’s New In Python 3.1

Author: Raymond Hettinger

This article explains the new features in Python 3.1, compared to 3.0.
PEP 372: Ordered Dictionaries

Regular Python dictionaries iterate over key/value pairs in arbitrary order. Over the years, a number of authors have written alternative implementations that remember the order that the keys were originally inserted. Based on the experiences from those implementations, a new `collections.OrderedDict` class has been introduced.

The OrderedDict API is substantially the same as regular dictionaries but will iterate over keys and values in a guaranteed order depending on when a key was first inserted. If a new entry overwrites an existing entry, the original insertion position is left unchanged. Deleting an entry and reinserting it will move it to the end.

The standard library now supports use of ordered dictionaries in several modules. The `configparser` module uses them by default. This lets configuration files be read, modified, and then written back in their original order. The `asdict()` method for `collections.namedtuple()` now returns an ordered dictionary with the values appearing in the same order as the underlying tuple indices. The `json` module is being built-out with an `object_pairs_hook` to allow OrderedDicts to be built by the decoder. Support was also added for third-party tools like PyYAML.

See also:

**PEP 372 - Ordered Dictionaries**

PEP written by Armin Ronacher and Raymond Hettinger. Implementation written by Raymond Hettinger.
PEP 378: Format Specifier for Thousands Separator

The built-in `format()` function and the `str.format()` method use a mini-language that now includes a simple, non-locale aware way to format a number with a thousands separator. That provides a way to humanize a program's output, improving its professional appearance and readability:

```python
>>> format(1234567, ',d')
'1,234,567'
>>> format(1234567.89, ',.2f')
'1,234,567.89'
>>> format(12345.6 + 8901234.12j, ',f')
'12,345.600000+8,901,234.120000j'
>>> format(Decimal('1234567.89'), ',f')
'1,234,567.89'
```

The supported types are `int`, `float`, `complex` and `decimal.Decimal`.

Discussions are underway about how to specify alternative separators like dots, spaces, apostrophes, or underscores. Locale-aware applications should use the existing `n` format specifier which already has some support for thousands separators.

See also:

**PEP 378 - Format Specifier for Thousands Separator**

PEP written by Raymond Hettinger and implemented by Eric Smith and Mark Dickinson.
Other Language Changes

Some smaller changes made to the core Python language are:

- Directories and zip archives containing a `__main__.py` file can now be executed directly by passing their name to the interpreter. The directory/zipfile is automatically inserted as the first entry in `sys.path`. (Suggestion and initial patch by Andy Chu; revised patch by Phillip J. Eby and Nick Coghlan; issue 1739468.)

- The `int()` type gained a `bit_length` method that returns the number of bits necessary to represent its argument in binary:

  ```
  >>> n = 37
  >>> bin(37)
  '0b100101'
  >>> n.bit_length()
  6
  >>> n = 2**123-1
  >>> n.bit_length()
  123
  >>> (n+1).bit_length()
  124
  ```

  (Contributed by Fredrik Johansson, Victor Stinner, Raymond Hettinger, and Mark Dickinson; issue 3439.)

- The fields in `format()` strings can now be automatically numbered:

  ```
  >>> 'Sir {} of {}'.format('Gallahad', 'Camelot')
  'Sir Gallahad of Camelot'
  ```
Formerly, the string would have required numbered fields such as: 'Sir {0} of {1}'.

(Contributed by Eric Smith; issue 5237.)

- The string.maketrans() function is deprecated and is replaced by new static methods, bytes.maketrans() and bytearray.maketrans(). This change solves the confusion around which types were supported by the string module. Now, str, bytes, and bytearray each have their own maketrans and translate methods with intermediate translation tables of the appropriate type.

  (Contributed by Georg Brandl; issue 5675.)

- The syntax of the with statement now allows multiple context managers in a single statement:

  ```
  >>> with open('mylog.txt') as infile, open('a.out', 'w') as outfile:
  ...     for line in infile:
  ...         if '<critical>' in line:
  ...             outfile.write(line)
  ```

  With the new syntax, the contextlib.nested() function is no longer needed and is now deprecated.

  (Contributed by Georg Brandl and Mattias Brändström;.appspot issue 53094.)

- round(x, n) now returns an integer if x is an integer. Previously it returned a float:

  ```
  >>> round(1123, -2)
  ```
Python now uses David Gay's algorithm for finding the shortest floating point representation that doesn't change its value. This should help mitigate some of the confusion surrounding binary floating point numbers.

The significance is easily seen with a number like 1.1 which does not have an exact equivalent in binary floating point. Since there is no exact equivalent, an expression like `float('1.1')` evaluates to the nearest representable value which is 0x1.1999999999999ap+0 in hex or 1.100000000000000000008881784197001252323389053344726 in decimal. That nearest value was and still is used in subsequent floating point calculations.

What is new is how the number gets displayed. Formerly, Python used a simple approach. The value of `repr(1.1)` was computed as `format(1.1, '.17g')` which evaluated to '1.10000000000000001'. The advantage of using 17 digits was that it relied on IEEE-754 guarantees to assure that `eval(repr(1.1))` would round-trip exactly to its original value. The disadvantage is that many people found the output to be confusing (mistaking intrinsic limitations of binary floating point representation as being a problem with Python itself).

The new algorithm for `repr(1.1)` is smarter and returns '1.1'. Effectively, it searches all equivalent string representations (ones that get stored with the same underlying float value) and returns the shortest representation.
The new algorithm tends to emit cleaner representations when possible, but it does not change the underlying values. So, it is still the case that $1.1 + 2.2 \neq 3.3$ even though the representations may suggest otherwise.

The new algorithm depends on certain features in the underlying floating point implementation. If the required features are not found, the old algorithm will continue to be used. Also, the text pickle protocols assure cross-platform portability by using the old algorithm.

(Contributed by Eric Smith and Mark Dickinson; issue 1580)
New, Improved, and Deprecated Modules

- Added a `collections.Counter` class to support convenient counting of unique items in a sequence or iterable:

  ```
  >>> Counter(['red', 'blue', 'red', 'green', 'blue'])
  Counter({'blue': 3, 'red': 2, 'green': 1})
  ```

  (Contributed by Raymond Hettinger; issue 1696199.)

- Added a new module, `tkinter.ttk` for access to the Tk themed widget set. The basic idea of ttk is to separate, to the extent possible, the code implementing a widget's behavior from the code implementing its appearance.

  (Contributed by Guilherme Polo; issue 2983.)

- The `gzip.GzipFile` and `bz2.BZ2File` classes now support the context management protocol:

  ```
  >>> # Automatically close file after writing
  >>> with gzip.GzipFile(filename, "wb") as f:
  ...     f.write(b"xxx")
  ```

  (Contributed by Antoine Pitrou.)

- The `decimal` module now supports methods for creating a decimal object from a binary `float`. The conversion is exact but can sometimes be surprising:

  ```
  >>> Decimal.from_float(1.1)
  Decimal('1.10000000000000008881784197001252323389179321875')
  ```
The long decimal result shows the actual binary fraction being stored for $1.1$. The fraction has many digits because $1.1$ cannot be exactly represented in binary.

(Contributed by Raymond Hettinger and Mark Dickinson.)

- The `itertools` module grew two new functions. The `itertools.combinations_with_replacement()` function is one of four for generating combinatorics including permutations and Cartesian products. The `itertools.compress()` function mimics its namesake from APL. Also, the existing `itertools.count()` function now has an optional `step` argument and can accept any type of counting sequence including `fractions.Fraction` and `decimal.Decimal`:

```
>>> [p+q for p,q in combinations_with_replacement(['LL', 'LO', 'LV', 'LE', 'OO', 'OV', 'OE', 'VV'],
       [2, 3, 5, 7])
>>> list(compress(data=range(10), selectors=[0, 0, 2, 3, 5, 7])
>>> c = count(start=Fraction(1,2), step=Fraction(1,3))
>>> [next(c), next(c), next(c)]
[Fraction(1, 2), Fraction(2, 3), Fraction(5, 6),
```

(Contributed by Raymond Hettinger.)

- `collections.namedtuple()` now supports a keyword argument `rename` which lets invalid fieldnames be automatically converted to positional names in the form _0, _1, etc. This is useful when the field names are being created by an external source such as a CSV header, SQL field list, or user input:
```python
>>> query = input()
SELECT region, dept, count(*) FROM main GROUP BY region, dept
```
```python
>>> cursor.execute(query)
>>> query_fields = [desc[0] for desc in cursor.description]
>>> UserQuery = namedtuple('UserQuery', query_fields)
>>> pprint.pprint([UserQuery(*row) for row in cursor])
[UserQuery(region='South', dept='Shipping', _2=185),
 UserQuery(region='North', dept='Accounting', _2=37),
 UserQuery(region='West', dept='Sales', _2=419)]
```
(Contributed by Raymond Hettinger; issue 1818.)

- The `re.sub()`, `re.subn()` and `re.split()` functions now accept a flags parameter.

(Contributed by Gregory Smith.)

- The `logging` module now implements a simple `logging.NullHandler` class for applications that are not using logging but are calling library code that does. Setting-up a null handler will suppress spurious warnings such as “No handlers could be found for logger foo”:

```python
>>> h = logging.NullHandler()
>>> logging.getLogger("foo").addHandler(h)
```
(Contributed by Vinay Sajip; issue 4384).

- The `runpy` module which supports the `-m` command line switch now supports the execution of packages by looking for and executing a `__main__` submodule when a package name is supplied.
The `pdb` module can now access and display source code loaded via `zipimport` (or any other conformant PEP 302 loader).

The `functools.partial` objects can now be pickled.

Add `pydoc` help topics for symbols so that `help('@')` works as expected in the interactive environment.

The `unittest` module now supports skipping individual tests or classes of tests. And it supports marking a test as an expected failure, a test that is known to be broken, but shouldn't be counted as a failure on a TestResult:

```python
class TestGizmo(unittest.TestCase):
    @unittest.skipUnless(sys.platform.startswith('win'))
    def test_gizmo_on_windows(self):
        ...

    @unittest.expectedFailure
    def test_gizmo_without_required_library(self):
        ...
```

Also, tests for exceptions have been builtout to work with context managers using the `with` statement:
```python
def test_division_by_zero(self):
    with self.assertRaises(ZeroDivisionError):
        x / 0
```

In addition, several new assertion methods were added including `assertSetEqual()`, `assertDictEqual()`, `assertDictContainsSubset()`, `assertListEqual()`, `assertTupleEqual()`, `assertSequenceEqual()`, `assertRaisesRegexp()`, `assertIsNone()`, and `assertIsNotNone()`.

(Contributed by Benjamin Peterson and Antoine Pitrou.)

- The `io` module has three new constants for the `seek()` method: `SEEK_SET`, `SEEK_CUR`, and `SEEK_END`.

- The `sys.version_info` tuple is now a named tuple:

```python
>>> sys.version_info
sys.version_info(major=3, minor=1, micro=0, releaselevel='alpha', serial=2)
```

(Contributed by Ross Light; issue 4285.)

- The `nntplib` and `imaplib` modules now support IPv6.

(Contributed by Derek Morr; issue 1655 and issue 1664.)

- The `pickle` module has been adapted for better interoperability with Python 2.x when used with protocol 2 or lower. The reorganization of the standard library changed the formal reference for many objects. For example, `__builtin__.set` in Python 2 is called `builtins.set` in Python 3. This change confounded efforts to share data between different versions of
Python. But now when protocol 2 or lower is selected, the pickler will automatically use the old Python 2 names for both loading and dumping. This remapping is turned-on by default but can be disabled with the `fix_imports` option:

```python
>>> s = {1, 2, 3}
>>> pickle.dumps(s, protocol=0)
b'c__builtin__\nset\np0\n((lp1\nL1L\naL2L\naL3L\n)
>>> pickle.dumps(s, protocol=0, fix_imports=False)
b'cbuiltins\nset\np0\n((lp1\nL1L\naL2L\naL3L\natp2\nRp3
.
```

An unfortunate but unavoidable side-effect of this change is that protocol 2 pickles produced by Python 3.1 won’t be readable with Python 3.0. The latest pickle protocol, protocol 3, should be used when migrating data between Python 3.x implementations, as it doesn’t attempt to remain compatible with Python 2.x.

(Contributed by Alexandre Vassalotti and Antoine Pitrou, issue 6137.)

- A new module, `importlib` was added. It provides a complete, portable, pure Python reference implementation of the `import` statement and its counterpart, the `__import__()` function. It represents a substantial step forward in documenting and defining the actions that take place during imports.

(Contributed by Brett Cannon.)
Optimizations

Major performance enhancements have been added:

- The new I/O library (as defined in PEP 3116) was mostly written in Python and quickly proved to be a problematic bottleneck in Python 3.0. In Python 3.1, the I/O library has been entirely rewritten in C and is 2 to 20 times faster depending on the task at hand. The pure Python version is still available for experimentation purposes through the _pyio module.

  (Contributed by Amaury Forgeot d'Arc and Antoine Pitrou.)

- Added a heuristic so that tuples and dicts containing only untrackable objects are not tracked by the garbage collector. This can reduce the size of collections and therefore the garbage collection overhead on long-running programs, depending on their particular use of datatypes.

  (Contributed by Antoine Pitrou, issue 4688.)

- Enabling a configure option named --with-computed-gotos on compilers that support it (notably: gcc, SunPro, icc), the bytecode evaluation loop is compiled with a new dispatch mechanism which gives speedups of up to 20%, depending on the system, the compiler, and the benchmark.

  (Contributed by Antoine Pitrou along with a number of other participants, issue 4753).

- The decoding of UTF-8, UTF-16 and LATIN-1 is now two to four times faster.
The `json` module now has a C extension to substantially improve its performance. In addition, the API was modified so that `json` works only with `str`, not with `bytes`. That change makes the module closely match the JSON specification which is defined in terms of Unicode.

Unpickling now interns the attribute names of pickled objects. This saves memory and allows pickles to be smaller.
IDLE

- IDLE's format menu now provides an option to strip trailing whitespace from a source file.

  (Contributed by Roger D. Serwy; issue 5150.)
Build and C API Changes

Changes to Python’s build process and to the C API include:

- Integers are now stored internally either in base 2**15 or in base 2**30, the base being determined at build time. Previously, they were always stored in base 2**15. Using base 2**30 gives significant performance improvements on 64-bit machines, but benchmark results on 32-bit machines have been mixed. Therefore, the default is to use base 2**30 on 64-bit machines and base 2**15 on 32-bit machines; on Unix, there’s a new configure option --enable-big-digits that can be used to override this default.

Apart from the performance improvements this change should be invisible to end users, with one exception: for testing and debugging purposes there’s a new `sys.int_info` that provides information about the internal format, giving the number of bits per digit and the size in bytes of the C type used to store each digit:

```python
>>> import sys
global sys
>>> sys.int_info
sys.int_info(bits_per_digit=30, sizeof_digit=4)
```

(Contributed by Mark Dickinson; issue 4258.)

- The `PyLong_AsUnsignedLongLong()` function now handles a negative `pylong` by raising `OverflowError` instead of `TypeError`.

(Contributed by Mark Dickinson and Lisandro Dalcrin; issue 5175.)
- Deprecated PyNumber_Int(). Use PyNumber_Long() instead.

  (Contributed by Mark Dickinson; issue 4910.)

- Added a new PyOS_string_to_double() function to replace the deprecated functions PyOS_ascii_strtod() and PyOS_ascii_atof().

  (Contributed by Mark Dickinson; issue 5914.)

- Added PyCapsule as a replacement for the PyCObject API. The principal difference is that the new type has a well defined interface for passing typing safety information and a less complicated signature for calling a destructor. The old type had a problematic API and is now deprecated.

  (Contributed by Larry Hastings; issue 5630.)
Porting to Python 3.1

This section lists previously described changes and other bugfixes that may require changes to your code:

- The new floating point string representations can break existing doctests. For example:

```python
def e():
    '''Compute the base of natural logarithms.'''

    >>> e()
    2.7182818284590451
    
    return sum(1/math.factorial(x) for x in reversed(doctest.testmod())

**********************************************************************
Failed example:
    e()
Expected:
    2.7182818284590451
Got:
    2.718281828459045
**********************************************************************
```

- The automatic name remapping in the pickle module for protocol 2 or lower can make Python 3.1 pickles unreadable in Python 3.0. One solution is to use protocol 3. Another solution is to set the `fix_imports` option to `False`. See the discussion above for more details.
What’s New In Python 3.0

Author: Guido van Rossum

This article explains the new features in Python 3.0, compared to 2.6. Python 3.0, also known as “Python 3000” or “Py3K”, is the first ever intentionally backwards incompatible Python release. There are more changes than in a typical release, and more that are important for all Python users. Nevertheless, after digesting the changes, you’ll find that Python really hasn’t changed all that much – by and large, we’re mostly fixing well-known annoyances and warts, and removing a lot of old cruft.

This article doesn’t attempt to provide a complete specification of all new features, but instead tries to give a convenient overview. For full details, you should refer to the documentation for Python 3.0, and/or the many PEPs referenced in the text. If you want to understand the complete implementation and design rationale for a particular feature, PEPs usually have more details than the regular documentation; but note that PEPs usually are not kept up-to-date once a feature has been fully implemented.

Due to time constraints this document is not as complete as it should have been. As always for a new release, the Misc/NEWS file in the source distribution contains a wealth of detailed information about every small thing that was changed.
Common Stumbling Blocks
This section lists those few changes that are most likely to trip you up
if you’re used to Python 2.5.

Print Is A Function
The print statement has been replaced with a print() function,
with keyword arguments to replace most of the special syntax of the
old print statement (PEP 3105). Examples:
Old: print "The answer is", 2*2
New: print("The answer is", 2*2)
Old: print x,
New: print(x, end=" ")

# Trailing comma suppresses newline
# Appends a space instead of a newli

Old: print
New: print()

# Prints a newline
# You must call the function!

Old: print >>sys.stderr, "fatal error"
New: print("fatal error", file=sys.stderr)
Old: print (x, y)
New: print((x, y))

# prints repr((x, y))
# Not the same as print(x, y)!

You can also customize the separator between items, e.g.:
print("There are <", 2**32, "> possibilities!", sep=

which produces:


There are $<4294967296>$ possibilities!

Note:

- The `print()` function doesn't support the “softspace” feature of the old `print` statement. For example, in Python 2.x, `print "A\n", "B"` would write "A
B
"; but in Python 3.0, `print("A\n", "B")` writes "A
 B
".
- Initially, you'll be finding yourself typing the old `print x` a lot in interactive mode. Time to retrain your fingers to type `print(x)` instead!
- When using the `2to3` source-to-source conversion tool, all `print` statements are automatically converted to `print()` function calls, so this is mostly a non-issue for larger projects.

Views And Iterators Instead Of Lists

Some well-known APIs no longer return lists:

- `dict` methods `dict.keys()`, `dict.items()` and `dict.values()` return “views” instead of lists. For example, this no longer works: `k = d.keys(); k.sort()`. Use `k = sorted(d)` instead (this works in Python 2.5 too and is just as efficient).
- Also, the `dict.iterkeys()`, `dict.iteritems()` and `dict.itervalues()` methods are no longer supported.
- `map()` and `filter()` return iterators. If you really need a list and the input sequences are all of equal length, a quick fix is to wrap `map()` in `list()`, e.g. `list(map(...))`, but a better fix is often to use a list comprehension (especially when the original code
uses **lambda**), or rewriting the code so it doesn't need a list at all. Particularly tricky is **map()** invoked for the side effects of the function; the correct transformation is to use a regular **for** loop (since creating a list would just be wasteful).

If the input sequences are not of equal length, **map()** will stop at the termination of the shortest of the sequences. For full compatibility with **map()** from Python 2.x, also wrap the sequences in **itertools.zip_longest()**, e.g.  
```python
map(func, *sequences)  
```
becomes
```python
list(map(func, itertools.zip_longest(*sequences)))
```

- **range()** now behaves like **xrange()** used to behave, except it works with values of arbitrary size. The latter no longer exists.

- **zip()** now returns an iterator.

### Ordering Comparisons

Python 3.0 has simplified the rules for ordering comparisons:

- The ordering comparison operators (**<**, **<=**, **>=**, **) raise a **TypeError** exception when the operands don’t have a meaningful natural ordering. Thus, expressions like `1 < ''`, `0 > None` or `len <= len` are no longer valid, and e.g. `None < None` raises **TypeError** instead of returning **False**. A corollary is that sorting a heterogeneous list no longer makes sense – all the elements must be comparable to each other. Note that this does not apply to the **==** and **!=** operators: objects of different incomparable types always compare unequal to each other.

- **builtin.sorted()** and **list.sort()** no longer accept the **cmp** argument providing a comparison function. Use the **key**
argument instead. N.B. the key and reverse arguments are now “keyword-only”.

- The cmp() function should be treated as gone, and the __cmp__() special method is no longer supported. Use __lt__() for sorting, __eq__() with __hash__(), and other rich comparisons as needed. (If you really need the cmp() functionality, you could use the expression (a > b) - (a < b) as the equivalent for cmp(a, b).)

Integers

- **PEP 0237**: Essentially, long renamed to int. That is, there is only one built-in integral type, named int; but it behaves mostly like the old long type.
- **PEP 0238**: An expression like 1/2 returns a float. Use 1//2 to get the truncating behavior. (The latter syntax has existed for years, at least since Python 2.2.)
- The sys.maxint constant was removed, since there is no longer a limit to the value of integers. However, sys.maxsize can be used as an integer larger than any practical list or string index. It conforms to the implementation’s “natural” integer size and is typically the same as sys.maxint in previous releases on the same platform (assuming the same build options).
- The repr() of a long integer doesn't include the trailing L anymore, so code that unconditionally strips that character will chop off the last digit instead. (Use str() instead.)
- Octal literals are no longer of the form 0720; use 0o720 instead.

Text Vs. Data Instead Of Unicode Vs. 8-bit

Everything you thought you knew about binary data and Unicode has changed.
Python 3.0 uses the concepts of text and (binary) data instead of Unicode strings and 8-bit strings. All text is Unicode; however encoded Unicode is represented as binary data. The type used to hold text is `str`, the type used to hold data is `bytes`. The biggest difference with the 2.x situation is that any attempt to mix text and data in Python 3.0 raises `TypeError`, whereas if you were to mix Unicode and 8-bit strings in Python 2.x, it would work if the 8-bit string happened to contain only 7-bit (ASCII) bytes, but you would get `UnicodeDecodeError` if it contained non-ASCII values. This value-specific behavior has caused numerous sad faces over the years.

As a consequence of this change in philosophy, pretty much all code that uses Unicode, encodings or binary data most likely has to change. The change is for the better, as in the 2.x world there were numerous bugs having to do with mixing encoded and unencoded text. To be prepared in Python 2.x, start using `unicode` for all unencoded text, and `str` for binary or encoded data only. Then the 2to3 tool will do most of the work for you.

You can no longer use `u"..."` literals for Unicode text. However, you must use `b"..."` literals for binary data.

As the `str` and `bytes` types cannot be mixed, you must always explicitly convert between them. Use `str.encode()` to go from `str` to `bytes`, and `bytes.decode()` to go from `bytes` to `str`. You can also use `bytes(s, encoding=...)` and `str(b, encoding=...)`, respectively.

Like `str`, the `bytes` type is immutable. There is a separate mutable type to hold buffered binary data, `bytearray`. Nearly all APIs that accept `bytes` also accept `bytearray`. The mutable API is based on `collections.MutableSequence`.

All backslashes in raw string literals are interpreted literally. This means that '\U' and '\u' escapes in raw strings are not treated specially. For example, `r'\u20ac'` is a string of 6 characters in Python 3.0, whereas in 2.6, `ur'\u20ac'` was the single “euro”
character. (Of course, this change only affects raw string literals; the euro character is '\u20ac' in Python 3.0.)

- The built-in basestring abstract type was removed. Use str instead. The str and bytes types don’t have functionality enough in common to warrant a shared base class. The 2to3 tool (see below) replaces every occurrence of basestring with str.
- Files opened as text files (still the default mode for open()) always use an encoding to map between strings (in memory) and bytes (on disk). Binary files (opened with a b in the mode argument) always use bytes in memory. This means that if a file is opened using an incorrect mode or encoding, I/O will likely fail loudly, instead of silently producing incorrect data. It also means that even Unix users will have to specify the correct mode (text or binary) when opening a file. There is a platform-dependent default encoding, which on Unixy platforms can be set with the LANG environment variable (and sometimes also with some other platform-specific locale-related environment variables). In many cases, but not all, the system default is UTF-8; you should never count on this default. Any application reading or writing more than pure ASCII text should probably have a way to override the encoding. There is no longer any need for using the encoding-aware streams in the codecs module.
- The initial values of sys.stdin, sys.stdout and sys.stderr are now unicode-only text files (i.e., they are instances of io.TextIOBase). To read and write bytes data with these streams, you need to use their io.TextIOBase.buffer attribute.
- Filenames are passed to and returned from APIs as (Unicode) strings. This can present platform-specific problems because on some platforms filenames are arbitrary byte strings. (On the other hand, on Windows filenames are natively stored as Unicode.) As a work-around, most APIs (e.g. open() and many functions in the os module) that take filenames accept bytes objects as well
as strings, and a few APIs have a way to ask for a `bytes` return value. Thus, `os.listdir()` returns a list of `bytes` instances if the argument is a `bytes` instance, and `os.getcwdb()` returns the current working directory as a `bytes` instance. Note that when `os.listdir()` returns a list of strings, filenames that cannot be decoded properly are omitted rather than raising `UnicodeError`.

- Some system APIs like `os.environ` and `sys.argv` can also present problems when the bytes made available by the system is not interpretable using the default encoding. Setting the LANG variable and rerunning the program is probably the best approach.
- **PEP 3138**: The `repr()` of a string no longer escapes non-ASCII characters. It still escapes control characters and code points with non-printable status in the Unicode standard, however.
- **PEP 3120**: The default source encoding is now UTF-8.
- **PEP 3131**: Non-ASCII letters are now allowed in identifiers. (However, the standard library remains ASCII-only with the exception of contributor names in comments.)
- The `StringIO` and `cStringIO` modules are gone. Instead, import the `io` module and use `io.StringIO` or `io.BytesIO` for text and data respectively.
- See also the [Unicode HOWTO](https://docs.python.org/3/library/unicodedata.html), which was updated for Python 3.0.
Overview Of Syntax Changes

This section gives a brief overview of every syntactic change in Python 3.0.

New Syntax

- **PEP 3107**: Function argument and return value annotations. This provides a standardized way of annotating a function’s parameters and return value. There are no semantics attached to such annotations except that they can be introspected at runtime using the `__annotations__` attribute. The intent is to encourage experimentation through metaclasses, decorators or frameworks.

- **PEP 3102**: Keyword-only arguments. Named parameters occurring after `*args` in the parameter list *must* be specified using keyword syntax in the call. You can also use a bare `*` in the parameter list to indicate that you don’t accept a variable-length argument list, but you do have keyword-only arguments.

- Keyword arguments are allowed after the list of base classes in a class definition. This is used by the new convention for specifying a metaclass (see next section), but can be used for other purposes as well, as long as the metaclass supports it.

- **PEP 3104**: `nonlocal` statement. Using `nonlocal x` you can now assign directly to a variable in an outer (but non-global) scope. `nonlocal` is a new reserved word.

- **PEP 3132**: Extended Iterable Unpacking. You can now write
things like a, b, *rest = some_sequence. And even
*rest, a = stuff. The rest object is always a (possibly
empty) list; the right-hand side may be any iterable. Example:

(a, *rest, b) = range(5)

This sets a to 0, b to 4, and rest to [1, 2, 3].

- Dictionary comprehensions: {k: v for k, v in stuff}
  means the same thing as dict(stuff) but is more flexible.
  (This is PEP 0274 vindicated. :-)

- Set literals, e.g. {1, 2}. Note that {} is an empty dictionary; use
  set() for an empty set. Set comprehensions are also supported;
  e.g., {x for x in stuff} means the same thing as
  set(stuff) but is more flexible.

- New octal literals, e.g. 0o720 (already in 2.6). The old octal
  literals (0720) are gone.

- New binary literals, e.g. 0b1010 (already in 2.6), and there is a
  new corresponding built-in function, bin().

- Bytes literals are introduced with a leading b or B, and there is a
  new corresponding built-in function, bytes().

Changed Syntax

- PEP 3109 and PEP 3134: new raise statement syntax: raise
  [expr [from expr]]. See below.

- as and with are now reserved words. (Since 2.6, actually.)
• True, False, and None are reserved words. (2.6 partially enforced the restrictions on None already.)

• Change from except exc, var to except exc as var. See PEP 3110.

• PEP 3115: New Metaclass Syntax. Instead of:

```python
class C:
    __metaclass__ = M
...
```

you must now use:

```python
class C(metaclass=M):
    ...
```

The module-global __metaclass__ variable is no longer supported. (It was a crutch to make it easier to default to new-style classes without deriving every class from object.)

• List comprehensions no longer support the syntactic form [... for var in item1, item2, ...]. Use [... for var in (item1, item2, ...)] instead. Also note that list comprehensions have different semantics: they are closer to syntactic sugar for a generator expression inside a list() constructor, and in particular the loop control variables are no longer leaked into the surrounding scope.

• The ellipsis (...) can be used as an atomic expression anywhere. (Previously it was only allowed in slices.) Also, it must now be spelled as . . . (Previously it could also be spelled as . . ., by a mere accident of the grammar.)
Removed Syntax

- **PEP 3113**: Tuple parameter unpacking removed. You can no longer write `def foo(a, (b, c)): ....` Use `def foo(a, b_c): b, c = b_c` instead.
- Removed backticks (use `repr()` instead).
- Removed `<>` (use `!=` instead).
- Removed keyword: `exec()` is no longer a keyword; it remains as a function. (Fortunately the function syntax was also accepted in 2.x.) Also note that `exec()` no longer takes a stream argument; instead of `exec(f)` you can use `exec(f.read())`.
- Integer literals no longer support a trailing `l` or `L`.
- String literals no longer support a leading `u` or `U`.
- The `from module import *` syntax is only allowed at the module level, no longer inside functions.
- The only acceptable syntax for relative imports is `from . [module] import name`. All `import` forms not starting with `.` are interpreted as absolute imports. *(PEP 0328)*
- Classic classes are gone.
Changes Already Present In Python 2.6

Since many users presumably make the jump straight from Python 2.5 to Python 3.0, this section reminds the reader of new features that were originally designed for Python 3.0 but that were back-ported to Python 2.6. The corresponding sections in What's New in Python 2.6 should be consulted for longer descriptions.

- **PEP 343: The ‘with’ statement.** The `with` statement is now a standard feature and no longer needs to be imported from the `__future__`. Also check out Writing Context Managers and The `contextlib` module.
- **PEP 366: Explicit Relative Imports From a Main Module.** This enhances the usefulness of the `-m` option when the referenced module lives in a package.
- **PEP 370: Per-user site-packages Directory.**
- **PEP 371: The multiprocessing Package.**
- **PEP 3101: Advanced String Formatting.** Note: the 2.6 description mentions the `format()` method for both 8-bit and Unicode strings. In 3.0, only the `str` type (text strings with Unicode support) supports this method; the `bytes` type does not. The plan is to eventually make this the only API for string formatting, and to start deprecating the `%` operator in Python 3.1.
- **PEP 3105: print As a Function.** This is now a standard feature and no longer needs to be imported from `__future__`. More details were given above.
- **PEP 3110: Exception-Handling Changes.** The `except exc as var` syntax is now standard and `except exc, var` is no longer supported. (Of course, the `as var` part is still optional.)
- **PEP 3112: Byte Literals.** The `b"..."` string literal notation (and its variants like `b'...', b"""..."""", and br"..."`) now produces a literal of type `bytes`. 
- **PEP 3116: New I/O Library.** The `io` module is now the standard way of doing file I/O. The built-in `open()` function is now an alias for `io.open()` and has additional keyword arguments `encoding`, `errors`, `newline` and `closefd`. Also note that an invalid `mode` argument now raises `ValueError`, not `IOError`. The binary file object underlying a text file object can be accessed as `f.buffer` (but beware that the text object maintains a buffer of itself in order to speed up the encoding and decoding operations).

- **PEP 3118: Revised Buffer Protocol.** The old built-in `buffer()` is now really gone; the new built-in `memoryview()` provides (mostly) similar functionality.

- **PEP 3119: Abstract Base Classes.** The `abc` module and the ABCs defined in the `collections` module plays a somewhat more prominent role in the language now, and built-in collection types like `dict` and `list` conform to the `collections.MutableMapping` and `collections.MutableSequence` ABCs, respectively.

- **PEP 3127: Integer Literal Support and Syntax.** As mentioned above, the new octal literal notation is the only one supported, and binary literals have been added.

- **PEP 3129: Class Decorators.**

- **PEP 3141: A Type Hierarchy for Numbers.** The `numbers` module is another new use of ABCs, defining Python’s “numeric tower”. Also note the new `fractions` module which implements `numbers.Rational`. 
Library Changes

Due to time constraints, this document does not exhaustively cover the very extensive changes to the standard library. PEP 3108 is the reference for the major changes to the library. Here’s a capsule review:

- Many old modules were removed. Some, like gopherlib (no longer used) and md5 (replaced by hashlib), were already deprecated by PEP 0004. Others were removed as a result of the removal of support for various platforms such as Irix, BeOS and Mac OS 9 (see PEP 0011). Some modules were also selected for removal in Python 3.0 due to lack of use or because a better replacement exists. See PEP 3108 for an exhaustive list.

- The bsddb3 package was removed because its presence in the core standard library has proved over time to be a particular burden for the core developers due to testing instability and Berkeley DB’s release schedule. However, the package is alive and well, externally maintained at http://www.jcea.es/programacion/pybsddb.htm.

- Some modules were renamed because their old name disobeyed PEP 0008, or for various other reasons. Here’s the list:

<table>
<thead>
<tr>
<th>Old Name</th>
<th>New Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>_winreg</td>
<td>winreg</td>
</tr>
<tr>
<td>ConfigParser</td>
<td>configparser</td>
</tr>
<tr>
<td>copy_reg</td>
<td>copyreg</td>
</tr>
<tr>
<td>Queue</td>
<td>queue</td>
</tr>
<tr>
<td>SocketServer</td>
<td>socketserver</td>
</tr>
</tbody>
</table>
A common pattern in Python 2.x is to have one version of a module implemented in pure Python, with an optional accelerated version implemented as a C extension; for example, pickle and cPickle. This places the burden of importing the accelerated version and falling back on the pure Python version on each user of these modules. In Python 3.0, the accelerated versions are considered implementation details of the pure Python versions. Users should always import the standard version, which attempts to import the accelerated version and falls back to the pure Python version. The pickle / cPickle pair received this treatment. The profile module is on the list for 3.1. The StringIO module has been turned into a class in the io module.

Some related modules have been grouped into packages, and usually the submodule names have been simplified. The resulting new packages are:

- dbm (anydbm, dbhash, dbm, dumbdbm, gdbm, whichdb).
- html (HTMLParser, htmlentitydefs).
- http (httplib, BaseHTTPServer, CGIHTTPServer, SimpleHTTPServer, Cookie, cookielib).
- tkinter (all Tkinter-related modules except turtle). The target audience of turtle doesn’t really care about tkinter. Also note that as of Python 2.6, the functionality of turtle has been greatly enhanced.
- urllib (urllib, urllib2, urlparse, robotparser).
- xmlrpc (xmlrpclib, DocXMLRPCServer, SimpleXMLRPCServer).
Some other changes to standard library modules, not covered by PEP 3108:

- Killed sets. Use the built-in `set()` class.
- Cleanup of the `sys` module: removed `sys.exitfunc()`, `sys.exc_clear()`, `sys.exc_type`, `sys.exc_value`, `sys.exc_traceback`. (Note that `sys.last_type` etc. remain.)
- Cleanup of the `array.array` type: the `read()` and `write()` methods are gone; use `fromfile()` and `tofile()` instead. Also, the 'c' typecode for array is gone – use either 'b' for bytes or 'u' for Unicode characters.
- Cleanup of the `operator` module: removed `sequenceIncludes()` and `isCallable()`.
- Cleanup of the `thread` module: `acquire_lock()` and `release_lock()` are gone; use `acquire()` and `release()` instead.
- Cleanup of the `random` module: removed the `jumpahead()` API.
- The new module is gone.
- The functions `os.tmpnam()`, `os.tempnam()` and `os.tmpfile()` have been removed in favor of the `tempfile` module.
- The `tokenize` module has been changed to work with bytes. The main entry point is now `tokenize.tokenize()`, instead of `generate_tokens`.
- `string.letters` and its friends (`string.lowercase` and `string.uppercase`) are gone. Use `string.ascii_letters` etc. instead. (The reason for the removal is that `string.letters` and friends had locale-specific behavior, which is a bad idea for such attractively-named global “constants”.)
- Renamed module `__builtin__` to `builtins` (removing the underscores, adding an ‘s’). The `__builtins__` variable found in most global namespaces is unchanged. To modify a builtin, you
should use `builtins`, not `__builtins__`!
PEP 3101: A New Approach To String Formatting

- A new system for built-in string formatting operations replaces the % string formatting operator. (However, the % operator is still supported; it will be deprecated in Python 3.1 and removed from the language at some later time.) Read PEP 3101 for the full scoop.
Changes To Exceptions

The APIs for raising and catching exception have been cleaned up and new powerful features added:

- **PEP 0352**: All exceptions must be derived (directly or indirectly) from `BaseException`. This is the root of the exception hierarchy. This is not new as a recommendation, but the requirement to inherit from `BaseException` is new. (Python 2.6 still allowed classic classes to be raised, and placed no restriction on what you can catch.) As a consequence, string exceptions are finally truly and utterly dead.

- Almost all exceptions should actually derive from `Exception`; `BaseException` should only be used as a base class for exceptions that should only be handled at the top level, such as `SystemExit` or `KeyboardInterrupt`. The recommended idiom for handling all exceptions except for this latter category is to use `except Exception`.

- `StandardError` was removed.

- Exceptions no longer behave as sequences. Use the `args` attribute instead.

- **PEP 3109**: Raising exceptions. You must now use `raise Exception(args)` instead of `raise Exception, args`. Additionally, you can no longer explicitly specify a traceback; instead, if you have to do this, you can assign directly to the `__traceback__` attribute (see below).

- **PEP 3110**: Catching exceptions. You must now use except
SomeException as variable instead of except SomeException, variable. Moreover, the variable is explicitly deleted when the except block is left.

- **PEP 3134**: Exception chaining. There are two cases: implicit chaining and explicit chaining. Implicit chaining happens when an exception is raised in an except or finally handler block. This usually happens due to a bug in the handler block; we call this a secondary exception. In this case, the original exception (that was being handled) is saved as the __context__ attribute of the secondary exception. Explicit chaining is invoked with this syntax:

```python
raise SecondaryException() from primary_exception
```

(where primary_exception is any expression that produces an exception object, probably an exception that was previously caught). In this case, the primary exception is stored on the __cause__ attribute of the secondary exception. The traceback printed when an unhandled exception occurs walks the chain of __cause__ and __context__ attributes and prints a separate traceback for each component of the chain, with the primary exception at the top. (Java users may recognize this behavior.)

- **PEP 3134**: Exception objects now store their traceback as the __traceback__ attribute. This means that an exception object now contains all the information pertaining to an exception, and there are fewer reasons to use `sys.exc_info()` (though the latter is not removed).

- A few exception messages are improved when Windows fails to load an extension module. For example, error code 193 is
now %1 is not a valid Win32 application. Strings now deal with non-English locales.
Miscellaneous Other Changes

Operators And Special Methods

- != now returns the opposite of ==, unless == returns `NotImplemented`.
- The concept of “unbound methods” has been removed from the language. When referencing a method as a class attribute, you now get a plain function object.
- `__getslice__()`, `__setslice__()`, and `__delslice__()` were killed. The syntax `a[i:j]` now translates to `a.__getitem__(slice(i, j))` (or `__setitem__()` or `__delitem__()`), when used as an assignment or deletion target, respectively.
- **PEP 3114**: the standard `next()` method has been renamed to `__next__()`.
- The `__oct__()`, `__hex__()`, special methods are removed – `oct()` and `hex()` use `__index__()` now to convert the argument to an integer.
- Removed support for `__members__` and `__methods__`.
- The function attributes named `func_X` have been renamed to use the `__X__` form, freeing up these names in the function attribute namespace for user-defined attributes. To wit, `func_closure`, `func_code`, `func_defaults`, `func_dict`, `func_doc`, `func_globals`, `func_name` were renamed to `__closure__`, `__code__`, `__defaults__`, `__dict__`, `__doc__`, `__globals__`, `__name__`, respectively.
- `__nonzero__()` is now `__bool__()`.

Builtin
• **PEP 3135**: New `super()`. You can now invoke `super()` without arguments and (assuming this is in a regular instance method defined inside a `class` statement) the right class and instance will automatically be chosen. With arguments, the behavior of `super()` is unchanged.
• **PEP 3111**: `raw_input()` was renamed to `input()`. That is, the new `input()` function reads a line from `sys.stdin` and returns it with the trailing newline stripped. It raises `EOFError` if the input is terminated prematurely. To get the old behavior of `input()`, use `eval(input())`.
• A new built-in function `next()` was added to call the `__next__()` method on an object.
• The `round()` function rounding strategy and return type have changed. Exact halfway cases are now rounded to the nearest even result instead of away from zero. (For example, `round(2.5)` now returns 2 rather than 3.) `round(x[, n])` now delegates to `x.__round__(n)` instead of always returning a float. It generally returns an integer when called with a single argument and a value of the same type as `x` when called with two arguments.
• Moved `intern()` to `sys.intern()`.
• Removed: `apply()`. Instead of `apply(f, args)` use `f(*args)`.
• Removed `callable()`. Instead of `callable(f)` you can use `isinstance(f, collections.Callable)`. The `operator.isCallable()` function is also gone.
• Removed `coerce()`. This function no longer serves a purpose now that classic classes are gone.
• Removed `execfile()`. Instead of `execfile(fn)` use `exec(open(fn).read())`.
• Removed the file type. Use `open()`. There are now several different kinds of streams that `open` can return in the `io` module.
• Removed reduce(). Use `functools.reduce()` if you really need it; however, 99 percent of the time an explicit `for` loop is more readable.
• Removed reload(). Use `imp.reload()`.
• Removed `dict.has_key()` – use the `in` operator instead.
Build and C API Changes

Due to time constraints, here is a very incomplete list of changes to the C API.

- Support for several platforms was dropped, including but not limited to Mac OS 9, BeOS, RISCOS, Irix, and Tru64.
- **PEP 3118**: New Buffer API.
- **PEP 3121**: Extension Module Initialization & Finalization.
- **PEP 3123**: Making `PyObject_HEAD` conform to standard C.
- No more C API support for restricted execution.
- `PyNumber_Coerce()`, `PyNumber_CoerceEx()`, `PyMember_Get()`, and `PyMember_Set()` C APIs are removed.
- New C API `PyImport_ImportModuleNoBlock()`, works like `PyImport_ImportModule()` but won't block on the import lock (returning an error instead).
- Renamed the boolean conversion C-level slot and method: `nb_nonzero` is now `nb_bool`.
- Removed `METH_OLDARGS` and `WITH_CYCLE_GC` from the C API.
Performance

The net result of the 3.0 generalizations is that Python 3.0 runs the pystone benchmark around 10% slower than Python 2.5. Most likely the biggest cause is the removal of special-casing for small integers. There's room for improvement, but it will happen after 3.0 is released!
Porting To Python 3.0

For porting existing Python 2.5 or 2.6 source code to Python 3.0, the best strategy is the following:

0. (Prerequisite:) Start with excellent test coverage.
1. Port to Python 2.6. This should be no more work than the average port from Python 2.x to Python 2.(x+1). Make sure all your tests pass.
2. (Still using 2.6:) Turn on the -3 command line switch. This enables warnings about features that will be removed (or change) in 3.0. Run your test suite again, and fix code that you get warnings about until there are no warnings left, and all your tests still pass.
3. Run the 2to3 source-to-source translator over your source code tree. (See 2to3 - Automated Python 2 to 3 code translation for more on this tool.) Run the result of the translation under Python 3.0. Manually fix up any remaining issues, fixing problems until all tests pass again.

It is not recommended to try to write source code that runs unchanged under both Python 2.6 and 3.0; you’d have to use a very contorted coding style, e.g. avoiding print statements, metaclasses, and much more. If you are maintaining a library that needs to support both Python 2.6 and Python 3.0, the best approach is to modify step 3 above by editing the 2.6 version of the source code and running the 2to3 translator again, rather than editing the 3.0 version of the source code.

For porting C extensions to Python 3.0, please see Porting Extension Modules to Python 3.
What’s New in Python 2.7

Author: A.M. Kuchling (amk at amk.ca)

This article explains the new features in Python 2.7. Python 2.7 was released on July 3, 2010.

Numeric handling has been improved in many ways, for both floating-point numbers and for the `Decimal` class. There are some useful additions to the standard library, such as a greatly enhanced `unittest` module, the `argparse` module for parsing command-line options, convenient `OrderedDict` and `Counter` classes in the `collections` module, and many other improvements.

Python 2.7 is planned to be the last of the 2.x releases, so we worked on making it a good release for the long term. To help with porting to Python 3, several new features from the Python 3.x series have been included in 2.7.

This article doesn’t attempt to provide a complete specification of the new features, but instead provides a convenient overview. For full details, you should refer to the documentation for Python 2.7 at https://docs.python.org. If you want to understand the rationale for the design and implementation, refer to the PEP for a particular new feature or the issue on https://bugs.python.org in which a change was discussed. Whenever possible, “What’s New in Python” links to the bug/patch item for each change.
The Future for Python 2.x

Python 2.7 is the last major release in the 2.x series, as the Python maintainers have shifted the focus of their new feature development efforts to the Python 3.x series. This means that while Python 2 continues to receive bug fixes, and to be updated to build correctly on new hardware and versions of supported operated systems, there will be no new full feature releases for the language or standard library.

However, while there is a large common subset between Python 2.7 and Python 3, and many of the changes involved in migrating to that common subset, or directly to Python 3, can be safely automated, some other changes (notably those associated with Unicode handling) may require careful consideration, and preferably robust automated regression test suites, to migrate effectively.

This means that Python 2.7 will remain in place for a long time, providing a stable and supported base platform for production systems that have not yet been ported to Python 3. The full expected lifecycle of the Python 2.7 series is detailed in **PEP 373**.

Some key consequences of the long-term significance of 2.7 are:

- As noted above, the 2.7 release has a much longer period of maintenance when compared to earlier 2.x versions. Python 2.7 is currently expected to remain supported by the core development team (receiving security updates and other bug fixes) until at least 2020 (10 years after its initial release, compared to the more typical support period of 18-24 months).
- As the Python 2.7 standard library ages, making effective use of the Python Package Index (either directly or via a redistributor) becomes more important for Python 2 users. In addition to a wide variety of third party packages for various tasks, the available
packages include backports of new modules and features from the Python 3 standard library that are compatible with Python 2, as well as various tools and libraries that can make it easier to migrate to Python 3. The Python Packaging User Guide provides guidance on downloading and installing software from the Python Package Index.

- While the preferred approach to enhancing Python 2 is now the publication of new packages on the Python Package Index, this approach doesn’t necessarily work in all cases, especially those related to network security. In exceptional cases that cannot be handled adequately by publishing new or updated packages on PyPI, the Python Enhancement Proposal process may be used to make the case for adding new features directly to the Python 2 standard library. Any such additions, and the maintenance releases where they were added, will be noted in the New Features Added to Python 2.7 Maintenance Releases section below.

For projects wishing to migrate from Python 2 to Python 3, or for library and framework developers wishing to support users on both Python 2 and Python 3, there are a variety of tools and guides available to help decide on a suitable approach and manage some of the technical details involved. The recommended starting point is the Porting Python 2 Code to Python 3 HOWTO guide.
Changes to the Handling of Deprecation Warnings

For Python 2.7, a policy decision was made to silence warnings only of interest to developers by default. DeprecationWarning and its descendants are now ignored unless otherwise requested, preventing users from seeing warnings triggered by an application. This change was also made in the branch that became Python 3.2. (Discussed on stdlib-sig and carried out in issue 7319.)

In previous releases, DeprecationWarning messages were enabled by default, providing Python developers with a clear indication of where their code may break in a future major version of Python.

However, there are increasingly many users of Python-based applications who are not directly involved in the development of those applications. DeprecationWarning messages are irrelevant to such users, making them worry about an application that's actually working correctly and burdening application developers with responding to these concerns.

You can re-enable display of DeprecationWarning messages by running Python with the -Wdefault (short form: -Wd) switch, or by setting the PYTHONWARNINGS environment variable to "default" (or "d") before running Python. Python code can also re-enable them by calling warnings.simplefilter('default').

The unittest module also automatically reenables deprecation warnings when running tests.
Python 3.1 Features

Much as Python 2.6 incorporated features from Python 3.0, version 2.7 incorporates some of the new features in Python 3.1. The 2.x series continues to provide tools for migrating to the 3.x series.

A partial list of 3.1 features that were backported to 2.7:

- The syntax for set literals (\{1, 2, 3\} is a mutable set).
- Dictionary and set comprehensions (\{i: i*2 for i in range(3)\}).
- Multiple context managers in a single `with` statement.
- A new version of the `io` library, rewritten in C for performance.
- The ordered-dictionary type described in PEP 372: Adding an Ordered Dictionary to collections.
- The new `","` format specifier described in PEP 378: Format Specifier for Thousands Separator.
- The `memoryview` object.
- A small subset of the `importlib` module, described below.
- The `repr()` of a float `x` is shorter in many cases: it's now based on the shortest decimal string that's guaranteed to round back to `x`. As in previous versions of Python, it's guaranteed that `float(repr(x))` recovers `x`.
- Float-to-string and string-to-float conversions are correctly rounded. The `round()` function is also now correctly rounded.
- The `PyCapsule` type, used to provide a C API for extension modules.
- The `PyLong_AsLongAndOverflow()` C API function.

Other new Python3-mode warnings include:

- `operator.isCallable()`
operator.sequenceIncludes(), which are not supported in 3.x, now trigger warnings.

- The -3 switch now automatically enables the -Qwarn switch that causes warnings about using classic division with integers and long integers.
PEP 372: Adding an Ordered Dictionary to collections

Regular Python dictionaries iterate over key/value pairs in arbitrary order. Over the years, a number of authors have written alternative implementations that remember the order that the keys were originally inserted. Based on the experiences from those implementations, 2.7 introduces a new `OrderedDict` class in the `collections` module.

The `OrderedDict` API provides the same interface as regular dictionaries but iterates over keys and values in a guaranteed order depending on when a key was first inserted:

```python
>>> from collections import OrderedDict
>>> d = OrderedDict([('first', 1), ...
                   ('second', 2), ...
                   ('third', 3)])
>>> d.items()
[('first', 1), ('second', 2), ('third', 3)]
```

If a new entry overwrites an existing entry, the original insertion position is left unchanged:

```python
>>> d['second'] = 4
>>> d.items()
[('first', 1), ('second', 4), ('third', 3)]
```

Deleting an entry and reinserting it will move it to the end:

```python
>>> del d['second']
>>> d['second'] = 5
>>> d.items()
[('first', 1), ('third', 3), ('second', 5)]
```
The `popitem()` method has an optional `last` argument that defaults to `True`. If `last` is `True`, the most recently added key is returned and removed; if it's `False`, the oldest key is selected:

```python
>>> od = OrderedDict([(x, 0) for x in range(20)])
>>> od.popitem()
(19, 0)
>>> od.popitem()
(18, 0)
>>> od.popitem(last=False)
(0, 0)
>>> od.popitem(last=False)
(1, 0)
```

Comparing two ordered dictionaries checks both the keys and values, and requires that the insertion order was the same:

```python
>>> od1 = OrderedDict([('first', 1), ...
...                      ('second', 2), ...
...                      ('third', 3)])
>>> od2 = OrderedDict([('third', 3), ...
...                      ('first', 1), ...
...                      ('second', 2)])
>>> od1 == od2
False
>>> # Move 'third' key to the end
>>> del od2['third']; od2['third'] = 3
>>> od1 == od2
True
```

Comparing an `OrderedDict` with a regular dictionary ignores the insertion order and just compares the keys and values.

How does the `OrderedDict` work? It maintains a doubly-linked list of keys, appending new keys to the list as they're inserted. A secondary
dictionary maps keys to their corresponding list node, so deletion doesn’t have to traverse the entire linked list and therefore remains O(1).

The standard library now supports use of ordered dictionaries in several modules.

- The ConfigParser module uses them by default, meaning that configuration files can now be read, modified, and then written back in their original order.
- The _asdict() method for collections.namedtuple() now returns an ordered dictionary with the values appearing in the same order as the underlying tuple indices.
- The json module’s JSONDecoder class constructor was extended with an object_pairs_hook parameter to allow OrderedDict instances to be built by the decoder. Support was also added for third-party tools like PyYAML.

See also:

**PEP 372 - Adding an ordered dictionary to collections**

PEP written by Armin Ronacher and Raymond Hettinger; implemented by Raymond Hettinger.
PEP 378: FormatSpecifier for Thousands Separator

To make program output more readable, it can be useful to add separators to large numbers, rendering them as 18,446,744,073,709,551,616 instead of 18446744073709551616.

The fully general solution for doing this is the `locale` module, which can use different separators (""," in North America, "." in Europe) and different grouping sizes, but `locale` is complicated to use and unsuitable for multi-threaded applications where different threads are producing output for different locales.

Therefore, a simple comma-grouping mechanism has been added to the mini-language used by the `str.format()` method. When formatting a floating-point number, simply include a comma between the width and the precision:

```python
>>> '{:20,.2f}'.format(18446744073709551616.0)
'18,446,744,073,709,551,616.00'
```

When formatting an integer, include the comma after the width:

```python
>>> '{:20,d}'.format(18446744073709551616)
'18,446,744,073,709,551,616'
```

This mechanism is not adaptable at all; commas are always used as the separator and the grouping is always into three-digit groups. The comma-formatting mechanism isn't as general as the `locale` module, but it's easier to use.

See also:
PEP 378 - Format Specifier for Thousands Separator

PEP written by Raymond Hettinger; implemented by Eric Smith.
The `argparse` module for parsing command-line arguments was added as a more powerful replacement for the `optparse` module.

This means Python now supports three different modules for parsing command-line arguments: `getopt`, `optparse`, and `argparse`. The `getopt` module closely resembles the C library's `getopt()` function, so it remains useful if you're writing a Python prototype that will eventually be rewritten in C. `optparse` becomes redundant, but there are no plans to remove it because there are many scripts still using it, and there's no automated way to update these scripts. (Making the `argparse` API consistent with `optparse`'s interface was discussed but rejected as too messy and difficult.)

In short, if you're writing a new script and don’t need to worry about compatibility with earlier versions of Python, use `argparse` instead of `optparse`.

Here’s an example:

```python
import argparse

parser = argparse.ArgumentParser(description='Command-line example.')

# Add optional switches
parser.add_argument('-v', action='store_true', dest='verbose', help='produce verbose output')
parser.add_argument('-o', action='store', dest='output', metavar='FILE', help='direct output to FILE instead of stdout')
```
parser.add_argument('-C', action='store', type=int,  
metavar='NUM', default=0,  
help='display NUM lines of added context')

# Allow any number of additional arguments.
parserr.add_argument(nargs='*', action='store', dest=  
help='input filenames (default is stdin')

args = parser.parse_args()  
print(args.__dict__)

Unless you override it, -h and --help switches are automatically added, and produce neatly formatted output:

```
> ./python.exe argparse-example.py --help
usage: argparse-example.py [-h] [-v] [-o FILE] [-C NUM]
Command-line example.

positional arguments:
  inputs            input filenames (default is stdin)

optional arguments:
  -h, --help  show this help message and exit
  -v          produce verbose output
  -o FILE    direct output to FILE instead of stdout
  -C NUM     display NUM lines of added context
```

As with optparse, the command-line switches and arguments are returned as an object with attributes named by the dest parameters:

```
> ./python.exe argparse-example.py -v
{'output': None,  
'is_verybose': True,  
'context': 0,}
argparse has much fancier validation than optparse; you can specify an exact number of arguments as an integer, 0 or more arguments by passing '*' , 1 or more by passing '+', or an optional argument with '?'. A top-level parser can contain sub-parsers to define subcommands that have different sets of switches, as in svn commit, svn checkout, etc. You can specify an argument's type as FileType, which will automatically open files for you and understands that '-' means standard input or output.

See also:

argparse documentation
The documentation page of the argparse module.

Upgrading optparse code
Part of the Python documentation, describing how to convert code that uses optparse.

PEP 389 - argparse - New Command Line Parsing Module
PEP written and implemented by Steven Bethard.
PEP 391: Dictionary-Based Configuration For Logging

The `logging` module is very flexible; applications can define a tree of logging subsystems, and each logger in this tree can filter out certain messages, format them differently, and direct messages to a varying number of handlers.

All this flexibility can require a lot of configuration. You can write Python statements to create objects and set their properties, but a complex set-up requires verbose but boring code. `logging` also supports a `fileConfig()` function that parses a file, but the file format doesn't support configuring filters, and it's messier to generate programmatically.

Python 2.7 adds a `dictConfig()` function that uses a dictionary to configure logging. There are many ways to produce a dictionary from different sources: construct one with code; parse a file containing JSON; or use a YAML parsing library if one is installed. For more information see Configuration functions.

The following example configures two loggers, the root logger and a logger named “network”. Messages sent to the root logger will be sent to the system log using the syslog protocol, and messages to the “network” logger will be written to a network.log file that will be rotated once the log reaches 1MB.

```python
import logging
import logging.config

configdict = {
    'version': 1,     # Configuration schema in use; must be 1
    'disable_existing_loggers': False,
    'formatters': {
        'standard': {
            'format': '%(asctime)s - %(levelname)s - %(message)s'
        }
    },
    'handlers': {
        'syslog': {
            'class': 'logging.handlers.SysLogHandler',
            'formatter': 'standard',
            'address': '/dev/log',
            'facility': 'local0'
        },
        'file': {
            'class': 'logging.handlers.RotatingFileHandler',
            'formatter': 'standard',
            'filename': 'network.log',
            'maxBytes': 1000000
        }
    },
    'loggers': {
        '': {
            'handlers': ['syslog'],
            'level': 'INFO'
        },
        'network': {
            'handlers': ['file'],
            'level': 'INFO'
        }
    }
}

logging.config.dictConfig(configdict)
```
'formatters': {
    'standard': {
        'format': ('%(asctime)s	%(name)-15s	%(levelname)-8s	%(message)s')
    }
},

'handlers': {
    'netlog': {
        'backupCount': 10,
        'class': 'logging.handlers.RotatingFileHandler',
        'filename': '/logs/network.log',
        'formatter': 'standard',
        'level': 'INFO',
        'maxBytes': 1000000,
    },
    'syslog': {
        'class': 'logging.handlers.SysLogHandler',
        'formatter': 'standard',
        'level': 'ERROR'
    }
},

# Specify all the subordinate loggers
'loggers': {
    'network': {
        'handlers': ['netlog']
    }
},

# Specify properties of the root logger
'root': {
    'handlers': ['syslog']
},

# Set up configuration
logging.config.dictConfig(configdict)

# As an example, log two error messages
logger = logging.getLogger('/')
logger.error('Database not found')

netlogger = logging.getLogger('network')
netlogger.error('Connection failed')
Three smaller enhancements to the `logging` module, all implemented by Vinay Sajip, are:

- The `SysLogHandler` class now supports syslogging over TCP. The constructor has a `socktype` parameter giving the type of socket to use, either `socket.SOCK_DGRAM` for UDP or `socket.SOCK_STREAM` for TCP. The default protocol remains UDP.
- `Logger` instances gained a `getChild()` method that retrieves a descendant logger using a relative path. For example, once you retrieve a logger by doing `log = getLogger('app')`, calling `log.getChild('network.listen')` is equivalent to `getLogger('app.network.listen')`.
- The `LoggerAdapter` class gained a `isEnabledFor()` method that takes a `level` and returns whether the underlying logger would process a message of that level of importance.

**See also:**

**PEP 391 - Dictionary-Based Configuration For Logging**

PEP written and implemented by Vinay Sajip.
PEP 3106: Dictionary Views

The dictionary methods `keys()`, `values()`, and `items()` are different in Python 3.x. They return an object called a `view` instead of a fully materialized list.

It's not possible to change the return values of `keys()`, `values()`, and `items()` in Python 2.7 because too much code would break. Instead the 3.x versions were added under the new names `viewkeys()`, `viewvalues()`, and `viewitems()`.

```python
>>> d = dict((i*10, chr(65+i)) for i in range(26))
>>> d
>>> d.viewkeys()
dict_keys([0, 130, 10, 140, 20, 150, 30, ..., 250])
```

Views can be iterated over, but the key and item views also behave like sets. The `&` operator performs intersection, and `|` performs a union:

```python
>>> d1 = dict((i*10, chr(65+i)) for i in range(26))
>>> d2 = dict((i**.5, i) for i in range(1000))
>>> d1.viewkeys() & d2.viewkeys()
set([0.0, 10.0, 20.0, 30.0])
>>> d1.viewkeys() | range(0, 30)
set([0, 1, 130, 3, 4, 5, 6, ..., 120, 250])
```

The view keeps track of the dictionary and its contents change as the dictionary is modified:

```python
>>> vk = d.viewkeys()
```
>>> vk
dict_keys([0, 130, 10, ..., 250])

>>> d[260] = '&'

>>> vk
dict_keys([0, 130, 260, 10, ..., 250])

However, note that you can't add or remove keys while you're iterating over the view:

```python
>>> for k in vk:
    ...
    d[k*2] = k
...
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
RuntimeError: dictionary changed size during iteration
```

You can use the view methods in Python 2.x code, and the 2to3 converter will change them to the standard `keys()`, `values()`, and `items()` methods.

See also:

**PEP 3106 - Revamping dict.keys(), .values() and .items()**

PEP written by Guido van Rossum. Backported to 2.7 by Alexandre Vassalotti; issue 1967.
PEP 3137: The memoryview Object

The `memoryview` object provides a view of another object's memory content that matches the `bytes` type's interface.

```python
>>> import string
>>> m = memoryview(string.letters)
>>> m
<memory at 0x37f850>
>>> len(m)        # Returns length of underlying
52
>>> m[0], m[25], m[26]  # Indexing returns one byte
('a', 'z', 'A')
>>> m2 = m[0:26]       # Slicing returns another memoryview
>>> m2
<memory at 0x37f080>
```

The content of the view can be converted to a string of bytes or a list of integers:

```python
>>> m2.tobytes()
'abcdefgijklmnopqrstuvwxyz'
>>> m2.tolist()
[97, 98, 99, 100, 101, 102, 103, ... 121, 122]
```

`memoryview` objects allow modifying the underlying object if it's a mutable object.

```python
>>> m2[0] = 75
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: cannot modify read-only memory
```
>>> b = bytearray(string.letters)  # Creating a mutable object
>>> b
bytearray(b'abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ')

>>> mb = memoryview(b)
>>> mb[0] = '*'  # Assign to view, changing the bytearray.
>>> b[0:5]  # The bytearray has been changed.
bytearray(b'*bcde')

See also:

**PEP 3137 - Immutable Bytes and Mutable Buffer**

PEP written by Guido van Rossum. Implemented by Travis Oliphant, Antoine Pitrou and others. Backported to 2.7 by Antoine Pitrou; issue 2396.
Other Language Changes

Some smaller changes made to the core Python language are:

- The syntax for set literals has been backported from Python 3.x. Curly brackets are used to surround the contents of the resulting mutable set; set literals are distinguished from dictionaries by not containing colons and values. `{}` continues to represent an empty dictionary; use set() for an empty set.

```python
>>> {1, 2, 3, 4, 5}
set([1, 2, 3, 4, 5])
>>> set() # empty set
set([])
>>> {}    # empty dict
{}
```

Backported by Alexandre Vassalotti; issue 2335.

- Dictionary and set comprehensions are another feature backported from 3.x, generalizing list/generator comprehensions to use the literal syntax for sets and dictionaries.

```python
>>> {x: x*x for x in range(6)}
{0: 0, 1: 1, 2: 4, 3: 9, 4: 16, 5: 25}
>>> {('a'*x) for x in range(6)}
set(['', 'a', 'aa', 'aaa', 'aaaa', 'aaaaa'])
```

Backported by Alexandre Vassalotti; issue 2333.

- The with statement can now use multiple context managers in one statement. Context managers are processed from left to right and each one is treated as beginning a new with statement. This
means that:

```
with A() as a, B() as b:
    ... suite of statements ...
```

is equivalent to:

```
with A() as a:
    with B() as b:
        ... suite of statements ...
```

The `contextlib.nested()` function provides a very similar function, so it's no longer necessary and has been deprecated.

(Proposed in https://codereview.appspot.com/53094; implemented by Georg Brandl.)

- Conversions between floating-point numbers and strings are now correctly rounded on most platforms. These conversions occur in many different places: `str()` on floats and complex numbers; the `float` and `complex` constructors; numeric formatting; serializing and deserializing floats and complex numbers using the `marshal`, `pickle` and `json` modules; parsing of float and imaginary literals in Python code; and `Decimal`-to-float conversion.

Related to this, the `repr()` of a floating-point number `x` now returns a result based on the shortest decimal string that's guaranteed to round back to `x` under correct rounding (with round-half-to-even rounding mode). Previously it gave a string based on rounding `x` to 17 decimal digits.

The rounding library responsible for this improvement works on
Windows and on Unix platforms using the gcc, icc, or suncc compilers. There may be a small number of platforms where correct operation of this code cannot be guaranteed, so the code is not used on such systems. You can find out which code is being used by checking `sys.float_repr_style`, which will be short if the new code is in use and legacy if it isn’t.

Implemented by Eric Smith and Mark Dickinson, using David Gay’s dtoa.c library; issue 7117.

- Conversions from long integers and regular integers to floating point now round differently, returning the floating-point number closest to the number. This doesn’t matter for small integers that can be converted exactly, but for large numbers that will unavoidably lose precision, Python 2.7 now approximates more closely. For example, Python 2.6 computed the following:

  ```python
  >>> n = 295147905179352891391
  >>> float(n)
  2.9514790517935283e+20
  >>> n - long(float(n))
  65535L
  ```

  Python 2.7’s floating-point result is larger, but much closer to the true value:

  ```python
  >>> n = 295147905179352891391
  >>> float(n)
  2.9514790517935289e+20
  >>> n - long(float(n))
  -1L
  ```

  (Implemented by Mark Dickinson; issue 3166.)
Integer division is also more accurate in its rounding behaviours. (Also implemented by Mark Dickinson; issue 1811.)

- Implicit coercion for complex numbers has been removed; the interpreter will no longer ever attempt to call a `__coerce__()` method on complex objects. (Removed by Meador Inge and Mark Dickinson; issue 5211.)

- The `str.format()` method now supports automatic numbering of the replacement fields. This makes using `str.format()` more closely resemble using `%s` formatting:

```python
>>> '{}:{}:{}'.format(2009, 04, 'Sunday')
'2009:4:Sunday'
>>> '{}:{},{day}'.format(2009, 4, day='Sunday')
'2009:4:Sunday'
```

The auto-numbering takes the fields from left to right, so the first `{...}` specifier will use the first argument to `str.format()`, the next specifier will use the next argument, and so on. You can’t mix auto-numbering and explicit numbering – either number all of your specifier fields or none of them – but you can mix auto-numbering and named fields, as in the second example above. (Contributed by Eric Smith; issue 5237.)

Complex numbers now correctly support usage with `format()`, and default to being right-aligned. Specifying a precision or comma-separation applies to both the real and imaginary parts of the number, but a specified field width and alignment is applied to the whole of the resulting `1.5+3j` output. (Contributed by Eric Smith; issue 1588 and issue 7988.)

The ‘F’ format code now always formats its output using
uppercase characters, so it will now produce ‘INF’ and ‘NAN’.
(Contributed by Eric Smith; issue 3382.)

A low-level change: the object.__format__() method now triggers a PendingDeprecationWarning if it’s passed a format string, because the __format__() method for object converts the object to a string representation and formats that. Previously the method silently applied the format string to the string representation, but that could hide mistakes in Python code. If you’re supplying formatting information such as an alignment or precision, presumably you’re expecting the formatting to be applied in some object-specific way. (Fixed by Eric Smith; issue 7994.)

- The int() and long() types gained a bit_length method that returns the number of bits necessary to represent its argument in binary:

```python
>>> n = 37
>>> bin(n)
'0b100101'
>>> n.bit_length()  # The int() and long() types gained a bit_length method that returns the number of bits necessary to represent its argument in binary.
6
>>> n = 2**123-1
>>> n.bit_length()  # The int() and long() types gained a bit_length method that returns the number of bits necessary to represent its argument in binary.
123
>>> (n+1).bit_length()  # The int() and long() types gained a bit_length method that returns the number of bits necessary to represent its argument in binary.
124
```

(Contributed by Fredrik Johansson and Victor Stinner; issue 3439.)

- The import statement will no longer try an absolute import if a relative import (e.g. from .os import sep) fails. This fixes a
bug, but could possibly break certain import statements that were only working by accident. (Fixed by Meador Inge; issue 7902.)

- It's now possible for a subclass of the built-in unicode type to override the __unicode__() method. (Implemented by Victor Stinner; issue 1583863.)

- The bytearray type's translate() method now accepts None as its first argument. (Fixed by Georg Brandl; issue 4759.)

- When using @classmethod and @staticmethod to wrap methods as class or static methods, the wrapper object now exposes the wrapped function as their __func__ attribute. (Contributed by Amaury Forgeot d'Arc, after a suggestion by George Sakkis; issue 5982.)

- When a restricted set of attributes were set using __slots__, deleting an unset attribute would not raise AttributeError as you would expect. Fixed by Benjamin Peterson; issue 7604.)

- Two new encodings are now supported: “cp720”, used primarily for Arabic text; and “cp858”, a variant of CP 850 that adds the euro symbol. (CP720 contributed by Alexander Belchenko and Amaury Forgeot d'Arc in issue 1616979; CP858 contributed by Tim Hatch in issue 8016.)

- The file object will now set the filename attribute on the IOError exception when trying to open a directory on POSIX platforms (noted by Jan Kaliszewski; issue 4764), and now explicitly checks for and forbids writing to read-only file objects instead of trusting the C library to catch and report the error (fixed by Stefan Krah; issue 5677).
• The Python tokenizer now translates line endings itself, so the `compile()` built-in function now accepts code using any line-ending convention. Additionally, it no longer requires that the code end in a newline.

• Extra parentheses in function definitions are illegal in Python 3.x, meaning that you get a syntax error from `def f((x)): pass`. In Python3-warning mode, Python 2.7 will now warn about this odd usage. (Noted by James Lingard; issue 7362.)

• It’s now possible to create weak references to old-style class objects. New-style classes were always weak-referenceable. (Fixed by Antoine Pitrou; issue 8268.)

• When a module object is garbage-collected, the module’s dictionary is now only cleared if no one else is holding a reference to the dictionary (issue 7140).

**Interpreter Changes**

A new environment variable, `PYTHONWARNINGS`, allows controlling warnings. It should be set to a string containing warning settings, equivalent to those used with the `-W` switch, separated by commas. (Contributed by Brian Curtin; issue 7301.)

For example, the following setting will print warnings every time they occur, but turn warnings from the Cookie module into an error. (The exact syntax for setting an environment variable varies across operating systems and shells.)

```
export PYTHONWARNINGS=all,error::Cookie:0
```
Optimizations

Several performance enhancements have been added:

- A new opcode was added to perform the initial setup for `with` statements, looking up the `__enter__()` and `__exit__()` methods. (Contributed by Benjamin Peterson.)

- The garbage collector now performs better for one common usage pattern: when many objects are being allocated without deallocating any of them. This would previously take quadratic time for garbage collection, but now the number of full garbage collections is reduced as the number of objects on the heap grows. The new logic only performs a full garbage collection pass when the middle generation has been collected 10 times and when the number of survivor objects from the middle generation exceeds 10% of the number of objects in the oldest generation. (Suggested by Martin von Löwis and implemented by Antoine Pitrou; issue 4074.)

- The garbage collector tries to avoid tracking simple containers which can’t be part of a cycle. In Python 2.7, this is now true for tuples and dicts containing atomic types (such as ints, strings, etc.). Transitively, a dict containing tuples of atomic types won’t be tracked either. This helps reduce the cost of each garbage collection by decreasing the number of objects to be considered and traversed by the collector. (Contributed by Antoine Pitrou; issue 4688.)

- Long integers are now stored internally either in base 2**15 or in base 2**30, the base being determined at build time. Previously, they were always stored in base 2**15. Using base 2**30 gives
significant performance improvements on 64-bit machines, but benchmark results on 32-bit machines have been mixed. Therefore, the default is to use base 2**30 on 64-bit machines and base 2**15 on 32-bit machines; on Unix, there's a new configure option --enable-big-digits that can be used to override this default.

Apart from the performance improvements this change should be invisible to end users, with one exception: for testing and debugging purposes there's a new struct seq sys.long_info that provides information about the internal format, giving the number of bits per digit and the size in bytes of the C type used to store each digit:

```python
>>> import sys
>>> sys.long_info
sys.long_info(bits_per_digit=30, sizeof_digit=4)
```

(Contributed by Mark Dickinson; issue 4258.)

Another set of changes made long objects a few bytes smaller: 2 bytes smaller on 32-bit systems and 6 bytes on 64-bit. (Contributed by Mark Dickinson; issue 5260.)

- The division algorithm for long integers has been made faster by tightening the inner loop, doing shifts instead of multiplications, and fixing an unnecessary extra iteration. Various benchmarks show speedups of between 50% and 150% for long integer divisions and modulo operations. (Contributed by Mark Dickinson; issue 5512.) Bitwise operations are also significantly faster (initial patch by Gregory Smith; issue 1087418).

- The implementation of % checks for the left-side operand being a
Python string and special-cases it; this results in a 1-3% performance increase for applications that frequently use % with strings, such as templating libraries. (Implemented by Collin Winter; issue 5176.)

- List comprehensions with an if condition are compiled into faster bytecode. (Patch by Antoine Pitrou, back-ported to 2.7 by Jeffrey Yasskin; issue 4715.)

- Converting an integer or long integer to a decimal string was made faster by special-casing base 10 instead of using a generalized conversion function that supports arbitrary bases. (Patch by Gawain Bolton; issue 6713.)

- The split(), replace(), rindex(), rpartition(), and rsplit() methods of string-like types (strings, Unicode strings, and bytearray objects) now use a fast reverse-search algorithm instead of a character-by-character scan. This is sometimes faster by a factor of 10. (Added by Florent Xicluna; issue 7462 and issue 7622.)

- The pickle and cPickle modules now automatically intern the strings used for attribute names, reducing memory usage of the objects resulting from unpickling. (Contributed by Jake McGuire; issue 5084.)

- The cPickle module now special-cases dictionaries, nearly halving the time required to pickle them. (Contributed by Collin Winter; issue 5670.)
New and Improved Modules

As in every release, Python's standard library received a number of enhancements and bug fixes. Here's a partial list of the most notable changes, sorted alphabetically by module name. Consult the Misc/NEWS file in the source tree for a more complete list of changes, or look through the Subversion logs for all the details.

- The **bdb** module's base debugging class **Bdb** gained a feature for skipping modules. The constructor now takes an iterable containing glob-style patterns such as django.*; the debugger will not step into stack frames from a module that matches one of these patterns. (Contributed by Maru Newby after a suggestion by Senthil Kumaran; issue 5142.)

- The **binascii** module now supports the buffer API, so it can be used with **memoryview** instances and other similar buffer objects. (Backported from 3.x by Florent Xicluna; issue 7703.)

- Updated module: the bsddb module has been updated from 4.7.2devel9 to version 4.8.4 of the **pybsddb** package. The new version features better Python 3.x compatibility, various bug fixes, and adds several new BerkeleyDB flags and methods. (Updated by Jesús Cea Avión; issue 8156. The pybsddb changelog can be read at [http://hg.jcea.es/pybsddb/file/tip/ChangeLog](http://hg.jcea.es/pybsddb/file/tip/ChangeLog).)

- The **bz2** module's **BZ2File** now supports the context management protocol, so you can write with `bz2.BZ2File(...) as f:`. (Contributed by Hagen Fürstenau; issue 3860.)

- New class: the **Counter** class in the **collections** module is
useful for tallying data. `Counter` instances behave mostly like dictionaries but return zero for missing keys instead of raising a `KeyError`:

```python
>>> from collections import Counter
>>> c = Counter()
>>> for letter in 'here is a sample of english text'
...     c[letter] += 1
...
>>> c
Counter({'\t': 6, 'e': 5, 's': 3, 'a': 2, 'i': 2, 'l': 2, 't': 2, 'g': 1, 'f': 1, 'm': 1, 'o': 1, 'n': 1, 'p': 1, 'r': 1, 'x': 1})
>>> c['e']
5
>>> c['z']
0
```

There are three additional `Counter` methods. `most_common()` returns the N most common elements and their counts. `elements()` returns an iterator over the contained elements, repeating each element as many times as its count. `subtract()` takes an iterable and subtracts one for each element instead of adding; if the argument is a dictionary or another Counter, the counts are subtracted.

```python
>>> c.most_common(5)
[(' ', 6), ('e', 5), ('s', 3), ('a', 2), ('i', 2)]
>>> c.elements() ->
'a', 'a', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', ' ', 'e', 'e', 'e', 'e', 'e', 'g', 'f', 'i', 'i', 'h', 'h', 'm', 'l', 'l', 'o', 'n', 'p', 's', 's', 's', 'r', 't', 't', 't', 'x'
>>> c['e']

```
Contributed by Raymond Hettinger; issue 1696199.

New class: `OrderedDict` is described in the earlier section PEP 372: Adding an Ordered Dictionary to collections.

New method: The `deque` data type now has a `count()` method that returns the number of contained elements equal to the supplied argument `x`, and a `reverse()` method that reverses the elements of the deque in-place. `deque` also exposes its maximum length as the read-only `maxlen` attribute. (Both features added by Raymond Hettinger.)

The `namedtuple` class now has an optional `rename` parameter. If `rename` is true, field names that are invalid because they've been repeated or aren't legal Python identifiers will be renamed to legal names that are derived from the field's position within the list of fields:

```python
>>> from collections import namedtuple
>>> T = namedtuple('T', ['field1', '$illegal', 'for'])
>>> T._fields
('field1', '_1', '_2', 'field2')
```

(Added by Raymond Hettinger; issue 1818.)

Finally, the Mapping abstract base class now returns `NotImplemented` if a mapping is compared to another type that
isn't a Mapping. (Fixed by Daniel Stutzbach; issue 8729.)

- Constructors for the parsing classes in the ConfigParser module now take an `allow_no_value` parameter, defaulting to false; if true, options without values will be allowed. For example:

```python
>>> import ConfigParser, StringIO
>>> sample_config = ""
... [mysqld]
... user = mysql
... pid-file = /var/run/mysqld/mysqld.pid
... skip-bdb
... ""
>>> config = ConfigParser.RawConfigParser(allow_no_value)
>>> config.readfp(StringIO.StringIO(sample_config))
>>> config.get('mysqld', 'user')
'mysql'
>>> print config.get('mysqld', 'skip-bdb')
None
>>> print config.get('mysqld', 'unknown')
Traceback (most recent call last):
  ...
NoOptionError: No option 'unknown' in section: 'mysqld'
```

(Contributed by Mats Kindahl; issue 7005.)

- Deprecated function: `contextlib.nested()`, which allows handling more than one context manager with a single `with` statement, has been deprecated, because the `with` statement now supports multiple context managers.

- The cookielib module now ignores cookies that have an invalid version field, one that doesn't contain an integer value. (Fixed by John J. Lee; issue 3924.)
• The `copy` module’s `deepcopy()` function will now correctly copy bound instance methods. (Implemented by Robert Collins; [issue 1515](#).)

• The `ctypes` module now always converts `None` to a C NULL pointer for arguments declared as pointers. (Changed by Thomas Heller; [issue 4606](#).) The underlying `libffi` library has been updated to version 3.0.9, containing various fixes for different platforms. (Updated by Matthias Klose; [issue 8142](#).)

• New method: the `datetime` module’s `timedelta` class gained a `total_seconds()` method that returns the number of seconds in the duration. (Contributed by Brian Quinlan; [issue 5788](#).)

• New method: the `Decimal` class gained a `from_float()` class method that performs an exact conversion of a floating-point number to a `Decimal`. This exact conversion strives for the closest decimal approximation to the floating-point representation’s value; the resulting decimal value will therefore still include the inaccuracy, if any. For example, `Decimal.from_float(0.1)` returns `Decimal('0.10000000000000000555111512312578270211')` (Implemented by Raymond Hettinger; [issue 4796](#).)

Comparing instances of `Decimal` with floating-point numbers now produces sensible results based on the numeric values of the operands. Previously such comparisons would fall back to Python’s default rules for comparing objects, which produced arbitrary results based on their type. Note that you still cannot combine `Decimal` and floating-point in other operations such as addition, since you should be explicitly choosing how to convert between `float` and `Decimal`. (Fixed by Mark Dickinson; [issue 3584](#).)
The constructor for **Decimal** now accepts floating-point numbers (added by Raymond Hettinger; issue 8257) and non-European Unicode characters such as Arabic-Indic digits (contributed by Mark Dickinson; issue 6595).

Most of the methods of the **Context** class now accept integers as well as **Decimal** instances; the only exceptions are the `canonical()` and `is_canonical()` methods. (Patch by Juan José Conti; issue 7633.)

When using **Decimal** instances with a string's `format()` method, the default alignment was previously left-alignment. This has been changed to right-alignment, which is more sensible for numeric types. (Changed by Mark Dickinson; issue 6857.)

Comparisons involving a signaling NaN value (or sNAN) now signal `InvalidOperation` instead of silently returning a true or false value depending on the comparison operator. Quiet NaN values (or NaN) are now hashable. (Fixed by Mark Dickinson; issue 7279.)

- The **difflib** module now produces output that is more compatible with modern **diff/patch** tools through one small change, using a tab character instead of spaces as a separator in the header giving the filename. (Fixed by Anatoly Techtonik; issue 7585.)

- The Distutils `sdist` command now always regenerates the MANIFEST file, since even if the MANIFEST.in or setup.py files haven't been modified, the user might have created some new files that should be included. (Fixed by Tarek Ziadé; issue 2531.)
The `doctest` module's `IGNORE_EXCEPTION_DETAIL` flag will now ignore the name of the module containing the exception being tested. (Patch by Lennart Regebro; issue 7490.)

The `email` module's `Message` class will now accept a Unicode-valued payload, automatically converting the payload to the encoding specified by `output_charset`. (Added by R. David Murray; issue 1368247.)

The `Fraction` class now accepts a single float or `Decimal` instance, or two rational numbers, as arguments to its constructor. (Implemented by Mark Dickinson; rationals added in issue 5812, and float/decimal in issue 8294.)

Ordering comparisons (`<`, `<=`, `>`, `>=`) between fractions and complex numbers now raise a `TypeError`. This fixes an oversight, making the `Fraction` match the other numeric types.

New class: `FTP_TLS` in the `ftplib` module provides secure FTP connections using TLS encapsulation of authentication as well as subsequent control and data transfers. (Contributed by Giampaolo Rodola; issue 2054.)

The `storbinary()` method for binary uploads can now restart uploads thanks to an added `rest` parameter (patch by Pablo Mouzo; issue 6845.)

New class decorator: `total_ordering()` in the `functools` module takes a class that defines an `__eq__()` method and one of `__lt__()`, `__le__()`, `__gt__()`, or `__ge__()`, and generates the missing comparison methods. Since the
__cmp__() method is being deprecated in Python 3.x, this decorator makes it easier to define ordered classes. (Added by Raymond Hettinger; issue 5479.)

New function: cmp_to_key() will take an old-style comparison function that expects two arguments and return a new callable that can be used as the key parameter to functions such as sorted(), min() and max(), etc. The primary intended use is to help with making code compatible with Python 3.x. (Added by Raymond Hettinger.)

- New function: the gc module's is_tracked() returns true if a given instance is tracked by the garbage collector, false otherwise. (Contributed by Antoine Pitrou; issue 4688.)

- The gzip module's GzipFile now supports the context management protocol, so you can write with gzip.GzipFile(...) as f: (contributed by Hagen Fürstenau; issue 3860), and it now implements the io.BufferedIOBase ABC, so you can wrap it with io.BufferedReader for faster processing (contributed by Nir Aides; issue 7471). It's also now possible to override the modification time recorded in a gzipped file by providing an optional timestamp to the constructor. (Contributed by Jacques Frechet; issue 4272.)

Files in gzip format can be padded with trailing zero bytes; the gzip module will now consume these trailing bytes. (Fixed by Tadek Pietraszek and Brian Curtin; issue 2846.)

- New attribute: the hashlib module now has an algorithms attribute containing a tuple naming the supported algorithms. In
Python 2.7, `hashlib.algorithms` contains ('md5', 'sha1', 'sha224', 'sha256', 'sha384', 'sha512'). (Contributed by Carl Chenet; issue 7418.)

- The default `HTTPResponse` class used by the `httplib` module now supports buffering, resulting in much faster reading of HTTP responses. (Contributed by Kristján Valur Jónsson; issue 4879.)

  The `HTTPConnection` and `HTTPSConnection` classes now support a `source_address` parameter, a `(host, port)` 2-tuple giving the source address that will be used for the connection. (Contributed by Eldon Ziegler; issue 3972.)

- The `ihooks` module now supports relative imports. Note that `ihooks` is an older module for customizing imports, superseded by the `imputil` module added in Python 2.0. (Relative import support added by Neil Schemenauer.)

- The `imaplib` module now supports IPv6 addresses. (Contributed by Derek Morr; issue 1655.)

- New function: the `inspect` module's `getcallargs()` takes a callable and its positional and keyword arguments, and figures out which of the callable's parameters will receive each argument, returning a dictionary mapping argument names to their values. For example:

```python
>>> from inspect import getcallargs
>>> def f(a, b=1, *pos, **named):
...     pass
>>> getcallargs(f, 1, 2, 3)
{'a': 1, 'b': 2, 'pos': (3,), 'named': {}}
>>> getcallargs(f, a=2, x=4)
```
Contributed by George Sakkis; issue 3135.

- Updated module: The `io` library has been upgraded to the version shipped with Python 3.1. For 3.1, the I/O library was entirely rewritten in C and is 2 to 20 times faster depending on the task being performed. The original Python version was renamed to the `_pyio` module.

  One minor resulting change: the `io.TextIOBase` class now has an `errors` attribute giving the error setting used for encoding and decoding errors (one of 'strict', 'replace', 'ignore').

  The `io.FileIO` class now raises an `OSError` when passed an invalid file descriptor. (Implemented by Benjamin Peterson; issue 4991.) The `truncate()` method now preserves the file position; previously it would change the file position to the end of the new file. (Fixed by Pascal Chambon; issue 6939.)

- New function: `itertools.compress(data, selectors)` takes two iterators. Elements of `data` are returned if the corresponding value in `selectors` is true:

  ```python
  itertools.compress('ABCDEF', [1,0,1,0,1,1]) => A, C, E, F
  ```

New function: `itertools.combinations_with_replacement(iter, r)`
returns all the possible $r$-length combinations of elements from the iterable `iter`. Unlike `combinations()`, individual elements can be repeated in the generated combinations:

```
import itertools

itertools.combinations_with_replacement('abc', 2)
# Output: [('a', 'a'), ('a', 'b'), ('a', 'c'),
# ('b', 'b'), ('b', 'c'), ('c', 'c')]
```

Note that elements are treated as unique depending on their position in the input, not their actual values.

The `itertools.count()` function now has a `step` argument that allows incrementing by values other than 1. `count()` also now allows keyword arguments, and using non-integer values such as floats or `Decimal` instances. (Implemented by Raymond Hettinger; issue 5032.)

`itertools.combinations()` and `itertools.product()` previously raised `ValueError` for values of $r$ larger than the input iterable. This was deemed a specification error, so they now return an empty iterator. (Fixed by Raymond Hettinger; issue 4816.)

- Updated module: The `json` module was upgraded to version 2.0.9 of the simplejson package, which includes a C extension that makes encoding and decoding faster. (Contributed by Bob Ippolito; issue 4136.)

To support the new `collections.OrderedDict` type, `json.load()` now has an optional `object_pairs_hook` parameter that will be called with any object literal that decodes to a list of pairs. (Contributed by Raymond Hettinger; issue 5381.)
The mailbox module’s Maildir class now records the timestamp on the directories it reads, and only re-reads them if the modification time has subsequently changed. This improves performance by avoiding unneeded directory scans. (Fixed by A.M. Kuchling and Antoine Pitrou; issue 1607951, issue 6896.)

New functions: the math module gained erf() and erfc() for the error function and the complementary error function, expm1() which computes e**x - 1 with more precision than using exp() and subtracting 1, gamma() for the Gamma function, and lgamma() for the natural log of the Gamma function. (Contributed by Mark Dickinson and nirinA raseliarison; issue 3366.)

The multiprocessing module’s Manager* classes can now be passed a callable that will be called whenever a subprocess is started, along with a set of arguments that will be passed to the callable. (Contributed by lekma; issue 5585.)

The Pool class, which controls a pool of worker processes, now has an optional maxtasksperchild parameter. Worker processes will perform the specified number of tasks and then exit, causing the Pool to start a new worker. This is useful if tasks may leak memory or other resources, or if some tasks will cause the worker to become very large. (Contributed by Charles Cazabon; issue 6963.)

The nntplib module now supports IPv6 addresses. (Contributed by Derek Morr; issue 1664.)

New functions: the os module wraps the following POSIX system calls: getresgid() and getresuid(), which return the real, effective, and saved GIDs and UIDs; setresgid() and
`setresuid()` sets the real, effective, and saved GIDs and UIDs to new values; `initgroups()`, which initialize the group access list for the current process. (GID/UID functions contributed by Travis H.; issue 6508. Support for `initgroups` added by Jean-Paul Calderone; issue 7333.)

The `os.fork()` function now re-initializes the import lock in the child process; this fixes problems on Solaris when `fork()` is called from a thread. (Fixed by Zsolt Cserna; issue 7242.)

- In the `os.path` module, the `normpath()` and `abspath()` functions now preserve Unicode; if their input path is a Unicode string, the return value is also a Unicode string. (`normpath()` fixed by Matt Giuca in issue 5827; `abspath()` fixed by Ezio Melotti in issue 3426.)

- The `pydoc` module now has help for the various symbols that Python uses. You can now do `help('<<')` or `help('@')`, for example. (Contributed by David Laban; issue 4739.)

- The `re` module’s `split()`, `sub()`, and `subn()` now accept an optional `flags` argument, for consistency with the other functions in the module. (Added by Gregory P. Smith.)

- New function: `run_path()` in the `runpy` module will execute the code at a provided `path` argument. `path` can be the path of a Python source file (example.py), a compiled bytecode file (example.pyc), a directory (./package/), or a zip archive (example.zip). If a directory or zip path is provided, it will be added to the front of `sys.path` and the module `__main__` will be imported. It’s expected that the directory or zip contains a `__main__.py`; if it doesn’t, some other `__main__.py` might be
imported from a location later in sys.path. This makes more of the machinery of runpy available to scripts that want to mimic the way Python’s command line processes an explicit path name. (Added by Nick Coghlan; issue 6816.)

- New function: in the shutil module, make_archive() takes a filename, archive type (zip or tar-format), and a directory path, and creates an archive containing the directory’s contents. (Added by Tarek Ziadé.)

    shutil’s copyfile() and copytree() functions now raise a SpecialFileError exception when asked to copy a named pipe. Previously the code would treat named pipes like a regular file by opening them for reading, and this would block indefinitely. (Fixed by Antoine Pitrou; issue 3002.)

- The signal module no longer re-installs the signal handler unless this is truly necessary, which fixes a bug that could make it impossible to catch the EINTR signal robustly. (Fixed by Charles-François Natali; issue 8354.)

- New functions: in the site module, three new functions return various site- and user-specific paths. getsitepackages() returns a list containing all global site-packages directories, getusersitepackages() returns the path of the user’s site-packages directory, and getuserbase() returns the value of the USER_BASE environment variable, giving the path to a directory that can be used to store data. (Contributed by Tarek Ziadé; issue 6693.)

    The site module now reports exceptions occurring when the sitecustomize module is imported, and will no longer catch
and swallow the `KeyboardInterrupt` exception. (Fixed by Victor Stinner; issue 3137.)

- The `create_connection()` function gained a `source_address` parameter, a `(host, port)` 2-tuple giving the source address that will be used for the connection. (Contributed by Eldon Ziegler; issue 3972.)

The `recv_into()` and `recvfrom_into()` methods will now write into objects that support the buffer API, most usefully the `bytearray` and `memoryview` objects. (Implemented by Antoine Pitrou; issue 8104.)

- The `SocketServer` module’s `TCPServer` class now supports socket timeouts and disabling the Nagle algorithm. The `disable_nagle_algorithm` class attribute defaults to False; if overridden to be True, new request connections will have the `TCP_NODELAY` option set to prevent buffering many small sends into a single TCP packet. The `timeout` class attribute can hold a timeout in seconds that will be applied to the request socket; if no request is received within that time, `handle_timeout()` will be called and `handle_request()` will return. (Contributed by Kristján Valur Jónsson; issue 6192 and issue 6267.)

- Updated module: the `sqlite3` module has been updated to version 2.6.0 of the `pysqlite` package. Version 2.6.0 includes a number of bugfixes, and adds the ability to load SQLite extensions from shared libraries. Call the `enable_load_extension(True)` method to enable extensions, and then call `load_extension()` to load a particular shared library. (Updated by Gerhard Häring.)
- The `ssl` module's `SSLSocket` objects now support the buffer API, which fixed a test suite failure (fix by Antoine Pitrou; issue 7133) and automatically set OpenSSL's `SSL_MODE_AUTO_RETRY`, which will prevent an error code being returned from `recv()` operations that trigger an SSL renegotiation (fix by Antoine Pitrou; issue 8222).

The `ssl.wrap_socket()` constructor function now takes a `ciphers` argument that’s a string listing the encryption algorithms to be allowed; the format of the string is described in the OpenSSL documentation. (Added by Antoine Pitrou; issue 8322.)

Another change makes the extension load all of OpenSSL's ciphers and digest algorithms so that they're all available. Some SSL certificates couldn't be verified, reporting an “unknown algorithm” error. (Reported by Beda Kosata, and fixed by Antoine Pitrou; issue 8484.)

The version of OpenSSL being used is now available as the module attributes `ssl.OPENSSL_VERSION` (a string), `ssl.OPENSSL_VERSION_INFO` (a 5-tuple), and `ssl.OPENSSL_VERSION_NUMBER` (an integer). (Added by Antoine Pitrou; issue 8321.)

- The `struct` module will no longer silently ignore overflow errors when a value is too large for a particular integer format code (one of bBhHiIlLqQ); it now always raises a `struct.error` exception. (Changed by Mark Dickinson; issue 1523.) The `pack()` function will also attempt to use `__index__()` to convert and pack non-integers before trying the `__int__()` method or reporting an error. (Changed by Mark Dickinson; issue 8300.)
New function: the `subprocess` module's `check_output()` runs a command with a specified set of arguments and returns the command's output as a string when the command runs without error, or raises a `CalledProcessError` exception otherwise.

```python
>>> subprocess.check_output(['df', '-h', '.'])
'Filesystem    Size   Used  Avail  Capacity  Mounted on
/dev/disk0s2  52G   49G   3.0G    94%  /
'
>>> subprocess.check_output(['df', '-h', '/bogus'])
subprocess.CalledProcessError: Command '['df', '-h', '/bogus']' returned non-zero exit status 1
```

(Contributed by Gregory P. Smith.)

The `subprocess` module will now retry its internal system calls on receiving an EINTR signal. (Reported by several people; final patch by Gregory P. Smith in issue 1068268.)

- New function: `is_declared_global()` in the `symtable` module returns true for variables that are explicitly declared to be global, false for ones that are implicitly global. (Contributed by Jeremy Hylton.)

- The `syslog` module will now use the value of `sys.argv[0]` as the identifier instead of the previous default value of 'python'. (Changed by Sean Reifschneider; issue 8451.)

- The `sys.version_info` value is now a named tuple, with attributes named major, minor, micro, releaselevel, and serial. (Contributed by Ross Light; issue 4285.)

`sys.getwindowsversion()` also returns a named tuple, with
attributes named major, minor, build, platform, service_pack, service_pack_major, service_pack_minor, suite_mask, and product_type. (Contributed by Brian Curtin; issue 7766.)

- The `tarfile` module's default error handling has changed, to no longer suppress fatal errors. The default error level was previously 0, which meant that errors would only result in a message being written to the debug log, but because the debug log is not activated by default, these errors go unnoticed. The default error level is now 1, which raises an exception if there's an error. (Changed by Lars Gustäbel; issue 7357.)

  `tarfile` now supports filtering the `TarInfo` objects being added to a tar file. When you call `add()`, you may supply an optional `filter` argument that's a callable. The `filter` callable will be passed the `TarInfo` for every file being added, and can modify and return it. If the callable returns None, the file will be excluded from the resulting archive. This is more powerful than the existing `exclude` argument, which has therefore been deprecated. (Added by Lars Gustäbel; issue 6856.) The `TarFile` class also now supports the context management protocol. (Added by Lars Gustäbel; issue 7232.)

- The `wait()` method of the `threading.Event` class now returns the internal flag on exit. This means the method will usually return true because `wait()` is supposed to block until the internal flag becomes true. The return value will only be false if a timeout was provided and the operation timed out. (Contributed by Tim Lesher; issue 1674032.)

- The Unicode database provided by the `unicodedata` module is
now used internally to determine which characters are numeric, whitespace, or represent line breaks. The database also includes information from the Unihan.txt data file (patch by Anders Chrigström and Amaury Forgeot d'Arc; issue 1571184) and has been updated to version 5.2.0 (updated by Florent Xicluna; issue 8024).

- The urlparse module's urlsplit() now handles unknown URL schemes in a fashion compliant with RFC 3986: if the URL is of the form "<something>://...", the text before the :// is treated as the scheme, even if it's a made-up scheme that the module doesn't know about. This change may break code that worked around the old behaviour. For example, Python 2.6.4 or 2.5 will return the following:

```python
>>> import urlparse
>>> urlparse.urlsplit('invented://host/filename?query')
('invented', '', '//host/filename?query', '', '')
```

Python 2.7 (and Python 2.6.5) will return:

```python
>>> import urlparse
>>> urlparse.urlsplit('invented://host/filename?query')
('invented', 'host', '/filename?query', '', '')
```

(Python 2.7 actually produces slightly different output, since it returns a named tuple instead of a standard tuple.)

The urlparse module also supports IPv6 literal addresses as defined by RFC 2732 (contributed by Senthil Kumaran; issue 2987).
New class: the WeakSet class in the weakref module is a set that only holds weak references to its elements; elements will be removed once there are no references pointing to them. (Originally implemented in Python 3.x by Raymond Hettinger, and backported to 2.7 by Michael Foord.)

The ElementTree library, xml.etree, no longer escapes ampersands and angle brackets when outputting an XML processing instruction (which looks like `<?xml-stylesheet href="#style1"?>`) or comment (which looks like `<!-- comment -->`). (Patch by Neil Muller; issue 2746.)

The XML-RPC client and server, provided by the xmlrpcclib and SimpleXMLRPCServer modules, have improved performance by supporting HTTP/1.1 keep-alive and by optionally using gzip encoding to compress the XML being exchanged. The gzip compression is controlled by the encode_threshold attribute of SimpleXMLRPCRequestHandler, which contains a size in bytes; responses larger than this will be compressed. (Contributed by Kristján Valur Jónsson; issue 6267.)

The zipfile module's ZipFile now supports the context management protocol, so you can write with `zipfile.ZipFile(...) as f:`. (Contributed by Brian Curtin; issue 5511.)

zipfile now also supports archiving empty directories and extracts them correctly. (Fixed by Kuba Wieczorek; issue 4710.)
Reading files out of an archive is faster, and interleaving `read()` and `readline()` now works correctly. (Contributed by Nir Aides; issue 7610.)

The `is_zipfile()` function now accepts a file object, in addition to the path names accepted in earlier versions. (Contributed by Gabriel Genellina; issue 4756.)

The `writestr()` method now has an optional `compress_type` parameter that lets you override the default compression method specified in the `ZipFile` constructor. (Contributed by Ronald Oussoren; issue 6003.)

**New module: importlib**

Python 3.1 includes the `importlib` package, a re-implementation of the logic underlying Python's `import` statement. `importlib` is useful for implementors of Python interpreters and to users who wish to write new importers that can participate in the import process. Python 2.7 doesn't contain the complete `importlib` package, but instead has a tiny subset that contains a single function, `import_module()`.

`import_module(name, package=None)` imports a module. `name` is a string containing the module or package's name. It's possible to do relative imports by providing a string that begins with a . character, such as `.utils.errors`. For relative imports, the `package` argument must be provided and is the name of the package that will be used as the anchor for the relative import. `import_module()` both inserts the imported module into `sys.modules` and returns the module object.

Here are some examples:
importlib was implemented by Brett Cannon and introduced in Python 3.1.

New module: sysconfig

The sysconfig module has been pulled out of the Distutils package, becoming a new top-level module in its own right. sysconfig provides functions for getting information about Python’s build process: compiler switches, installation paths, the platform name, and whether Python is running from its source directory.

Some of the functions in the module are:

- **get_config_var()** returns variables from Python’s Makefile and the pyconfig.h file.
- **get_config_vars()** returns a dictionary containing all of the configuration variables.
- **get_path()** returns the configured path for a particular type of module: the standard library, site-specific modules, platform-specific modules, etc.
- **is_python_build()** returns true if you’re running a binary from a Python source tree, and false otherwise.

Consult the sysconfig documentation for more details and for a
complete list of functions.

The Distutils package and sysconfig are now maintained by Tarek Ziadé, who has also started a Distutils2 package (source repository at https://hg.python.org/distutils2/) for developing a next-generation version of Distutils.

**ttk: Themed Widgets for Tk**

Tcl/Tk 8.5 includes a set of themed widgets that re-implement basic Tk widgets but have a more customizable appearance and can therefore more closely resemble the native platform's widgets. This widget set was originally called Tile, but was renamed to Ttk (for “themed Tk”) on being added to Tcl/Tk release 8.5.

To learn more, read the ttk module documentation. You may also wish to read the Tcl/Tk manual page describing the Ttk theme engine, available at http://www.tcl.tk/man/tcl8.5/TkCmd/ttk_intro.htm. Some screenshots of the Python/Ttk code in use are at http://code.google.com/p/python-ttk/wiki/Screenshots.

The ttk module was written by Guilherme Polo and added in issue 2983. An alternate version called Tile.py, written by Martin Franklin and maintained by Kevin Walzer, was proposed for inclusion in issue 2618, but the authors argued that Guilherme Polo's work was more comprehensive.

**Updated module: unittest**

The unittest module was greatly enhanced; many new features were added. Most of these features were implemented by Michael Foord, unless otherwise noted. The enhanced version of the module is
downloadable separately for use with Python versions 2.4 to 2.6, packaged as the unittest2 package, from https://pypi.python.org/pypi/unittest2.

When used from the command line, the module can automatically discover tests. It's not as fancy as py.test or nose, but provides a simple way to run tests kept within a set of package directories. For example, the following command will search the test/ subdirectory for any importable test files named test*.py:

```
python -m unittest discover -s test
```

Consult the unittest module documentation for more details. (Developed in issue 6001.)

The main() function supports some other new options:

- `-b` or `--buffer` will buffer the standard output and standard error streams during each test. If the test passes, any resulting output will be discarded; on failure, the buffered output will be displayed.

- `-c` or `--catch` will cause the control-C interrupt to be handled more gracefully. Instead of interrupting the test process immediately, the currently running test will be completed and then the partial results up to the interruption will be reported. If you're impatient, a second press of control-C will cause an immediate interruption.

This control-C handler tries to avoid causing problems when the code being tested or the tests being run have defined a signal handler of their own, by noticing that a signal handler was already set and calling it. If this doesn't work for you, there's a
removeHandler() decorator that can be used to mark tests that should have the control-C handling disabled.

- -f or --failfast makes test execution stop immediately when a test fails instead of continuing to execute further tests. (Suggested by Cliff Dyer and implemented by Michael Foord; issue 8074.)

The progress messages now show ‘x’ for expected failures and ‘u’ for unexpected successes when run in verbose mode. (Contributed by Benjamin Peterson.)

Test cases can raise the SkipTest exception to skip a test (issue 1034053).

The error messages for assertEqual(), assertTrue(), and assertFalse() failures now provide more information. If you set the longMessage attribute of your TestCase classes to True, both the standard error message and any additional message you provide will be printed for failures. (Added by Michael Foord; issue 5663.)

The assertRaises() method now returns a context handler when called without providing a callable object to run. For example, you can write this:

```python
with self.assertRaises(KeyError):
    {}['foo']
```

(Implemented by Antoine Pitrou; issue 4444.)

Module- and class-level setup and teardown fixtures are now supported. Modules can contain setUpModule() and tearDownModule() functions. Classes can have setUpClass()
and `tearDownClass()` methods that must be defined as class methods (using `@classmethod` or equivalent). These functions and methods are invoked when the test runner switches to a test case in a different module or class.

The methods `addCleanup()` and `doCleanups()` were added. `addCleanup()` lets you add cleanup functions that will be called unconditionally (after `setUp()` if `setUp()` fails, otherwise after `tearDown()`). This allows for much simpler resource allocation and deallocation during tests (issue 5679).

A number of new methods were added that provide more specialized tests. Many of these methods were written by Google engineers for use in their test suites; Gregory P. Smith, Michael Foord, and GvR worked on merging them into Python's version of `unittest`.

- `assertIsNone()` and `assertIsNotNone()` take one expression and verify that the result is or is not None.
- `assertIs()` and `assertIsNot()` take two values and check whether the two values evaluate to the same object or not. (Added by Michael Foord; issue 2578.)
- `assertIsInstance()` and `assertNotIsInstance()` check whether the resulting object is an instance of a particular class, or of one of a tuple of classes. (Added by Georg Brandl; issue 7031.)
- `assertGreater()`, `assertGreaterEqual()`, `assertLess()`, and `assertLessEqual()` compare two quantities.
- `assertMultiLineEqual()` compares two strings, and if they're not equal, displays a helpful comparison that highlights the differences in the two strings. This comparison is now used by default when Unicode strings are compared with `assertEqual()`.
- `assertRegexpMatches()` and `assertNotRegexpMatches()`
checks whether the first argument is a string matching or not matching the regular expression provided as the second argument (issue 8038).

- `assertRaisesRegexp()` checks whether a particular exception is raised, and then also checks that the string representation of the exception matches the provided regular expression.
- `assertIn()` and `assertNotIn()` tests whether `first` is or is not in `second`.
- `assertItemsEqual()` tests whether two provided sequences contain the same elements.
- `assertSetEqual()` compares whether two sets are equal, and only reports the differences between the sets in case of error.
- Similarly, `assertListEqual()` and `assertTupleEqual()` compare the specified types and explain any differences without necessarily printing their full values; these methods are now used by default when comparing lists and tuples using `assertEqual()`. More generally, `assertSequenceEqual()` compares two sequences and can optionally check whether both sequences are of a particular type.
- `assertDictEqual()` compares two dictionaries and reports the differences; it's now used by default when you compare two dictionaries using `assertEqual()`. `assertDictContainsSubset()` checks whether all of the key/value pairs in `first` are found in `second`.
- `assertAlmostEqual()` and `assertNotAlmostEqual()` test whether `first` and `second` are approximately equal. This method can either round their difference to an optionally-specified number of places (the default is 7) and compare it to zero, or require the difference to be smaller than a supplied `delta` value.
- `loadTestsFromName()` properly honors the `suiteClass` attribute of the `TestLoader`. (Fixed by Mark Roddy; issue 6866.)
- A new hook lets you extend the `assertEqual()` method to handle new data types. The `addTypeEqualityFunc()` method
takes a type object and a function. The function will be used when both of the objects being compared are of the specified type. This function should compare the two objects and raise an exception if they don’t match; it’s a good idea for the function to provide additional information about why the two objects aren’t matching, much as the new sequence comparison methods do.

unittest.main() now takes an optional exit argument. If False, main() doesn't call sys.exit(), allowing main() to be used from the interactive interpreter. (Contributed by J. Pablo Fernández; issue 3379.)

TestResult has new startTestRun() and stopTestRun() methods that are called immediately before and after a test run. (Contributed by Robert Collins; issue 5728.)

With all these changes, the unittest.py was becoming awkwardly large, so the module was turned into a package and the code split into several files (by Benjamin Peterson). This doesn’t affect how the module is imported or used.

See also:

http://www.voidspace.org.uk/python/articles/unittest2.shtml

Describes the new features, how to use them, and the rationale for various design decisions. (By Michael Foord.)

Updated module: ElementTree 1.3

The version of the ElementTree library included with Python was updated to version 1.3. Some of the new features are:

- The various parsing functions now take a parser keyword
argument giving an **XMLParser** instance that will be used. This makes it possible to override the file’s internal encoding:

```python
p = ET.XMLParser(encoding='utf-8')
t = ET.XML("""<root/>"""", parser=p)
```

Errors in parsing XML now raise a **ParseError** exception, whose instances have a `position` attribute containing a `(line, column)` tuple giving the location of the problem.

- ElementTree’s code for converting trees to a string has been significantly reworked, making it roughly twice as fast in many cases. The **ElementTree.write()** and **Element.write()** methods now have a `method` parameter that can be “xml” (the default), “html”, or “text”. HTML mode will output empty elements as `<empty></empty>` instead of `<empty/>`, and text mode will skip over elements and only output the text chunks. If you set the `tag` attribute of an element to `None` but leave its children in place, the element will be omitted when the tree is written out, so you don’t need to do more extensive rearrangement to remove a single element.

Namespace handling has also been improved. All `xmlns:<whatever>` declarations are now output on the root element, not scattered throughout the resulting XML. You can set the default namespace for a tree by setting the `default_namespace` attribute and can register new prefixes with **register_namespace()**. In XML mode, you can use the true/false `xml_declaration` parameter to suppress the XML declaration.

- New **Element** method: **extend()** appends the items from a
sequence to the element’s children. Elements themselves behave like sequences, so it’s easy to move children from one element to another:

```python
from xml.etree import ElementTree as ET

t = ET.XML("""<list>
    <item>1</item> <item>2</item> <item>3</item>
</list>"""
new = ET.XML('<root/>')
new.extend(t)

# Outputs <root><item>1</item>...</root>
print ET.tostring(new)
```

- New Element method: `iter()` yields the children of the element as a generator. It’s also possible to write `for child in elem:` to loop over an element’s children. The existing method `getiterator()` is now deprecated, as is `getchildren()` which constructs and returns a list of children.

- New Element method: `itertext()` yields all chunks of text that are descendants of the element. For example:

```python
t = ET.XML("""<list>
    <item>1</item> <item>2</item> <item>3</item>
</list>"""

# Outputs ['\n ', '1', ' ', '2', ' ', '3', ' \n
print list(t.itertext())
```

- Deprecated: using an element as a Boolean (i.e., `if elem:`) would return true if the element had any children, or false if there were no children. This behaviour is confusing – None is false, but
so is a childless element? – so it will now trigger a \texttt{FutureWarning}. In your code, you should be explicit: write \texttt{len(elem) \neq 0} if you’re interested in the number of children, or \texttt{elem is not None}.

Fredrik Lundh develops ElementTree and produced the 1.3 version; you can read his article describing 1.3 at \url{http://effbot.org/zone/elementtree-13-intro.htm}. Florent Xicluna updated the version included with Python, after discussions on python-dev and in issue 6472.)
Build and C API Changes

Changes to Python’s build process and to the C API include:

- The latest release of the GNU Debugger, GDB 7, can be scripted using Python. When you begin debugging an executable program P, GDB will look for a file named P-gdb.py and automatically read it. Dave Malcolm contributed a python-gdb.py that adds a number of commands useful when debugging Python itself. For example, py-up and py-down go up or down one Python stack frame, which usually corresponds to several C stack frames. py-print prints the value of a Python variable, and py-bt prints the Python stack trace. (Added as a result of issue 8032.)

- If you use the .gdbinit file provided with Python, the “pyo” macro in the 2.7 version now works correctly when the thread being debugged doesn’t hold the GIL; the macro now acquires it before printing. (Contributed by Victor Stinner; issue 3632.)

- Py_AddPendingCall() is now thread-safe, letting any worker thread submit notifications to the main Python thread. This is particularly useful for asynchronous IO operations. (Contributed by Kristján Valur Jónsson; issue 4293.)

- New function: PyCode_NewEmpty() creates an empty code object; only the filename, function name, and first line number are required. This is useful for extension modules that are attempting to construct a more useful traceback stack. Previously such extensions needed to call PyCode_New(), which had many more arguments. (Added by Jeffrey Yasskin.)

- New function: PyErr_NewExceptionWithDoc() creates a new
exception class, just as the existing `PyErr_NewException()`
does, but takes an extra char * argument containing the
docstring for the new exception class. (Added by 'lekma' on the
Python bug tracker; issue 7033.)

- New function: `PyFrame_GetLineNumber()` takes a frame
  object and returns the line number that the frame is currently
  executing. Previously code would need to get the index of the
  bytecode instruction currently executing, and then look up the line
  number corresponding to that address. (Added by Jeffrey
  Yasskin.)

- New functions: `PyLong_AsLongAndOverflow()` and
  `PyLong_AsLongLongAndOverflow()` approximates a Python
  long integer as a C long or long long. If the number is too
  large to fit into the output type, an overflow flag is set and returned
  to the caller. (Contributed by Case Van Horsen; issue 7528 and
  issue 7767.)

- New function: stemming from the rewrite of string-to-float
  conversion, a new `PyOS_string_to_double()` function was
  added. The old `PyOS_ascii_strtod()` and
  `PyOS_ascii_atof()` functions are now deprecated.

- New function: `PySys_SetArgvEx()` sets the value of sys.argv
  and can optionally update sys.path to include the directory
  containing the script named by sys.argv[0] depending on the
  value of an updatepath parameter.

This function was added to close a security hole for applications
that embed Python. The old function, `PySys_SetArgv()`, would
always update sys.path, and sometimes it would add the
current directory. This meant that, if you ran an application embedding Python in a directory controlled by someone else, attackers could put a Trojan-horse module in the directory (say, a file named os.py) that your application would then import and run.

If you maintain a C/C++ application that embeds Python, check whether you're calling `PySys_SetArgv()` and carefully consider whether the application should be using `PySys_SetArgvEx()` with `updatepath` set to false.

Security issue reported as CVE-2008-5983; discussed in issue 5753, and fixed by Antoine Pitrou.

- New macros: the Python header files now define the following macros: `Py_ISALNUM`, `Py_ISALPHA`, `Py_ISDIGIT`, `Py_ISLOWER`, `Py_ISSPACE`, `Py_ISUPPER`, `Py_ISXDIGIT`, `Py_TOLOWER`, and `Py_TOUPPER`. All of these functions are analogous to the C standard macros for classifying characters, but ignore the current locale setting, because in several places Python needs to analyze characters in a locale-independent way. (Added by Eric Smith; issue 5793.)

- Removed function: `PyEval_CallObject` is now only available as a macro. A function version was being kept around to preserve ABI linking compatibility, but that was in 1997; it can certainly be deleted by now. (Removed by Antoine Pitrou; issue 8276.)

- New format codes: the `PyFormat_FromString()`, `PyFormat_FromStringV()`, and `PyErr_Format()` functions now accept `%lld` and `%llu` format codes for displaying C's `long long` types. (Contributed by Mark Dickinson; issue 7228.)
- The complicated interaction between threads and process forking has been changed. Previously, the child process created by \texttt{os.fork()} might fail because the child is created with only a single thread running, the thread performing the \texttt{os.fork()}. If other threads were holding a lock, such as Python's import lock, when the fork was performed, the lock would still be marked as “held” in the new process. But in the child process nothing would ever release the lock, since the other threads weren't replicated, and the child process would no longer be able to perform imports.

  Python 2.7 acquires the import lock before performing an \texttt{os.fork()}, and will also clean up any locks created using the \texttt{threading} module. C extension modules that have internal locks, or that call \texttt{fork()} themselves, will not benefit from this clean-up.

  (Fixed by Thomas Wouters; issue 1590864.)

- The \texttt{Py_Finalize()} function now calls the internal \texttt{threading._shutdown()} function; this prevents some exceptions from being raised when an interpreter shuts down. (Patch by Adam Olsen; issue 1722344.)

- When using the \texttt{PyMemberDef} structure to define attributes of a type, Python will no longer let you try to delete or set a \texttt{T\_STRING\_INPLACE} attribute.

- Global symbols defined by the \texttt{ctypes} module are now prefixed with \texttt{Py}, or with \texttt{\_ctypes}. (Implemented by Thomas Heller; issue 3102.)

- New configure option: the \texttt{--with-system-expat} switch allows
building the pyexpat module to use the system Expat library. (Contributed by Arfrever Frehtes Taifersar Arahesis; issue 7609.)

- New configure option: the --with-valgrind option will now disable the pymalloc allocator, which is difficult for the Valgrind memory-error detector to analyze correctly. Valgrind will therefore be better at detecting memory leaks and overruns. (Contributed by James Henstridge; issue 2422.)

- New configure option: you can now supply an empty string to --with-dbmliborder= in order to disable all of the various DBM modules. (Added by Arfrever Frehtes Taifersar Arahesis; issue 6491.)

- The configure script now checks for floating-point rounding bugs on certain 32-bit Intel chips and defines a X87_DOUBLE_ROUNDING preprocessor definition. No code currently uses this definition, but it’s available if anyone wishes to use it. (Added by Mark Dickinson; issue 2937.)

configure also now sets a LDCXXSHARED Makefile variable for supporting C++ linking. (Contributed by Arfrever Frehtes Taifersar Arahesis; issue 1222585.)

- The build process now creates the necessary files for pkg-config support. (Contributed by Clinton Roy; issue 3585.)

- The build process now supports Subversion 1.7. (Contributed by Arfrever Frehtes Taifersar Arahesis; issue 6094.)

Capsules

Python 3.1 adds a new C datatype, PyCapsule, for providing a C API
to an extension module. A capsule is essentially the holder of a C void * pointer, and is made available as a module attribute; for example, the socket module's API is exposed as socket.CAPI, and unicodedata exposes ucnhash_CAPI. Other extensions can import the module, access its dictionary to get the capsule object, and then get the void * pointer, which will usually point to an array of pointers to the module's various API functions.

There is an existing data type already used for this, PyCObject, but it doesn’t provide type safety. Evil code written in pure Python could cause a segmentation fault by taking a PyCObject from module A and somehow substituting it for the PyCObject in module B. Capsules know their own name, and getting the pointer requires providing the name:

```c
void *vtable;

if (!PyCapsule_IsValid(capsule, "mymodule.CAPI") {
    PyErr_SetString(PyExc_ValueError, "argument type invalid");
    return NULL;
}

vtable = PyCapsule_GetPointer(capsule, "mymodule.CAPI");
```

You are assured that vtable points to whatever you’re expecting. If a different capsule was passed in, PyCapsule_IsValid() would detect the mismatched name and return false. Refer to Providing a C API for an Extension Module for more information on using these objects.

Python 2.7 now uses capsules internally to provide various extension-module APIs, but the PyCObject_AsVoidPtr() was modified to
handle capsules, preserving compile-time compatibility with the CObject interface. Use of PyObject_AsVoidPtr() will signal a PendingDeprecationWarning, which is silent by default.

Implemented in Python 3.1 and backported to 2.7 by Larry Hastings; discussed in issue 5630.

**Port-Specific Changes: Windows**

- The msvcrtd module now contains some constants from the crtassem.h header file: CRT_ASSEMBLY_VERSION, VC_ASSEMBLY_PUBLICKEYTOKEN, and LIBRARIES_ASSEMBLY_NAME_PREFIX. (Contributed by David Cournapeau; issue 4365.)
- The _winreg module for accessing the registry now implements the CreateKeyEx() and DeleteKeyEx() functions, extended versions of previously-supported functions that take several extra arguments. The DisableReflectionKey(), EnableReflectionKey(), and QueryReflectionKey() were also tested and documented. (Implemented by Brian Curtin: issue 7347.)
- The new _beginthreadex() API is used to start threads, and the native thread-local storage functions are now used. (Contributed by Kristján Valur Jónsson; issue 3582.)
- The os.kill() function now works on Windows. The signal value can be the constants CTRL_C_EVENT, CTRL_BREAK_EVENT, or any integer. The first two constants will send Control-C and Control-Break keystroke events to subprocesses; any other value will use the TerminateProcess() API. (Contributed by Miki Tebeka; issue 1220212.)
- The os.listdir() function now correctly fails for an empty
The mimelib module will now read the MIME database from the Windows registry when initializing. (Patch by Gabriel Genellina; issue 4969.)

Port-Specific Changes: Mac OS X

- The path /Library/Python/2.7/site-packages is now appended to sys.path, in order to share added packages between the system installation and a user-installed copy of the same version. (Changed by Ronald Oussoren; issue 4865.)

Port-Specific Changes: FreeBSD

- FreeBSD 7.1's SO_SETFIB constant, used with getsockopt()/setsockopt() to select an alternate routing table, is now available in the socket module. (Added by Kyle VanderBeek; issue 8235.)
Other Changes and Fixes

- Two benchmark scripts, iobench and ccbench, were added to the Tools directory. iobench measures the speed of the built-in file I/O objects returned by `open()` while performing various operations, and ccbench is a concurrency benchmark that tries to measure computing throughput, thread switching latency, and IO processing bandwidth when performing several tasks using a varying number of threads.

- The Tools/i18n/msgfmt.py script now understands plural forms in .po files. (Fixed by Martin von Löwis; issue 5464.)

- When importing a module from a .pyc or .pyo file with an existing .py counterpart, the co_filename attributes of the resulting code objects are overwritten when the original filename is obsolete. This can happen if the file has been renamed, moved, or is accessed through different paths. (Patch by Ziga Seilnacht and Jean-Paul Calderone; issue 1180193.)

- The regrtest.py script now takes a `-randseed=` switch that takes an integer that will be used as the random seed for the `-r` option that executes tests in random order. The `-r` option also reports the seed that was used (Added by Collin Winter.)

- Another regrtest.py switch is `-j`, which takes an integer specifying how many tests run in parallel. This allows reducing the total runtime on multi-core machines. This option is compatible with several other options, including the `-R` switch which is known to produce long runtimes. (Added by Antoine Pitrou; issue 6152.) This can also be used with a new `-F` switch that runs selected tests in a loop until they fail. (Added by Antoine Pitrou; issue 7312.)

- When executed as a script, the py_compile.py module now accepts `'- '` as an argument, which will read standard input for the list of filenames to be compiled. (Contributed by Piotr
Ożarowski; issue 8233.)
Porting to Python 2.7

This section lists previously described changes and other bugfixes that may require changes to your code:

- The `range()` function processes its arguments more consistently; it will now call `__int__()` on non-float, non-integer arguments that are supplied to it. (Fixed by Alexander Belopolsky; issue 1533.)
- The string `format()` method changed the default precision used for floating-point and complex numbers from 6 decimal places to 12, which matches the precision used by `str()`. (Changed by Eric Smith; issue 5920.)
- Because of an optimization for the `with` statement, the special methods `__enter__()` and `__exit__()` must belong to the object's type, and cannot be directly attached to the object's instance. This affects new-style classes (derived from `object`) and C extension types. (issue 6101.)
- Due to a bug in Python 2.6, the `exc_value` parameter to `__exit__()` methods was often the string representation of the exception, not an instance. This was fixed in 2.7, so `exc_value` will be an instance as expected. (Fixed by Florent Xicluna; issue 7853.)
- When a restricted set of attributes were set using `__slots__`, deleting an unset attribute would not raise `AttributeError` as you would expect. Fixed by Benjamin Peterson; issue 7604.)

In the standard library:

- Operations with `datetime` instances that resulted in a year falling outside the supported range didn't always raise `OverflowError`. Such errors are now checked more carefully and will now raise
the exception. (Reported by Mark Leander, patch by Anand B. Pillai and Alexander Belopolsky; issue 7150.)

- When using Decimal instances with a string's format() method, the default alignment was previously left-alignment. This has been changed to right-alignment, which might change the output of your programs. (Changed by Mark Dickinson; issue 6857.)

Comparisons involving a signaling NaN value (or sNAN) now signal InvalidOperation instead of silently returning a true or false value depending on the comparison operator. Quiet NaN values (or NaN) are now hashable. (Fixed by Mark Dickinson; issue 7279.)

- The ElementTree library, xml.etree, no longer escapes ampersands and angle brackets when outputting an XML processing instruction (which looks like <\!\-\!xml-stylesheet href="\#style1"\?>) or comment (which looks like <\!\-\!– comment –>). (Patch by Neil Muller; issue 2746.)

- The readline() method of StringIO objects now does nothing when a negative length is requested, as other file-like objects do. (issue 7348).

- The syslog module will now use the value of sys.argv[0] as the identifier instead of the previous default value of 'python'. (Changed by Sean Reifschneider; issue 8451.)

- The tarfile module's default error handling has changed, to no longer suppress fatal errors. The default error level was previously 0, which meant that errors would only result in a message being written to the debug log, but because the debug log is not
activated by default, these errors go unnoticed. The default error level is now 1, which raises an exception if there's an error. (Changed by Lars Gustäbel; issue 7357.)

- The urlparse module's urlsplit() now handles unknown URL schemes in a fashion compliant with RFC 3986: if the URL is of the form "<something>://...", the text before the :// is treated as the scheme, even if it's a made-up scheme that the module doesn't know about. This change may break code that worked around the old behaviour. For example, Python 2.6.4 or 2.5 will return the following:

```python
>>> import urlparse
>>> urlparse.urlsplit('invented://host/filename?query')
('invented', '', '//host/filename?query', '', '')
```

Python 2.7 (and Python 2.6.5) will return:

```python
>>> import urlparse
>>> urlparse.urlsplit('invented://host/filename?query')
('invented', 'host', '/filename?query', '', '')
```

(Python 2.7 actually produces slightly different output, since it returns a named tuple instead of a standard tuple.)

For C extensions:

- C extensions that use integer format codes with the PyArg_Parse* family of functions will now raise a TypeError exception instead of triggering a DeprecationWarning (issue 5080).
- Use the new PyOS_string_to_double() function instead of the old PyOS_ascii_strtod() and PyOS_ascii_atof()
functions, which are now deprecated.

For applications that embed Python:

- The `PySys_SetArgvEx()` function was added, letting applications close a security hole when the existing `PySys_SetArgv()` function was used. Check whether you're calling `PySys_SetArgv()` and carefully consider whether the application should be using `PySys_SetArgvEx()` with `updatepath` set to false.
New Features Added to Python 2.7 Maintenance Releases

New features may be added to Python 2.7 maintenance releases when the situation genuinely calls for it. Any such additions must go through the Python Enhancement Proposal process, and make a compelling case for why they can't be adequately addressed by either adding the new feature solely to Python 3, or else by publishing it on the Python Package Index.

In addition to the specific proposals listed below, there is a general exemption allowing new -3 warnings to be added in any Python 2.7 maintenance release.

PEP 434: IDLE Enhancement Exception for All Branches

PEP 434 describes a general exemption for changes made to the IDLE development environment shipped along with Python. This exemption makes it possible for the IDLE developers to provide a more consistent user experience across all supported versions of Python 2 and 3.

For details of any IDLE changes, refer to the NEWS file for the specific release.

PEP 466: Network Security Enhancements for Python 2.7

PEP 466 describes a number of network security enhancement
proposals that have been approved for inclusion in Python 2.7 maintenance releases, with the first of those changes appearing in the Python 2.7.7 release.

**PEP 466** related features added in Python 2.7.7:

- `hmac.compare_digest()` was backported from Python 3 to make a timing attack resistant comparison operation available to Python 2 applications. (Contributed by Alex Gaynor; issue 21306.)
- OpenSSL 1.0.1g was upgraded in the official Windows installers published on python.org. (Contributed by Zachary Ware; issue 21462.)

**PEP 466** related features added in Python 2.7.8:

- `hashlib.pbkdf2_hmac()` was backported from Python 3 to make a hashing algorithm suitable for secure password storage broadly available to Python 2 applications. (Contributed by Alex Gaynor; issue 21304.)
- OpenSSL 1.0.1h was upgraded for the official Windows installers published on python.org. (contributed by Zachary Ware in issue 21671 for CVE-2014-0224)

**PEP 466** related features added in Python 2.7.9:

- Most of Python 3.4’s `ssl` module was backported. This means `ssl` now supports Server Name Indication, TLS1.x settings, access to the platform certificate store, the `SSLContext` class, and other features. (Contributed by Alex Gaynor and David Reid; issue 21308.)
- `os.urandom()` was changed to cache a file descriptor to `/dev/urandom` instead of reopening `/dev/urandom` on every call. (Contributed by Alex Gaynor; issue 21305.)
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What’s New in Python 2.6

Author: A.M. Kuchling (amk at amk.ca)

This article explains the new features in Python 2.6, released on October 1 2008. The release schedule is described in PEP 361.

The major theme of Python 2.6 is preparing the migration path to Python 3.0, a major redesign of the language. Whenever possible, Python 2.6 incorporates new features and syntax from 3.0 while remaining compatible with existing code by not removing older features or syntax. When it’s not possible to do that, Python 2.6 tries to do what it can, adding compatibility functions in a future_builtins module and a -3 switch to warn about usages that will become unsupported in 3.0.

Some significant new packages have been added to the standard library, such as the multiprocessing and json modules, but there aren’t many new features that aren’t related to Python 3.0 in some way.

Python 2.6 also sees a number of improvements and bugfixes throughout the source. A search through the change logs finds there were 259 patches applied and 612 bugs fixed between Python 2.5 and 2.6. Both figures are likely to be underestimates.

This article doesn’t attempt to provide a complete specification of the new features, but instead provides a convenient overview. For full details, you should refer to the documentation for Python 2.6. If you want to understand the rationale for the design and implementation, refer to the PEP for a particular new feature. Whenever possible, “What’s New in Python” links to the bug/patch item for each change.
Python 3.0

The development cycle for Python versions 2.6 and 3.0 was synchronized, with the alpha and beta releases for both versions being made on the same days. The development of 3.0 has influenced many features in 2.6.

Python 3.0 is a far-ranging redesign of Python that breaks compatibility with the 2.x series. This means that existing Python code will need some conversion in order to run on Python 3.0. However, not all the changes in 3.0 necessarily break compatibility. In cases where new features won’t cause existing code to break, they’ve been backported to 2.6 and are described in this document in the appropriate place. Some of the 3.0-derived features are:

- A `__complex__() method for converting objects to a complex number.
- Alternate syntax for catching exceptions: except TypeError as exc.
- The addition of `functools.reduce()` as a synonym for the built-in `reduce()` function.

Python 3.0 adds several new built-in functions and changes the semantics of some existing builtins. Functions that are new in 3.0 such as `bin()` have simply been added to Python 2.6, but existing builtins haven’t been changed; instead, the `future_builtins` module has versions with the new 3.0 semantics. Code written to be compatible with 3.0 can do from `future_builtins import hex, map as necessary.

A new command-line switch, -3, enables warnings about features that will be removed in Python 3.0. You can run code with this switch to see
how much work will be necessary to port code to 3.0. The value of this switch is available to Python code as the boolean variable `sys.py3kwarning`, and to C extension code as `Py_Py3kWarningFlag`.

**See also:** The 3xxx series of PEPs, which contains proposals for Python 3.0. PEP 3000 describes the development process for Python 3.0. Start with PEP 3100 that describes the general goals for Python 3.0, and then explore the higher-numbered PEPS that propose specific features.
Changes to the Development Process

While 2.6 was being developed, the Python development process underwent two significant changes: we switched from SourceForge's issue tracker to a customized Roundup installation, and the documentation was converted from LaTeX to reStructuredText.

New Issue Tracker: Roundup

For a long time, the Python developers had been growing increasingly annoyed by SourceForge's bug tracker. SourceForge's hosted solution doesn't permit much customization; for example, it wasn't possible to customize the life cycle of issues.

The infrastructure committee of the Python Software Foundation therefore posted a call for issue trackers, asking volunteers to set up different products and import some of the bugs and patches from SourceForge. Four different trackers were examined: Jira, Launchpad, Roundup, and Trac. The committee eventually settled on Jira and Roundup as the two candidates. Jira is a commercial product that offers no-cost hosted instances to free-software projects; Roundup is an open-source project that requires volunteers to administer it and a server to host it.

After posting a call for volunteers, a new Roundup installation was set up at https://bugs.python.org. One installation of Roundup can host multiple trackers, and this server now also hosts issue trackers for Jython and for the Python web site. It will surely find other uses in the future. Where possible, this edition of “What’s New in Python” links to the bug/patch item for each change.
Hosting of the Python bug tracker is kindly provided by Upfront Systems of Stellenbosch, South Africa. Martin von Löwis put a lot of effort into importing existing bugs and patches from SourceForge; his scripts for this import operation are at http://svn.python.org/view/tracker/importer/ and may be useful to other projects wishing to move from SourceForge to Roundup.

See also:

https://bugs.python.org
  The Python bug tracker.

http://bugs.jython.org:
  The Jython bug tracker.

http://roundup.sourceforge.net/
  Roundup downloads and documentation.

http://svn.python.org/view/tracker/importer/
  Martin von Löwis’s conversion scripts.

New Documentation Format: reStructuredText
Using Sphinx

The Python documentation was written using LaTeX since the project started around 1989. In the 1980s and early 1990s, most documentation was printed out for later study, not viewed online. LaTeX was widely used because it provided attractive printed output while remaining straightforward to write once the basic rules of the markup were learned.

Today LaTeX is still used for writing publications destined for printing, but the landscape for programming tools has shifted. We no longer print out reams of documentation; instead, we browse through it online
and HTML has become the most important format to support. Unfortunately, converting LaTeX to HTML is fairly complicated and Fred L. Drake Jr., the long-time Python documentation editor, spent a lot of time maintaining the conversion process. Occasionally people would suggest converting the documentation into SGML and later XML, but performing a good conversion is a major task and no one ever committed the time required to finish the job.

During the 2.6 development cycle, Georg Brandl put a lot of effort into building a new toolchain for processing the documentation. The resulting package is called Sphinx, and is available from http://sphinx.pocoo.org/.

Sphinx concentrates on HTML output, producing attractively styled and modern HTML; printed output is still supported through conversion to LaTeX. The input format is reStructuredText, a markup syntax supporting custom extensions and directives that is commonly used in the Python community.

Sphinx is a standalone package that can be used for writing, and almost two dozen other projects (listed on the Sphinx web site) have adopted Sphinx as their documentation tool.

See also:

- **Documenting Python**
  Describes how to write for Python’s documentation.

- **Sphinx**
  Documentation and code for the Sphinx toolchain.

- **Docutils**
  The underlying reStructuredText parser and toolset.
PEP 343: The ‘with’ statement

The previous version, Python 2.5, added the ‘with’ statement as an optional feature, to be enabled by a from __future__ import with_statement directive. In 2.6 the statement no longer needs to be specially enabled; this means that with is now always a keyword. The rest of this section is a copy of the corresponding section from the “What’s New in Python 2.5” document; if you’re familiar with the ‘with’ statement from Python 2.5, you can skip this section.

The ‘with’ statement clarifies code that previously would use try...finally blocks to ensure that clean-up code is executed. In this section, I’ll discuss the statement as it will commonly be used. In the next section, I’ll examine the implementation details and show how to write objects for use with this statement.

The ‘with’ statement is a control-flow structure whose basic structure is:

```
with expression [as variable]:
  with-block
```

The expression is evaluated, and it should result in an object that supports the context management protocol (that is, has __enter__() and __exit__() methods).

The object's __enter__() is called before with-block is executed and therefore can run set-up code. It also may return a value that is bound to the name variable, if given. (Note carefully that variable is not assigned the result of expression.)

After execution of the with-block is finished, the object's __exit__()}
method is called, even if the block raised an exception, and can therefore run clean-up code.

Some standard Python objects now support the context management protocol and can be used with the 'with' statement. File objects are one example:

```python
with open('/etc/passwd', 'r') as f:
    for line in f:
        print line
... more processing code ...
```

After this statement has executed, the file object in f will have been automatically closed, even if the for loop raised an exception part-way through the block.

**Note:** In this case, f is the same object created by `open()`, because file.__enter__() returns `self`.

The `threading` module's locks and condition variables also support the 'with' statement:

```python
lock = threading.Lock()
with lock:
    # Critical section of code
...```

The lock is acquired before the block is executed and always released once the block is complete.

The `localcontext()` function in the `decimal` module makes it easy to save and restore the current decimal context, which encapsulates the desired precision and rounding characteristics for
computations:

```python
from decimal import Decimal, Context, localcontext

# Displays with default precision of 28 digits
v = Decimal('578')
print(v.sqrt())

with localcontext(Context(prec=16)):
    # All code in this block uses a precision of 16
    # The original context is restored on exiting the block.
    print(v.sqrt())
```

Writing Context Managers

Under the hood, the 'with' statement is fairly complicated. Most people will only use 'with' in company with existing objects and don't need to know these details, so you can skip the rest of this section if you like. Authors of new objects will need to understand the details of the underlying implementation and should keep reading.

A high-level explanation of the context management protocol is:

- The expression is evaluated and should result in an object called a “context manager”. The context manager must have `__enter__()` and `__exit__()` methods.
- The context manager's `__enter__()` method is called. The value returned is assigned to `VAR`. If no `as VAR` clause is present, the value is simply discarded.
- The code in `BLOCK` is executed.
- If `BLOCK` raises an exception, the context manager's `__exit__()` method is called with three arguments, the exception details (type, value, traceback), the same values
returned by `sys.exc_info()`, which can also be `None` if no exception occurred). The method's return value controls whether an exception is re-raised: any false value re-raises the exception, and `True` will result in suppressing it. You'll only rarely want to suppress the exception, because if you do the author of the code containing the `with` statement will never realize anything went wrong.

- If `BLOCK` didn't raise an exception, the `__exit__()` method is still called, but `type`, `value`, and `traceback` are all `None`.

Let's think through an example. I won’t present detailed code but will only sketch the methods necessary for a database that supports transactions.

(For people unfamiliar with database terminology: a set of changes to the database are grouped into a transaction. Transactions can be either committed, meaning that all the changes are written into the database, or rolled back, meaning that the changes are all discarded and the database is unchanged. See any database textbook for more information.)

Let's assume there's an object representing a database connection. Our goal will be to let the user write code like this:

```python
db_connection = DatabaseConnection()
with db_connection as cursor:
    cursor.execute('insert into ...')
    cursor.execute('delete from ...')
    # ... more operations ...
```

The transaction should be committed if the code in the block runs flawlessly or rolled back if there's an exception. Here's the basic interface for `DatabaseConnection` that I'll assume:
class DatabaseConnection:
# Database interface
def cursor(self):
    "Returns a cursor object and starts a new transaction"
def commit(self):
    "Commits current transaction"
def rollback(self):
    "Rolls back current transaction"

The __enter__() method is pretty easy, having only to start a new transaction. For this application the resulting cursor object would be a useful result, so the method will return it. The user can then add as cursor to their 'with' statement to bind the cursor to a variable name.

class DatabaseConnection:

def __enter__(self):
    # Code to start a new transaction
    cursor = self.cursor()
    return cursor

The __exit__() method is the most complicated because it's where most of the work has to be done. The method has to check if an exception occurred. If there was no exception, the transaction is committed. The transaction is rolled back if there was an exception.

In the code below, execution will just fall off the end of the function, returning the default value of None. None is false, so the exception will be re-raised automatically. If you wished, you could be more explicit and add a return statement at the marked location.
... def __exit__(self, type, value, tb):
    if tb is None:
        # No exception, so commit
        self.commit()
    else:
        # Exception occurred, so rollback.
        self.rollback()
    # return False

The contextlib module

The `contextlib` module provides some functions and a decorator that are useful when writing objects for use with the `with` statement.

The decorator is called `contextmanager()`, and lets you write a single generator function instead of defining a new class. The generator should yield exactly one value. The code up to the `yield` will be executed as the `__enter__()` method, and the value yielded will be the method’s return value that will get bound to the variable in the `with` statement’s `as` clause, if any. The code after the `yield` will be executed in the `__exit__()` method. Any exception raised in the block will be raised by the `yield` statement.

Using this decorator, our database example from the previous section could be written as:

```python
from contextlib import contextmanager

@contextmanager
def db_transaction(connection):
    cursor = connection.cursor()
    try:
        yield cursor
```
except:
    connection.rollback()
    raise
else:
    connection.commit()

db = DatabaseConnection()
with db_transaction(db) as cursor:
    ...

The `contextlib` module also has a nested(mgr1, mgr2, ...) function that combines a number of context managers so you don’t need to write nested `with` statements. In this example, the single `with` statement both starts a database transaction and acquires a thread lock:

```
lock = threading.Lock()
with nested(db_transaction(db), lock) as (cursor, lock):
    ...
```

Finally, the `closing()` function returns its argument so that it can be bound to a variable, and calls the argument's `.close()` method at the end of the block.

```
import urllib, sys
from contextlib import closing

with closing(urllib.urlopen('http://www.yahoo.com')) as f:
    for line in f:
        sys.stdout.write(line)
```

See also:
**PEP 343 - The “with” statement**

PEP written by Guido van Rossum and Nick Coghlan; implemented by Mike Bland, Guido van Rossum, and Neal Norwitz. The PEP shows the code generated for a ‘with’ statement, which can be helpful in learning how the statement works.

The documentation for the `contextlib` module.
PEP 366: Explicit Relative Imports From a Main Module

Python’s -m switch allows running a module as a script. When you ran a module that was located inside a package, relative imports didn’t work correctly.

The fix for Python 2.6 adds a __package__ attribute to modules. When this attribute is present, relative imports will be relative to the value of this attribute instead of the __name__ attribute.

PEP 302-style importers can then set __package__ as necessary. The runpy module that implements the -m switch now does this, so relative imports will now work correctly in scripts running from inside a package.
When you run Python, the module search path sys.path usually includes a directory whose path ends in "site-packages". This directory is intended to hold locally-installed packages available to all users using a machine or a particular site installation.

Python 2.6 introduces a convention for user-specific site directories. The directory varies depending on the platform:

- Unix and Mac OS X: ~/.local/
- Windows: %APPDATA%/Python

Within this directory, there will be version-specific subdirectories, such as lib/python2.6/site-packages on Unix/Mac OS and Python26/site-packages on Windows.

If you don’t like the default directory, it can be overridden by an environment variable. PYTHONUSERBASE sets the root directory used for all Python versions supporting this feature. On Windows, the directory for application-specific data can be changed by setting the APPDATA environment variable. You can also modify the site.py file for your Python installation.

The feature can be disabled entirely by running Python with the -s option or setting the PYTHONNOUSERSITE environment variable.

See also:

PEP 370 - Per-user site-packages Directory

PEP written and implemented by Christian Heimes.
PEP 371: The multiprocessing Package

The new multiprocessing package lets Python programs create new processes that will perform a computation and return a result to the parent. The parent and child processes can communicate using queues and pipes, synchronize their operations using locks and semaphores, and can share simple arrays of data.

The multiprocessing module started out as an exact emulation of the threading module using processes instead of threads. That goal was discarded along the path to Python 2.6, but the general approach of the module is still similar. The fundamental class is the Process, which is passed a callable object and a collection of arguments. The start() method sets the callable running in a subprocess, after which you can call the is_alive() method to check whether the subprocess is still running and the join() method to wait for the process to exit.

Here's a simple example where the subprocess will calculate a factorial. The function doing the calculation is written strangely so that it takes significantly longer when the input argument is a multiple of 4.

```python
import time
from multiprocessing import Process, Queue

def factorial(queue, N):
    "Compute a factorial."
    # If N is a multiple of 4, this function will take longer
    if (N % 4) == 0:
        time.sleep(.05 * N/4)
```
A Queue is used to communicate the result of the factorial. The Queue object is stored in a global variable. The child process will use the value of the variable when the child was created; because it's a Queue, parent and child can use the object to communicate. (If the parent were to change the value of the global variable, the child's value would be unaffected, and vice versa.)

Two other classes, Pool and Manager, provide higher-level interfaces. Pool will create a fixed number of worker processes, and requests can then be distributed to the workers by calling apply() or apply_async() to add a single request, and map() or map_async() to add a number of requests. The following code uses a Pool to spread requests across 5 worker processes and retrieve a
list of results:

```python
from multiprocessing import Pool

def factorial(N, dictionary):
    "Compute a factorial."
    ...

p = Pool(5)
result = p.map(factorial, range(1, 1000, 10))
for v in result:
    print v
```

This produces the following output:

```
1
39916800
51090942171709440000
8222838654177922817725562880000000
33452526613163807108170062053440751665152000000000
...
```

The other high-level interface, the Manager class, creates a separate server process that can hold master copies of Python data structures. Other processes can then access and modify these data structures using proxy objects. The following example creates a shared dictionary by calling the `dict()` method; the worker processes then insert values into the dictionary. (Locking is not done for you automatically, which doesn't matter in this example. Manager's methods also include `Lock()`, `RLock()`, and `Semaphore()` to create shared locks.)

```python
import time
from multiprocessing import Pool, Manager
```
def factorial(N, dictionary):
    "Compute a factorial."
    # Calculate the result
    fact = 1L
    for i in range(1, N+1):
        fact = fact * i

    # Store result in dictionary
    dictionary[N] = fact

if __name__ == '__main__':
    p = Pool(5)
    mgr = Manager()
    d = mgr.dict()  # Create shared dictionary

    # Run tasks using the pool
    for N in range(1, 1000, 10):
        p.apply_async(factorial, (N, d))

    # Mark pool as closed -- no more tasks can be added.
    p.close()

    # Wait for tasks to exit
    p.join()

    # Output results
    for k, v in sorted(d.items()):
        print k, v

This will produce the output:

1 1
11 39916800
21 51090942171709440000
31 8222838654177922817725562880000000
41 3345252661316380710817006205344075166515200000000

1 1
11 39916800
21 51090942171709440000
31 8222838654177922817725562880000000
41 3345252661316380710817006205344075166515200000000
See also: The documentation for the `multiprocessing` module.

PEP 371 - Addition of the multiprocessing package
PEP written by Jesse Noller and Richard Oudkerk; implemented by Richard Oudkerk and Jesse Noller.
PEP 3101: Advanced String Formatting

In Python 3.0, the % operator is supplemented by a more powerful string formatting method, `format()`. Support for the `str.format()` method has been backported to Python 2.6.

In 2.6, both 8-bit and Unicode strings have a `format()` method that treats the string as a template and takes the arguments to be formatted. The formatting template uses curly brackets (`,,`) as special characters:

```python
>>> # Substitute positional argument 0 into the string
>>> "User ID: {0}".format("root")
'User ID: root'
>>> # Use the named keyword arguments
>>> "User ID: {uid} Last seen: {last_login}".format(uid="root", last_login = "5 Mar 2008 07:20")
'User ID: root Last seen: 5 Mar 2008 07:20'
```

Curly brackets can be escaped by doubling them:

```python
>>> "Empty dict: {{{}}}".format()
"Empty dict: {}"
```

Field names can be integers indicating positional arguments, such as `{0}`, `{1}`, etc. or names of keyword arguments. You can also supply compound field names that read attributes or access dictionary keys:

```python
>>> import sys
>>> print 'Platform: {0.platform}\nPython version: {1}'
Platform: darwin
Python version: 2.6a1+ (trunk:61261M, Mar 5 2008, 2
```
Note that when using dictionary-style notation such as [.mp4], you don’t need to put any quotation marks around the string; it will look up the value using .mp4 as the key. Strings beginning with a number will be converted to an integer. You can’t write more complicated expressions inside a format string.

So far we’ve shown how to specify which field to substitute into the resulting string. The precise formatting used is also controllable by adding a colon followed by a format specifier. For example:

```python
>>> # Field 0: left justify, pad to 15 characters
>>> # Field 1: right justify, pad to 6 characters
>>> fmt = '{0:15} ${1:>6}'
>>> fmt.format('Registration', 35)
'Registration   $  35'
>>> fmt.format('Tutorial', 50)
'Tutorial      $  50'
>>> fmt.format('Banquet', 125)
'Banquet       $ 125'
```

Format specifiers can reference other fields through nesting:

```python
>>> fmt = '{0:{1}}'
>>> width = 15
>>> fmt.format('Invoice #1234', width)
'Invoice #1234  
>>> width = 35
>>> fmt.format('Invoice #1234', width)
'Invoice #1234  
```
The alignment of a field within the desired width can be specified:

<table>
<thead>
<tr>
<th>Character</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; (default)</td>
<td>Left-align</td>
</tr>
<tr>
<td>&gt;</td>
<td>Right-align</td>
</tr>
<tr>
<td>^</td>
<td>Center</td>
</tr>
<tr>
<td>=</td>
<td>(For numeric types only) Pad after the sign.</td>
</tr>
</tbody>
</table>

Format specifiers can also include a presentation type, which controls how the value is formatted. For example, floating-point numbers can be formatted as a general number or in exponential notation:

```
>>> '{0:g}'.format(3.75)
'3.75'
>>> '{0:e}'.format(3.75)
'3.750000e+00'
```

A variety of presentation types are available. Consult the 2.6 documentation for a complete list; here's a sample:

<table>
<thead>
<tr>
<th>Character</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>Binary. Outputs the number in base 2.</td>
</tr>
<tr>
<td>c</td>
<td>Character. Converts the integer to the corresponding Unicode character before printing.</td>
</tr>
<tr>
<td>d</td>
<td>Decimal Integer. Outputs the number in base 10.</td>
</tr>
<tr>
<td>o</td>
<td>Octal format. Outputs the number in base 8.</td>
</tr>
<tr>
<td>x</td>
<td>Hex format. Outputs the number in base 16, using lower-case letters for the digits above 9.</td>
</tr>
<tr>
<td>e</td>
<td>Exponent notation. Prints the number in scientific notation using the letter ‘e’ to indicate the exponent.</td>
</tr>
<tr>
<td></td>
<td>General format. This prints the number as a fixed-point number, unless the number is too large, in which case it switches to ‘e’ exponent notation.</td>
</tr>
<tr>
<td></td>
<td>Number. This is the same as ‘g’ (for floats) or ‘d’ (for integers), except that it uses the current locale setting to insert the appropriate number separator characters.</td>
</tr>
<tr>
<td></td>
<td>Percentage. Multiplies the number by 100 and displays in fixed (‘f’) format, followed by a percent sign.</td>
</tr>
</tbody>
</table>

Classes and types can define a `__format__()` method to control how they’re formatted. It receives a single argument, the format specifier:

```python
def __format__(self, format_spec):
    if isinstance(format_spec, unicode):
        return unicode(str(self))
    else:
        return str(self)
```

There’s also a `format()` built-in that will format a single value. It calls the type’s `__format__()` method with the provided specifier:

```python
>>> format(75.6564, '.2f')
'75.66'
```

**See also:**

**Format String Syntax**

The reference documentation for format fields.

**PEP 3101 - Advanced String Formatting**

PEP written by Talin. Implemented by Eric Smith.
PEP 3105: print As a Function

The print statement becomes the `print()` function in Python 3.0. Making `print()` a function makes it possible to replace the function by doing `def print(...)` or importing a new function from somewhere else.

Python 2.6 has a `__future__` import that removes print as language syntax, letting you use the functional form instead. For example:

```python
>>> from __future__ import print_function
>>> print('# of entries', len(dictionary), file=sys.
```

The signature of the new function is:

```python
def print(*args, sep=' ', end='
', file=None)
```

The parameters are:

- `args`: positional arguments whose values will be printed out.
- `sep`: the separator, which will be printed between arguments.
- `end`: the ending text, which will be printed after all of the arguments have been output.
- `file`: the file object to which the output will be sent.

See also:

**PEP 3105 - Make print a function**
PEP written by Georg Brandl.
PEP 3110: Exception-Handling Changes

One error that Python programmers occasionally make is writing the following code:

```
try:
...
except TypeError, ValueError:    # Wrong!
...
```

The author is probably trying to catch both `TypeError` and `ValueError` exceptions, but this code actually does something different: it will catch `TypeError` and bind the resulting exception object to the local name "ValueError". The `ValueError` exception will not be caught at all. The correct code specifies a tuple of exceptions:

```
try:
...
except (TypeError, ValueError):
...
```

This error happens because the use of the comma here is ambiguous: does it indicate two different nodes in the parse tree, or a single node that's a tuple?

Python 3.0 makes this unambiguous by replacing the comma with the word “as”. To catch an exception and store the exception object in the variable `exc`, you must write:

```
try:
...
except TypeError as exc:
```
Python 3.0 will only support the use of “as”, and therefore interprets the first example as catching two different exceptions. Python 2.6 supports both the comma and “as”, so existing code will continue to work. We therefore suggest using “as” when writing new Python code that will only be executed with 2.6.

See also:

**PEP 3110** - Catching Exceptions in Python 3000

PEP written and implemented by Collin Winter.
PEP 3112: Byte Literals

Python 3.0 adopts Unicode as the language's fundamental string type and denotes 8-bit literals differently, either as b'string' or using a bytes constructor. For future compatibility, Python 2.6 adds bytes as a synonym for the str type, and it also supports the b'' notation.

The 2.6 str differs from 3.0's bytes type in various ways; most notably, the constructor is completely different. In 3.0, bytes([65, 66, 67]) is 3 elements long, containing the bytes representing ABC; in 2.6, bytes([65, 66, 67]) returns the 12-byte string representing the str() of the list.

The primary use of bytes in 2.6 will be to write tests of object type such as isinstance(x, bytes). This will help the 2to3 converter, which can't tell whether 2.x code intends strings to contain either characters or 8-bit bytes; you can now use either bytes or str to represent your intention exactly, and the resulting code will also be correct in Python 3.0.

There's also a __future__ import that causes all string literals to become Unicode strings. This means that \u escape sequences can be used to include Unicode characters:

```python
from __future__ import unicode_literals
s = ('\u751f\u3080\u304e\u3000\u751f\u3054\u305f\u307e\u3054'  
     '\u3081\u3000\u751f\u305f\u307e\u3054')
print len(s)  # 12 Unicode characters
```

At the C level, Python 3.0 will rename the existing 8-bit string type,
called PyStringObject in Python 2.x, to **PyBytesObject**. Python 2.6 uses `#define` to support using the names `PyBytesObject()`, `PyBytes_Check()`, `PyBytes_FromStringAndSize()`, and all the other functions and macros used with strings.

Instances of the `bytes` type are immutable just as strings are. A new `bytearray` type stores a mutable sequence of bytes:

```python
>>> bytearray([65, 66, 67])
bytearray(b'ABC')
>>> b = bytearray(u'\u21ef\u3244', 'utf-8')
>>> b
bytearray(b'\xe2\x87\xaf\xe3\x89\x84')
>>> b[0] = '\xe3'
>>> b
bytearray(b'\xe3\x87\xaf\xe3\x89\x84')
>>> unicode(str(b), 'utf-8')
u'\u31ef ㉄'
```

Byte arrays support most of the methods of string types, such as `startswith()`, `endswith()`, `find()`, `rfind()`, and some of the methods of lists, such as `append()`, `pop()`, and `reverse()`.

```python
>>> b = bytearray('ABC')
>>> b.append('d')
>>> b.append(ord('e'))
>>> b
bytearray(b'ABCde')
```

There's also a corresponding C API, with `PyByteArray_FromObject()`, `PyByteArray_FromStringAndSize()`, and various other functions.
See also:

**PEP 3112 - Bytes literals in Python 3000**

PEP written by Jason Orendorff; backported to 2.6 by Christian Heimes.
PEP 3116: New I/O Library

Python’s built-in file objects support a number of methods, but file-like objects don’t necessarily support all of them. Objects that imitate files usually support read() and write(), but they may not support readline(), for example. Python 3.0 introduces a layered I/O library in the io module that separates buffering and text-handling features from the fundamental read and write operations.

There are three levels of abstract base classes provided by the io module:

- **RawIOBase** defines raw I/O operations: read(), readinto(), write(), seek(), tell(), truncate(), and close(). Most of the methods of this class will often map to a single system call. There are also readable(), writable(), and seekable() methods for determining what operations a given object will allow.

  Python 3.0 has concrete implementations of this class for files and sockets, but Python 2.6 hasn’t restructured its file and socket objects in this way.

- **BufferedIOBase** is an abstract base class that buffers data in memory to reduce the number of system calls used, making I/O processing more efficient. It supports all of the methods of RawIOBase, and adds a raw attribute holding the underlying raw object.

  There are five concrete classes implementing this ABC. BufferedWriter and BufferedReader are for objects that support write-only or read-only usage that have a seek() method
for random access. BufferedRandom objects support read and write access upon the same underlying stream, and BufferedRWPair is for objects such as TTYs that have both read and write operations acting upon unconnected streams of data. The BytesIO class supports reading, writing, and seeking over an in-memory buffer.

- TextIOBase: Provides functions for reading and writing strings (remember, strings will be Unicode in Python 3.0), and supporting universal newlines. TextIOBase defines the `readline()` method and supports iteration upon objects.

There are two concrete implementations. TextIOWrapper wraps a buffered I/O object, supporting all of the methods for text I/O and adding a buffer attribute for access to the underlying object. StringIO simply buffers everything in memory without ever writing anything to disk.

(In Python 2.6, `io.StringIO` is implemented in pure Python, so it’s pretty slow. You should therefore stick with the existing StringIO module or cStringIO for now. At some point Python 3.0’s `io` module will be rewritten into C for speed, and perhaps the C implementation will be backported to the 2.x releases.)

In Python 2.6, the underlying implementations haven’t been restructured to build on top of the `io` module’s classes. The module is being provided to make it easier to write code that’s forward-compatible with 3.0, and to save developers the effort of writing their own implementations of buffering and text I/O.

**See also:**
PEP 3116 - New I/O

PEP 3118: Revised Buffer Protocol

The buffer protocol is a C-level API that lets Python types exchange pointers into their internal representations. A memory-mapped file can be viewed as a buffer of characters, for example, and this lets another module such as re treat memory-mapped files as a string of characters to be searched.

The primary users of the buffer protocol are numeric-processing packages such as NumPy, which expose the internal representation of arrays so that callers can write data directly into an array instead of going through a slower API. This PEP updates the buffer protocol in light of experience from NumPy development, adding a number of new features such as indicating the shape of an array or locking a memory region.

The most important new C API function is PyObject_GetBuffer(PyObject *obj, Py_buffer *view, int flags), which takes an object and a set of flags, and fills in the Py_buffer structure with information about the object's memory representation. Objects can use this operation to lock memory in place while an external caller could be modifying the contents, so there's a corresponding PyBuffer_Release(Py_buffer *view) to indicate that the external caller is done.

The flags argument to PyObject_GetBuffer() specifies constraints upon the memory returned. Some examples are:

- PyBUF_WRITABLE indicates that the memory must be writable.
- PyBUF_LOCK requests a read-only or exclusive lock on the memory.
• PyBUF_C_CONTIGUOUS and PyBUF_F_CONTIGUOUS requests a C-contiguous (last dimension varies the fastest) or Fortran-contiguous (first dimension varies the fastest) array layout.

Two new argument codes for PyArg_ParseTuple(), s* and z*, return locked buffer objects for a parameter.

See also:

**PEP 3118 - Revising the buffer protocol**
PEP written by Travis Oliphant and Carl Banks; implemented by Travis Oliphant.
PEP 3119: Abstract Base Classes

Some object-oriented languages such as Java support interfaces, declaring that a class has a given set of methods or supports a given access protocol. Abstract Base Classes (or ABCs) are an equivalent feature for Python. The ABC support consists of an `abc` module containing a metaclass called `ABCMeta`, special handling of this metaclass by the `isinstance()` and `issubclass()` builtins, and a collection of basic ABCs that the Python developers think will be widely useful. Future versions of Python will probably add more ABCs.

Let's say you have a particular class and wish to know whether it supports dictionary-style access. The phrase “dictionary-style” is vague, however. It probably means that accessing items with `obj[1]` works. Does it imply that setting items with `obj[2] = value` works? Or that the object will have `keys()`, `values()`, and `items()` methods? What about the iterative variants such as `iterkeys()`? `copy()` and `update()`? Iterating over the object with `iter()`?

The Python 2.6 `collections` module includes a number of different ABCs that represent these distinctions. `Iterable` indicates that a class defines `__iter__()`, and `Container` means the class defines a `__contains__()` method and therefore supports `x in y` expressions. The basic dictionary interface of getting items, setting items, and `keys()`, `values()`, and `items()`, is defined by the `MutableMapping` ABC.

You can derive your own classes from a particular ABC to indicate they support that ABC's interface:

```python
import collections
```
class Storage(collections.MutableMapping):
    ...

Alternatively, you could write the class without deriving from the desired ABC and instead register the class by calling the ABC's register() method:

```python
import collections
class Storage:
    ...
collections.MutableMapping.register(Storage)
```

For classes that you write, deriving from the ABC is probably clearer. The register() method is useful when you've written a new ABC that can describe an existing type or class, or if you want to declare that some third-party class implements an ABC. For example, if you defined a PrintableType ABC, it's legal to do:

```python
# Register Python's types
PrintableType.register(int)
PrintableType.register(float)
PrintableType.register(str)
```

Classes should obey the semantics specified by an ABC, but Python can't check this; it's up to the class author to understand the ABC's requirements and to implement the code accordingly.

To check whether an object supports a particular interface, you can now write:

```python
def func(d):
```
if not isinstance(d, collections.MutableMapping):
    raise ValueError("Mapping object expected, got %r")

Don't feel that you must now begin writing lots of checks as in the above example. Python has a strong tradition of duck-typing, where explicit type-checking is never done and code simply calls methods on an object, trusting that those methods will be there and raising an exception if they aren't. Be judicious in checking for ABCs and only do it where it's absolutely necessary.

You can write your own ABCs by using abc.ABCMeta as the metaclass in a class definition:

```python
from abc import ABCMeta, abstractmethod

class Drawable():
    __metaclass__ = ABCMeta

    @abstractmethod
def draw(self, x, y, scale=1.0):
        pass

    def draw_doubled(self, x, y):
        self.draw(x, y, scale=2.0)

class Square(Drawable):
    def draw(self, x, y, scale):
        ...
```

In the Drawable ABC above, the draw_doubled() method renders the object at twice its size and can be implemented in terms of other methods described in Drawable. Classes implementing this ABC therefore don't need to provide their own implementation of
draw_doubled(), though they can do so. An implementation of draw() is necessary, though; the ABC can't provide a useful generic implementation.

You can apply the @abstractmethod decorator to methods such as draw() that must be implemented; Python will then raise an exception for classes that don't define the method. Note that the exception is only raised when you actually try to create an instance of a subclass lacking the method:

```python
>>> class Circle(Drawable):
...     pass
...
>>> c = Circle()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Can't instantiate abstract class Circle with abstract methods draw
```  

Abstract data attributes can be declared using the @abstractproperty decorator:

```python
from abc import abstractproperty
...
@abstractproperty
def readonly(self):
    return self._x
```

Subclasses must then define a readonly() property.

See also:

PEP 3119 - Introducing Abstract Base Classes
PEP written by Guido van Rossum and Talin. Implemented by Guido van Rossum. Backported to 2.6 by Benjamin Aranguren, with Alex Martelli.
PEP 3127: Integer Literal Support and Syntax

Python 3.0 changes the syntax for octal (base-8) integer literals, prefixing them with "0o" or "0O" instead of a leading zero, and adds support for binary (base-2) integer literals, signalled by a "0b" or "0B" prefix.

Python 2.6 doesn't drop support for a leading 0 signalling an octal number, but it does add support for "0o" and "0b":

```python
>>> 0o21, 2*8 + 1
(17, 17)
>>> 0b10111
47
```

The `oct()` builtin still returns numbers prefixed with a leading zero, and a new `bin()` builtin returns the binary representation for a number:

```python
>>> oct(42)
'0o52'
>>> future_builtins.oct(42)
'0o52'
>>> bin(173)
'0b10101101'
```

The `int()` and `long()` builtns will now accept the "0o" and "0b" prefixes when base-8 or base-2 are requested, or when the `base` argument is zero (signalling that the base used should be determined from the string):
See also:

**PEP 3127 - Integer Literal Support and Syntax**

PEP written by Patrick Maupin; backported to 2.6 by Eric Smith.
PEP 3129: Class Decorators

Decorators have been extended from functions to classes. It’s now legal to write:

```
@foo
@bar
class A:
    pass
```

This is equivalent to:

```
class A:
    pass

A = foo(bar(A))
```

See also:

**PEP 3129 - Class Decorators**

PEP written by Collin Winter.
PEP 3141: A Type Hierarchy for Numbers

Python 3.0 adds several abstract base classes for numeric types inspired by Scheme's numeric tower. These classes were backported to 2.6 as the numbers module.

The most general ABC is Number. It defines no operations at all, and only exists to allow checking if an object is a number by doing isinstance(obj, Number).

Complex is a subclass of Number. Complex numbers can undergo the basic operations of addition, subtraction, multiplication, division, and exponentiation, and you can retrieve the real and imaginary parts and obtain a number's conjugate. Python's built-in complex type is an implementation of Complex.

Real further derives from Complex, and adds operations that only work on real numbers: floor(), trunc(), rounding, taking the remainder mod N, floor division, and comparisons.

Rational numbers derive from Real, have numerator and denominator properties, and can be converted to floats. Python 2.6 adds a simple rational-number class, Fraction, in the fractions module. (It's called Fraction instead of Rational to avoid a name clash with numbers.Rational.)

Integral numbers derive from Rational, and can be shifted left and right with << and >>, combined using bitwise operations such as & and |, and can be used as array indexes and slice boundaries.

In Python 3.0, the PEP slightly redefines the existing builtins round(),
math.floor(), math.ceil(), and adds a new one, math.trunc(), that's been backported to Python 2.6. math.trunc() rounds toward zero, returning the closest Integral that's between the function's argument and zero.

See also:

PEP 3141 - A Type Hierarchy for Numbers
PEP written by Jeffrey Yasskin.

Scheme's numerical tower, from the Guile manual.

Scheme's number datatypes from the R5RS Scheme specification.

The fractions Module

To fill out the hierarchy of numeric types, the fractions module provides a rational-number class. Rational numbers store their values as a numerator and denominator forming a fraction, and can exactly represent numbers such as 2/3 that floating-point numbers can only approximate.

The Fraction constructor takes two Integral values that will be the numerator and denominator of the resulting fraction.

```python
>>> from fractions import Fraction
>>> a = Fraction(2, 3)
>>> b = Fraction(2, 5)
>>> float(a), float(b)
(0.6666666666666666, 0.40000000000000002)
>>> a+b
Fraction(16, 15)
>>> a/b
```
For converting floating-point numbers to rationals, the float type now has an as_integer_ratio() method that returns the numerator and denominator for a fraction that evaluates to the same floating-point value:

```python
>>> (2.5).as_integer_ratio()
(5, 2)
>>> (3.1415).as_integer_ratio()
(7074029114692207L, 2251799813685248L)
>>> (1./3).as_integer_ratio()
(6004799503160661L, 18014398509481984L)
```

Note that values that can only be approximated by floating-point numbers, such as \( 1./3 \), are not simplified to the number being approximated; the fraction attempts to match the floating-point value exactly.

The `fractions` module is based upon an implementation by Sjoerd Mullender that was in Python’s Demo/classes/ directory for a long time. This implementation was significantly updated by Jeffrey Yasskin.
Other Language Changes

Some smaller changes made to the core Python language are:

- Directories and zip archives containing a `__main__.py` file can now be executed directly by passing their name to the interpreter. The directory or zip archive is automatically inserted as the first entry in `sys.path`. (Suggestion and initial patch by Andy Chu, subsequently revised by Phillip J. Eby and Nick Coghlan; issue 1739468.)

- The `hasattr()` function was catching and ignoring all errors, under the assumption that they meant a `__getattr__()` method was failing somehow and the return value of `hasattr()` would therefore be False. This logic shouldn't be applied to `KeyboardInterrupt` and `SystemExit`, however; Python 2.6 will no longer discard such exceptions when `hasattr()` encounters them. (Fixed by Benjamin Peterson; issue 2196.)

- When calling a function using the ** syntax to provide keyword arguments, you are no longer required to use a Python dictionary; any mapping will now work:

```python
def f(**kw):
    ...    print sorted(kw)
    ...
ud=UserDict.UserDict()
ud['a'] = 1
ud['b'] = 'string'
f(**ud)
['a', 'b']
```
It's also become legal to provide keyword arguments after a *args argument to a function call.

```
>>> def f(*args, **kw):
...    print args, kw
...

>>> f(1, 2, 3, *(4, 5, 6), keyword=13)
(1, 2, 3, 4, 5, 6) {'keyword': 13}
```

Previously this would have been a syntax error. (Contributed by Amaury Forgeot d'Arc; issue 3473.)

- A new builtin, next(iterator, [default]) returns the next item from the specified iterator. If the default argument is supplied, it will be returned if iterator has been exhausted; otherwise, the StopIteration exception will be raised. (Backported in issue 2719.)

- Tuples now have index() and count() methods matching the list type's index() and count() methods:

```
>>> t = (0, 1, 2, 3, 4, 0, 1, 2)
>>> t.index(3)
3
>>> t.count(0)
2
```

(Contributed by Raymond Hettinger)

- The built-in types now have improved support for extended slicing syntax, accepting various combinations of (start, stop, step). Previously, the support was partial and certain corner
cases wouldn’t work. (Implemented by Thomas Wouters.)

- Properties now have three attributes, getter, setter and deleter, that are decorators providing useful shortcuts for adding a getter, setter or deleter function to an existing property. You would use them like this:

```python
class C(object):
    @property
    def x(self):
        return self._x

    @x.setter
    def x(self, value):
        self._x = value

    @x.deleter
    def x(self):
        del self._x

class D(C):
    @C.x.getter
    def x(self):
        return self._x * 2

    @x.setter
    def x(self, value):
        self._x = value / 2
```

- Several methods of the built-in set types now accept multiple iterables: `intersection()`, `intersection_update()`, `union()`, `update()`, `difference()` and `difference_update()`.

```python
>>> s=set('1234567890')
```
Many floating-point features were added. The `float()` function will now turn the string `nan` into an IEEE 754 Not A Number value, and `+inf` and `-inf` into positive or negative infinity. This works on any platform with IEEE 754 semantics. (Contributed by Christian Heimes; issue 1635.)

Other functions in the `math` module, `isinf()` and `isnan()`, return true if their floating-point argument is infinite or Not A Number. (issue 1640)

Conversion functions were added to convert floating-point numbers into hexadecimal strings (issue 3008). These functions convert floats to and from a string representation without introducing rounding errors from the conversion between decimal and binary. Floats have a `hex()` method that returns a string representation, and the `float.fromhex()` method converts a string back into a number:
• A numerical nicety: when creating a complex number from two floats on systems that support signed zeros (-0 and +0), the `complex()` constructor will now preserve the sign of the zero. (Fixed by Mark T. Dickinson; issue 1507.)

• Classes that inherit a `__hash__()` method from a parent class can set `__hash__ = None` to indicate that the class isn't hashable. This will make `hash(obj)` raise a `TypeError` and the class will not be indicated as implementing the `Hashable` ABC.

You should do this when you've defined a `__cmp__()` or `__eq__()` method that compares objects by their value rather than by identity. All objects have a default hash method that uses `id(obj)` as the hash value. There's no tidy way to remove the `__hash__()` method inherited from a parent class, so assigning `None` was implemented as an override. At the C level, extensions can set `tp_hash` to `PyObject_HashNotImplemented()`. (Fixed by Nick Coghlan and Amaury Forgeot d'Arc; issue 2235.)

• The `GeneratorExit` exception now subclasses `BaseException` instead of `Exception`. This means that an exception handler that does except `Exception:` will not inadvertently catch `GeneratorExit`. (Contributed by Chad Austin; issue 1537.)

• Generator objects now have a `gi_code` attribute that refers to the original code object backing the generator. (Contributed by Collin Winter; issue 1473257.)

• The `compile()` built-in function now accepts keyword arguments as well as positional parameters. (Contributed by Thomas Wouters; issue 1444529.)
The `complex()` constructor now accepts strings containing parenthesized complex numbers, meaning that `complex(repr(cplx))` will now round-trip values. For example, `complex('(3+4j)')` now returns the value `(3+4j)`. (issue 1491866)

The string `translate()` method now accepts `None` as the translation table parameter, which is treated as the identity transformation. This makes it easier to carry out operations that only delete characters. (Contributed by Bengt Richter and implemented by Raymond Hettinger; issue 1193128.)

The built-in `dir()` function now checks for a `__dir__()` method on the objects it receives. This method must return a list of strings containing the names of valid attributes for the object, and lets the object control the value that `dir()` produces. Objects that have `__getattr__()` or `__getattribute__()` methods can use this to advertise pseudo-attributes they will honor. (issue 1591665)

Instance method objects have new attributes for the object and function comprising the method; the new synonym for `im_self` is `__self__`, and `im_func` is also available as `__func__`. The old names are still supported in Python 2.6, but are gone in 3.0.

An obscure change: when you use the `locals()` function inside a `class` statement, the resulting dictionary no longer returns free variables. (Free variables, in this case, are variables referenced in the `class` statement that aren’t attributes of the class.)

Optimizations
• The **warnings** module has been rewritten in C. This makes it possible to invoke warnings from the parser, and may also make the interpreter’s startup faster. (Contributed by Neal Norwitz and Brett Cannon; issue 163117.)

• Type objects now have a cache of methods that can reduce the work required to find the correct method implementation for a particular class; once cached, the interpreter doesn’t need to traverse base classes to figure out the right method to call. The cache is cleared if a base class or the class itself is modified, so the cache should remain correct even in the face of Python’s dynamic nature. (Original optimization implemented by Armin Rigo, updated for Python 2.6 by Kevin Jacobs; issue 1700288.)

By default, this change is only applied to types that are included with the Python core. Extension modules may not necessarily be compatible with this cache, so they must explicitly add `Py_TPFLAGS_HAVE_VERSION_TAG` to the module’s `tp_flags` field to enable the method cache. (To be compatible with the method cache, the extension module’s code must not directly access and modify the `tp_dict` member of any of the types it implements. Most modules don’t do this, but it’s impossible for the Python interpreter to determine that. See issue 1878 for some discussion.)

• Function calls that use keyword arguments are significantly faster by doing a quick pointer comparison, usually saving the time of a full string comparison. (Contributed by Raymond Hettinger, after an initial implementation by Antoine Pitrou; issue 1819.)

• All of the functions in the **struct** module have been rewritten in C, thanks to work at the Need For Speed sprint. (Contributed by Raymond Hettinger.)
• Some of the standard built-in types now set a bit in their type objects. This speeds up checking whether an object is a subclass of one of these types. (Contributed by Neal Norwitz.)

• Unicode strings now use faster code for detecting whitespace and line breaks; this speeds up the split() method by about 25% and splitlines() by 35%. (Contributed by Antoine Pitrou.) Memory usage is reduced by using pymalloc for the Unicode string’s data.

• The with statement now stores the __exit__() method on the stack, producing a small speedup. (Implemented by Jeffrey Yasskin.)

• To reduce memory usage, the garbage collector will now clear internal free lists when garbage-collecting the highest generation of objects. This may return memory to the operating system sooner.

Interpreter Changes

Two command-line options have been reserved for use by other Python implementations. The -J switch has been reserved for use by Jython for Jython-specific options, such as switches that are passed to the underlying JVM. -X has been reserved for options specific to a particular implementation of Python such as CPython, Jython, or IronPython. If either option is used with Python 2.6, the interpreter will report that the option isn’t currently used.

Python can now be prevented from writing .pyc or .pyo files by supplying the -B switch to the Python interpreter, or by setting the
PYTHONDONTWRITEBYTECODE environment variable before running the interpreter. This setting is available to Python programs as the sys.dont_write_bytecode variable, and Python code can change the value to modify the interpreter’s behaviour. (Contributed by Neal Norwitz and Georg Brandl.)

The encoding used for standard input, output, and standard error can be specified by setting the PYTHONIOENCODING environment variable before running the interpreter. The value should be a string in the form <encoding> or <encoding>:<errorhandler>. The encoding part specifies the encoding’s name, e.g. utf-8 or latin-1; the optional errorhandler part specifies what to do with characters that can’t be handled by the encoding, and should be one of “error”, “ignore”, or “replace”. (Contributed by Martin von Löwis.)
New and Improved Modules

As in every release, Python’s standard library received a number of enhancements and bug fixes. Here's a partial list of the most notable changes, sorted alphabetically by module name. Consult the Misc/NEWS file in the source tree for a more complete list of changes, or look through the Subversion logs for all the details.

- The asyncore and asynchat modules are being actively maintained again, and a number of patches and bugfixes were applied. (Maintained by Josiah Carlson; see issue 1736190 for one patch.)

- The bsddb module also has a new maintainer, Jesús Cea Avión, and the package is now available as a standalone package. The web page for the package is www.jcea.es/programacion/pybsddb.htm. The plan is to remove the package from the standard library in Python 3.0, because its pace of releases is much more frequent than Python’s.

  The bsddb.dbshelve module now uses the highest pickling protocol available, instead of restricting itself to protocol 1. (Contributed by W. Barnes.)

- The cgi module will now read variables from the query string of an HTTP POST request. This makes it possible to use form actions with URLs that include query strings such as “/cgi-bin/add.py?category=1”. (Contributed by Alexandre Fiori and Nubis; issue 1817.)

  The parse_qs() and parse_qsl() functions have been relocated from the cgi module to the urlparse module. The
versions still available in the **cgi** module will trigger \texttt{PendingDeprecationWarning} messages in 2.6 (issue 600362).

- The **cmath** module underwent extensive revision, contributed by Mark Dickinson and Christian Heimes. Five new functions were added:

  - \texttt{polar()} converts a complex number to polar form, returning the modulus and argument of the complex number.
  - \texttt{rect()} does the opposite, turning a modulus, argument pair back into the corresponding complex number.
  - \texttt{phase()} returns the argument (also called the angle) of a complex number.
  - \texttt{isnan()} returns True if either the real or imaginary part of its argument is a NaN.
  - \texttt{isinf()} returns True if either the real or imaginary part of its argument is infinite.

The revisions also improved the numerical soundness of the **cmath** module. For all functions, the real and imaginary parts of the results are accurate to within a few units of least precision (ulps) whenever possible. See issue 1381 for the details. The branch cuts for \texttt{asinh()}, \texttt{atanh()}: and \texttt{atan()} have also been corrected.

The tests for the module have been greatly expanded; nearly 2000 new test cases exercise the algebraic functions.

On IEEE 754 platforms, the **cmath** module now handles IEEE 754 special values and floating-point exceptions in a manner consistent with Annex ‘G’ of the C99 standard.
A new data type in the `collections` module: `namedtuple(typename, fieldnames)` is a factory function that creates subclasses of the standard tuple whose fields are accessible by name as well as index. For example:

```python
>>> var_type = collections.namedtuple('variable',
    ...    'id name type size')
>>> # Names are separated by spaces or commas.
>>> # 'id, name, type, size' would also work.
>>> var_type._fields
('id', 'name', 'type', 'size')

>>> var = var_type(1, 'frequency', 'int', 4)
>>> print var[0], var.id   # Equivalent
1 1
>>> print var[2], var.type # Equivalent
int int
>>> var._asdict()
{'size': 4, 'type': 'int', 'id': 1, 'name': 'frequency'}

>>> v2 = var._replace(name='amplitude')
>>> v2
variable(id=1, name='amplitude', type='int', size=4)
```

Several places in the standard library that returned tuples have been modified to return `namedtuple` instances. For example, the `Decimal.as_tuple()` method now returns a named tuple with `sign`, `digits`, and `exponent` fields.

(Contributed by Raymond Hettinger.)

Another change to the `collections` module is that the `deque` type now supports an optional `maxlen` parameter; if supplied, the deque's size will be restricted to no more than `maxlen` items. Adding more items to a full deque causes old items to be
discarded.

```python
>>> from collections import deque
>>> dq=deque(maxlen=3)
>>> dq
deque([], maxlen=3)
>>> dq.append(1); dq.append(2); dq.append(3)
>>> dq
deque([1, 2, 3], maxlen=3)
>>> dq.append(4)
>>> dq
deque([2, 3, 4], maxlen=3)
```

(Contributed by Raymond Hettinger.)

- The Cookie module's Morsel objects now support an `httponly` attribute. In some browsers, cookies with this attribute set cannot be accessed or manipulated by JavaScript code. (Contributed by Arvin Schnell; issue 1638033.)

- A new window method in the `curses` module, `chgat()`, changes the display attributes for a certain number of characters on a single line. (Contributed by Fabian Kreutz.)

```python
# Boldface text starting at y=0, x=21
# and affecting the rest of the line.
stdscr.chgat(0, 21, curses.A_BOLD)
```

The Textbox class in the `curses.textpad` module now supports editing in insert mode as well as overwrite mode. Insert mode is enabled by supplying a true value for the `insert_mode` parameter when creating the Textbox instance.

- The `datetime` module's `strftime()` methods now support a
%f format code that expands to the number of microseconds in the object, zero-padded on the left to six places. (Contributed by Skip Montanaro; issue 1158.)

- The `decimal` module was updated to version 1.66 of the General Decimal Specification. New features include some methods for some basic mathematical functions such as `exp()` and `log10()`:

```python
>>> Decimal(1).exp()
Decimal("2.718281828459045235360287471")
>>> Decimal("2.7182818").ln()
Decimal("0.999999895305022877376682436")
>>> Decimal(1000).log10()
Decimal("3")
```

The `as_tuple()` method of Decimal objects now returns a named tuple with `sign`, `digits`, and `exponent` fields.

(Implemented by Facundo Batista and Mark Dickinson. Named tuple support added by Raymond Hettinger.)

- The `difflib` module's `SequenceMatcher` class now returns named tuples representing matches, with `a`, `b`, and `size` attributes. (Contributed by Raymond Hettinger.)

- An optional timeout parameter, specifying a timeout measured in seconds, was added to the `ftp`. `FTP` class constructor as well as the `connect()` method. (Added by Facundo Batista.) Also, the FTP class's `storbinary()` and `storlines()` now take an optional `callback` parameter that will be called with each block of data after the data has been sent. (Contributed by Phil Schwartz; issue 1221598.)
- The `reduce()` built-in function is also available in the `functools` module. In Python 3.0, the built-in has been dropped and `reduce()` is only available from `functools`; currently there are no plans to drop the builtin in the 2.x series. (Patched by Christian Heimes; issue 1739906.)

- When possible, the `getpass` module will now use `/dev/tty` to print a prompt message and read the password, falling back to standard error and standard input. If the password may be echoed to the terminal, a warning is printed before the prompt is displayed. (Contributed by Gregory P. Smith.)

- The `glob.glob()` function can now return Unicode filenames if a Unicode path was used and Unicode filenames are matched within the directory. (issue 1001604)

- A new function in the `heapq` module, `merge(iter1, iter2, ...)`, takes any number of iterables returning data in sorted order, and returns a new generator that returns the contents of all the iterators, also in sorted order. For example:

  ```python
  >>> list(heapq.merge([1, 3, 5, 9], [2, 8, 16]))
  [1, 2, 3, 5, 8, 9, 16]
  ```

  Another new function, `heappushpop(heap, item)`, pushes `item` onto `heap`, then pops off and returns the smallest item. This is more efficient than making a call to `heappush()` and then `heappop()`.

  `heapq` is now implemented to only use less-than comparison, instead of the less-than-or-equal comparison it previously used. This makes `heapq`'s usage of a type match the `list.sort()`
method. (Contributed by Raymond Hettinger.)

- An optional timeout parameter, specifying a timeout measured in seconds, was added to the `httplib.HTTPConnection` and `HTTPSConnection` class constructors. (Added by Facundo Batista.)

- Most of the `inspect` module's functions, such as `getmoduleinfo()` and `getargs()`, now return named tuples. In addition to behaving like tuples, the elements of the return value can also be accessed as attributes. (Contributed by Raymond Hettinger.)

Some new functions in the module include `isgenerator()`, `isgeneratorfunction()`, and `isabstract()`.

- The `itertools` module gained several new functions.

  `izip_longest(iter1, iter2, ...[, fillvalue])` makes tuples from each of the elements; if some of the iterables are shorter than others, the missing values are set to `fillvalue`. For example:

  ```python
  >>> tuple(itertools.izip_longest([1,2,3], [1,2,3,4,5], fillvalue=None))
  ((1, 1), (2, 2), (3, 3), (None, 4), (None, 5))
  ```

  `product(iter1, iter2, ..., [repeat=N])` returns the Cartesian product of the supplied iterables, a set of tuples containing every possible combination of the elements returned from each iterable.

  ```python
  >>> list(itertools.product([1,2,3], [4,5,6]))
  [(1, 4), (1, 5), (1, 6),
  ```
The optional `repeat` keyword argument is used for taking the product of an iterable or a set of iterables with themselves, repeated \( N \) times. With a single iterable argument, \( N \)-tuples are returned:

```
>>> list(itertools.product([1,2], repeat=3))
[(1, 1, 1), (1, 1, 2), (1, 2, 1), (1, 2, 2),
 (2, 1, 1), (2, 1, 2), (2, 2, 1), (2, 2, 2)]
```

With two iterables, \( 2N \)-tuples are returned.

```
>>> list(itertools.product([1,2], [3,4], repeat=2))
[(1, 3, 1, 3), (1, 3, 1, 4), (1, 3, 2, 3), (1, 3, 2, 4),
 (1, 4, 1, 3), (1, 4, 1, 4), (1, 4, 2, 3), (1, 4, 2, 4),
 (2, 3, 1, 3), (2, 3, 1, 4), (2, 3, 2, 3), (2, 3, 2, 4),
 (2, 4, 1, 3), (2, 4, 1, 4), (2, 4, 2, 3), (2, 4, 2, 4)]
```

combinations(iterable, \( r \)) returns sub-sequences of length \( r \) from the elements of `iterable`.

```
>>> list(itertools.combinations('123', 2))
[['1', '2'], ['1', '3'], ['2', '3']]
```

```
>>> list(itertools.combinations('123', 3))
[['1', '2', '3']]  
```

```
>>> list(itertools.combinations('1234', 3))
[['1', '2', '3'], ['1', '2', '4'],
 ['1', '3', '4'], ['2', '3', '4']]
```

permutations(iter[, \( r \)]) returns all the permutations of length \( r \) of the iterable’s elements. If \( r \) is not specified, it will default to the number of elements produced by the iterable.
>>> list(itertools.permutations([1,2,3,4], 2))
[(1, 2), (1, 3), (1, 4),
 (2, 1), (2, 3), (2, 4),
 (3, 1), (3, 2), (3, 4),
 (4, 1), (4, 2), (4, 3)]

itertools.chain(*iterables) is an existing function in *itertools* that gained a new constructor in Python 2.6. *itertools.chain.from_iterable(iterable)* takes a single iterable that should return other iterables. *chain()* will then return all the elements of the first iterable, then all the elements of the second, and so on.

>>> list(itertools.chain.from_iterable([[1,2,3],
 [1, 2, 3, 4, 5, 6]
 ))

(All contributed by Raymond Hettinger.)

- The *logging* module's *FileHandler* class and its subclasses *WatchedFileHandler*, *RotatingFileHandler*, and *TimedRotatingFileHandler* now have an optional *delay* parameter to their constructors. If *delay* is true, opening of the log file is deferred until the first *emit()* call is made. (Contributed by Vinay Sajip.)

*TimedRotatingFileHandler* also has a *utc* constructor parameter. If the argument is true, UTC time will be used in determining when midnight occurs and in generating filenames; otherwise local time will be used.

- Several new functions were added to the *math* module:
  - *isinf()* and *isnan()* determine whether a given float is a
(positive or negative) infinity or a NaN (Not a Number), respectively.

- **copysign()** copies the sign bit of an IEEE 754 number, returning the absolute value of \(x\) combined with the sign bit of \(y\). For example, \(\text{math.copysign}(1, \ -0.0)\) returns \(-1.0\). (Contributed by Christian Heimes.)
- **factorial()** computes the factorial of a number. (Contributed by Raymond Hettinger; issue 2138.)
- **fsum()** adds up the stream of numbers from an iterable, and is careful to avoid loss of precision through using partial sums. (Contributed by Jean Brouwers, Raymond Hettinger, and Mark Dickinson; issue 2819.)
- **acosh(), asinh() and atanh()** compute the inverse hyperbolic functions.
- **log1p()** returns the natural logarithm of \(1+x\) (base \(e\)).
- **trunc()** rounds a number toward zero, returning the closest Integral that's between the function’s argument and zero. Added as part of the backport of PEP 3141’s type hierarchy for numbers.

- The **math** module has been improved to give more consistent behaviour across platforms, especially with respect to handling of floating-point exceptions and IEEE 754 special values.

Whenever possible, the module follows the recommendations of the C99 standard about 754’s special values. For example, **sqrt(-1.)** should now give a **ValueError** across almost all platforms, while **sqrt(float('NaN'))** should return a NaN on all IEEE 754 platforms. Where Annex ‘F’ of the C99 standard recommends signaling ‘divide-by-zero’ or ‘invalid’, Python will raise **ValueError**. Where Annex ‘F’ of the C99 standard recommends signaling ‘overflow’, Python will raise **OverflowError**. (See issue 711019 and issue 1640.)
• mmap objects now have a rfind() method that searches for a substring beginning at the end of the string and searching backwards. The find() method also gained an end parameter giving an index at which to stop searching. (Contributed by John Lenton.)

• The operator module gained a methodcaller() function that takes a name and an optional set of arguments, returning a callable that will call the named function on any arguments passed to it. For example:

```python
>>> # Equivalent to lambda s: s.replace('old', 'new')
>>> replacer = operator.methodcaller('replace', 'old')
>>> replacer('old wine in old bottles')
'new wine in new bottles'
```

(Contributed by Georg Brandl, after a suggestion by Gregory Petrosyan.)

The attrgetter() function now accepts dotted names and performs the corresponding attribute lookups:

```python
>>> inst_name = operator.attrgetter(  ...
...             '__class__.__name__' )
>>> inst_name('')
'str'
>>> inst_name(help)
'_Helper'
```

(Contributed by Georg Brandl, after a suggestion by Barry Warsaw.)
The os module now wraps several new system calls. `fchmod(fd, mode)` and `fchown(fd, uid, gid)` change the mode and ownership of an opened file, and `lchmod(path, mode)` changes the mode of a symlink. (Contributed by Georg Brandl and Christian Heimes.)

`chflags()` and `lchflags()` are wrappers for the corresponding system calls (where they're available), changing the flags set on a file. Constants for the flag values are defined in the `stat` module; some possible values include `UF_IMMUTABLE` to signal the file may not be changed and `UF_APPEND` to indicate that data can only be appended to the file. (Contributed by M. Levinson.)

`os.closerange(low, high)` efficiently closes all file descriptors from low to high, ignoring any errors and not including high itself. This function is now used by the `subprocess` module to make starting processes faster. (Contributed by Georg Brandl; issue 1663329.)

The os.environ object's `clear()` method will now unset the environment variables using `os.unsetenv()` in addition to clearing the object's keys. (Contributed by Martin Horcicka; issue 1181.)

The `os.walk()` function now has a `followlinks` parameter. If set to True, it will follow symlinks pointing to directories and visit the directory's contents. For backward compatibility, the parameter's default value is false. Note that the function can fall into an infinite recursion if there's a symlink that points to a parent directory. (issue 1273829)
- In the `os.path` module, the `splitext()` function has been changed to not split on leading period characters. This produces better results when operating on Unix's dot-files. For example, `os.path.splitext('.ipython')` now returns ('.ipython', '') instead of ('', '.ipython'). (issue 1115886)

A new function, `os.path.relpath(path, start='.')`, returns a relative path from the start path, if it's supplied, or from the current working directory to the destination path. (Contributed by Richard Barran; issue 1339796.)

On Windows, `os.path.expandvars()` will now expand environment variables given in the form “%var%”, and “~user” will be expanded into the user's home directory path. (Contributed by Josiah Carlson; issue 957650.)

- The Python debugger provided by the `pdb` module gained a new command: “run” restarts the Python program being debugged and can optionally take new command-line arguments for the program. (Contributed by Rocky Bernstein; issue 1393667.)

- The `pdb.post_mortem()` function, used to begin debugging a traceback, will now use the traceback returned by `sys.exc_info()` if no traceback is supplied. (Contributed by Facundo Batista; issue 1106316.)

- The `pickletools` module now has an `optimize()` function that takes a string containing a pickle and removes some unused opcodes, returning a shorter pickle that contains the same data structure. (Contributed by Raymond Hettinger.)

- A `get_data()` function was added to the `pkgutil` module that
returns the contents of resource files included with an installed Python package. For example:

```python
>>> import pkgutil
>>> print(pkgutil.get_data('test', 'exception_hierarchy.txt'))
BaseException
   +-- SystemExit
   +-- KeyboardInterrupt
   +-- GeneratorExit
   +-- Exception
      +-- StopIteration
      +-- StandardError
...```

(Contributed by Paul Moore; issue 2439.)

- The pyexpat module's Parser objects now allow setting their buffer_size attribute to change the size of the buffer used to hold character data. (Contributed by Achim Gaedke; issue 1137.)

- The Queue module now provides queue variants that retrieve entries in different orders. The PriorityQueue class stores queued items in a heap and retrieves them in priority order, and LifoQueue retrieves the most recently added entries first, meaning that it behaves like a stack. (Contributed by Raymond Hettinger.)

- The random module's Random objects can now be pickled on a 32-bit system and unpickled on a 64-bit system, and vice versa. Unfortunately, this change also means that Python 2.6's Random objects can't be unpickled correctly on earlier versions of Python. (Contributed by Shawn Ligocki; issue 1727780.)
The new triangular(low, high, mode) function returns random numbers following a triangular distribution. The returned values are between low and high, not including high itself, and with mode as the most frequently occurring value in the distribution. (Contributed by Wladimir van der Laan and Raymond Hettinger; issue 1681432.)

- Long regular expression searches carried out by the re module will check for signals being delivered, so time-consuming searches can now be interrupted. (Contributed by Josh Hoyt and Ralf Schmitt; issue 846388.)

The regular expression module is implemented by compiling bytecodes for a tiny regex-specific virtual machine. Untrusted code could create malicious strings of bytecode directly and cause crashes, so Python 2.6 includes a verifier for the regex bytecode. (Contributed by Guido van Rossum from work for Google App Engine; issue 3487.)

- The rlcompleter module's Completer.complete() method will now ignore exceptions triggered while evaluating a name. (Fixed by Lorenz Quack; issue 2250.)

- The sched module's scheduler instances now have a read-only queue attribute that returns the contents of the scheduler's queue, represented as a list of named tuples with the fields (time, priority, action, argument). (Contributed by Raymond Hettinger; issue 1861.)

- The select module now has wrapper functions for the Linux epoll() and BSD kqueue() system calls. modify() method was added to the existing poll objects; pollobj.modify(fd,
eventmask) takes a file descriptor or file object and an event mask, modifying the recorded event mask for that file. (Contributed by Christian Heimes; issue 1657.)

- The `shutil.copytree()` function now has an optional `ignore` argument that takes a callable object. This callable will receive each directory path and a list of the directory’s contents, and returns a list of names that will be ignored, not copied.

The `shutil` module also provides an `ignore_patterns()` function for use with this new parameter. `ignore_patterns()` takes an arbitrary number of glob-style patterns and returns a callable that will ignore any files and directories that match any of these patterns. The following example copies a directory tree, but skips both `.svn` directories and Emacs backup files, which have names ending with ‘~’:

```python
shutil.copytree('Doc/library', '/tmp/library',
                ignore=shutil.ignore_patterns('*.~'))
```

(Contributed by Tarek Ziadé; issue 2663.)

- Integrating signal handling with GUI handling event loops like those used by Tkinter or GTK+ has long been a problem; most software ends up polling, waking up every fraction of a second to check if any GUI events have occurred. The `signal` module can now make this more efficient. Calling `signal.set_wakeup_fd(fd)` sets a file descriptor to be used; when a signal is received, a byte is written to that file descriptor. There’s also a C-level function, `PySignal_SetWakeupFd()`, for setting the descriptor.
Event loops will use this by opening a pipe to create two descriptors, one for reading and one for writing. The writable descriptor will be passed to set_wakeup_fd(), and the readable descriptor will be added to the list of descriptors monitored by the event loop via select() or poll(). On receiving a signal, a byte will be written and the main event loop will be woken up, avoiding the need to poll.

(Contributed by Adam Olsen; issue 1583.)

The siginterrupt() function is now available from Python code, and allows changing whether signals can interrupt system calls or not. (Contributed by Ralf Schmitt.)

The setitimer() and getitimer() functions have also been added (where they're available). setitimer() allows setting interval timers that will cause a signal to be delivered to the process after a specified time, measured in wall-clock time, consumed process time, or combined process+system time. (Contributed by Guilherme Polo; issue 2240.)

- The smtplib module now supports SMTP over SSL thanks to the addition of the SMTP_SSL class. This class supports an interface identical to the existing SMTP class. (Contributed by Monty Taylor.) Both class constructors also have an optional timeout parameter that specifies a timeout for the initial connection attempt, measured in seconds. (Contributed by Facundo Batista.)

An implementation of the LMTP protocol ([RFC 2033](https://tools.ietf.org/html/rfc2033)) was also added to the module. LMTP is used in place of SMTP when transferring e-mail between agents that don’t manage a mail
queue. (LMTP implemented by Leif Hedstrom; issue 957003.)

SMTP.starttls() now complies with RFC 3207 and forgets any knowledge obtained from the server not obtained from the TLS negotiation itself. (Patch contributed by Bill Fenner; issue 829951.)

- The socket module now supports TIPC (http://tipc.sourceforge.net/), a high-performance non-IP-based protocol designed for use in clustered environments. TIPC addresses are 4- or 5-tuples. (Contributed by Alberto Bertogli; issue 1646.)

A new function, create_connection(), takes an address and connects to it using an optional timeout value, returning the connected socket object. This function also looks up the address's type and connects to it using IPv4 or IPv6 as appropriate. Changing your code to use create_connection() instead of socket(socket.AF_INET, ...) may be all that's required to make your code work with IPv6.

- The base classes in the SocketServer module now support calling a handle_timeout() method after a span of inactivity specified by the server's timeout attribute. (Contributed by Michael Pomraning.) The serve_forever() method now takes an optional poll interval measured in seconds, controlling how often the server will check for a shutdown request. (Contributed by Pedro Werneck and Jeffrey Yasskin; issue 742598, issue 1193577.)

- The sqlite3 module, maintained by Gerhard Häring, has been updated from version 2.3.2 in Python 2.5 to version 2.4.1.
The **struct** module now supports the C99 _Bool type, using the format character '?'. (Contributed by David Remahl.)

The Popen objects provided by the **subprocess** module now have `terminate()`, `kill()`, and `send_signal()` methods. On Windows, `send_signal()` only supports the SIGTERM signal, and all these methods are aliases for the Win32 API function `TerminateProcess()`. (Contributed by Christian Heimes.)

A new variable in the **sys** module, `float_info`, is an object containing information derived from the float.h file about the platform's floating-point support. Attributes of this object include `mant_dig` (number of digits in the mantissa), `epsilon` (smallest difference between 1.0 and the next largest value representable), and several others. (Contributed by Christian Heimes; issue 1534.)

Another new variable, `dont_write_bytecode`, controls whether Python writes any .pyc or .pyo files on importing a module. If this variable is true, the compiled files are not written. The variable is initially set on start-up by supplying the `-B` switch to the Python interpreter, or by setting the `PYTHONDONTWRITEBYTECODE` environment variable before running the interpreter. Python code can subsequently change the value of this variable to control whether bytecode files are written or not. (Contributed by Neal Norwitz and Georg Brandl.)

Information about the command-line arguments supplied to the Python interpreter is available by reading attributes of a named tuple available as `sys.flags`. For example, the `verbose` attribute is true if Python was executed in verbose mode, debug
is true in debugging mode, etc. These attributes are all read-only. (Contributed by Christian Heimes.)

A new function, `getsizeof()`, takes a Python object and returns the amount of memory used by the object, measured in bytes. Built-in objects return correct results; third-party extensions may not, but can define a `__sizeof__()` method to return the object's size. (Contributed by Robert Schuppenies; issue 2898.)

It's now possible to determine the current profiler and tracer functions by calling `sys.getprofile()` and `sys.gettrace()`. (Contributed by Georg Brandl; issue 1648.)

- The `tarfile` module now supports POSIX.1-2001 (pax) tarfiles in addition to the POSIX.1-1988 (ustar) and GNU tar formats that were already supported. The default format is GNU tar; specify the `format` parameter to open a file using a different format:

  ```python
  tar = tarfile.open("output.tar", "w",
                      format=tarfile.PAX_FORMAT)
  ```

  The new encoding and errors parameters specify an encoding and an error handling scheme for character conversions. 'strict', 'ignore', and 'replace' are the three standard ways Python can handle errors.; 'utf-8' is a special value that replaces bad characters with their UTF-8 representation. (Character conversions occur because the PAX format supports Unicode filenames, defaulting to UTF-8 encoding.)

  The `TarFile.add()` method now accepts an exclude argument that's a function that can be used to exclude certain filenames from an archive. The function must take a filename and return true if the file should be excluded or false if it should be
archived. The function is applied to both the name initially passed to `add()` and to the names of files in recursively-added directories.

(All changes contributed by Lars Gustäbel).

- An optional timeout parameter was added to the `telnetlib.Telnet` class constructor, specifying a timeout measured in seconds. (Added by Facundo Batista.)

- The `tempfile.NamedTemporaryFile` class usually deletes the temporary file it created when the file is closed. This behaviour can now be changed by passing `delete=False` to the constructor. (Contributed by Damien Miller; issue 1537850.)

A new class, `SpooledTemporaryFile`, behaves like a temporary file but stores its data in memory until a maximum size is exceeded. On reaching that limit, the contents will be written to an on-disk temporary file. (Contributed by Dustin J. Mitchell.)

The `NamedTemporaryFile` and `SpooledTemporaryFile` classes both work as context managers, so you can write with `with tempfile.NamedTemporaryFile() as tmp:` .... (Contributed by Alexander Belopolsky; issue 2021.)

- The `test.test_support` module gained a number of context managers useful for writing tests. EnvironmentVarGuard() is a context manager that temporarily changes environment variables and automatically restores them to their old values.

Another context manager, TransientResource, can surround calls to resources that may or may not be available; it will catch and ignore a specified list of exceptions. For example, a network
test may ignore certain failures when connecting to an external web site:

```python
with test_support.TransientResource(IOError,
    errno=errno.E_TIMEOUT)
    f = urllib.urlopen('https://sf.net')
... 
```

Finally, check_warnings() resets the warning module's warning filters and returns an object that will record all warning messages triggered (issue 3781):

```python
with test_support.check_warnings() as wrec:
    warnings.simplefilter("always")
    # ... code that triggers a warning ...
    assert str(wrec.message) == "function is outdated"
    assert len(wrec.warnings) == 1, "Multiple warnings"
```

(Contributed by Brett Cannon.)

- The textwrap module can now preserve existing whitespace at the beginnings and ends of the newly-created lines by specifying drop_whitespace=False as an argument:

```python
>>> S = "This sentence has a bunch of ... extra whitespace."
>>> print textwrap.fill(S, width=15)
This sentence has a bunch of extra whitespace.
>>> print textwrap.fill(S, drop_whitespace=False)
This sentence has a bunch
of extra whitespace.

>>> (Contributed by Dwayne Bailey; issue 1581073.)

- The `threading` module API is being changed to use properties such as daemon instead of `setDaemon()` and `isDaemon()` methods, and some methods have been renamed to use underscores instead of camel-case; for example, the `activeCount()` method is renamed to `active_count()`. Both the 2.6 and 3.0 versions of the module support the same properties and renamed methods, but don’t remove the old methods. No date has been set for the deprecation of the old APIs in Python 3.x; the old APIs won’t be removed in any 2.x version. (Carried out by several people, most notably Benjamin Peterson.)

The `threading` module's `Thread` objects gained an `ident` property that returns the thread's identifier, a nonzero integer. (Contributed by Gregory P. Smith; issue 2871.)

- The `timeit` module now accepts callables as well as strings for the statement being timed and for the setup code. Two convenience functions were added for creating `Timer` instances: `repeat(stmt, setup, time, repeat, number)` and `timeit(stmt, setup, time, number)` create an instance and call the corresponding method. (Contributed by Erik Demaine; issue 1533909.)

- The `Tkinter` module now accepts lists and tuples for options, separating the elements by spaces before passing the resulting value to Tcl/Tk. (Contributed by Guilherme Polo; issue 2906.)
The `turtle` module for turtle graphics was greatly enhanced by Gregor Lingl. New features in the module include:

- Better animation of turtle movement and rotation.
- Control over turtle movement using the new `delay()`, `tracer()`, and `speed()` methods.
- The ability to set new shapes for the turtle, and to define a new coordinate system.
- Turtles now have an `undo()` method that can roll back actions.
- Simple support for reacting to input events such as mouse and keyboard activity, making it possible to write simple games.
- A `turtle.cfg` file can be used to customize the starting appearance of the turtle's screen.
- The module's docstrings can be replaced by new docstrings that have been translated into another language.

(issue 1513695)

An optional timeout parameter was added to the `urllib.urlopen()` function and the `urllib.ftpwrapper` class constructor, as well as the `urllib2.urlopen()` function. The parameter specifies a timeout measured in seconds. For example:

```python
>>> u = urllib2.urlopen("http://slow.example.com" , timeout=3)
Traceback (most recent call last):
  ...  
urllib2.URLError: <urlopen error timed out>
```
The Unicode database provided by the `unicodedata` module has been updated to version 5.1.0. (Updated by Martin von Löwis; issue 3811.)

The `warnings` module's `formatwarning()` and `showwarning()` gained an optional `line` argument that can be used to supply the line of source code. (Added as part of issue 1631171, which re-implemented part of the `warnings` module in C code.)

A new function, `catch_warnings()`, is a context manager intended for testing purposes that lets you temporarily modify the warning filters and then restore their original values (issue 3781).

The XML-RPC `SimpleXMLRPCServer` and `DocXMLRPCServer` classes can now be prevented from immediately opening and binding to their socket by passing True as the `bind_and_activate` constructor parameter. This can be used to modify the instance's `allow_reuse_address` attribute before calling the `server_bind()` and `server_activate()` methods to open the socket and begin listening for connections. (Contributed by Peter Parente; issue 1599845.)

`SimpleXMLRPCServer` also has a `_send_traceback_header` attribute; if true, the exception and formatted traceback are returned as HTTP headers “X-Exception” and “X-Traceback”. This feature is for debugging purposes only and should not be used on production servers because the tracebacks might reveal passwords or other sensitive information. (Contributed by Alan McIntyre as part of his project for Google’s Summer of Code)
2007.)

- The `xmlrpclib` module no longer automatically converts `datetime.date` and `datetime.time` to the `xmlrpclib.DateTime` type; the conversion semantics were not necessarily correct for all applications. Code using `xmlrpclib` should convert date and `time` instances. (issue 1330538) The code can also handle dates before 1900 (contributed by Ralf Schmitt; issue 2014) and 64-bit integers represented by using `<i8>` in XML-RPC responses (contributed by Riku Lindblad; issue 2985).

- The `zipfile` module's `ZipFile` class now has `extract()` and `extractall()` methods that will unpack a single file or all the files in the archive to the current directory, or to a specified directory:

```python
z = zipfile.ZipFile('python-251.zip')

# Unpack a single file, writing it relative
# to the /tmp directory.
z.extract('Python/sysmodule.c', '/tmp')

# Unpack all the files in the archive.
z.extractall()
```

(Contributed by Alan McIntyre; issue 467924.)

The `open()`, `read()` and `extract()` methods can now take either a filename or a `ZipInfo` object. This is useful when an archive accidentally contains a duplicated filename. (Contributed by Graham Horler; issue 1775025.)
Finally, `zipfile` now supports using Unicode filenames for archived files. (Contributed by Alexey Borzenkov; issue 1734346.)

The **ast** module

The `ast` module provides an Abstract Syntax Tree representation of Python code, and Armin Ronacher contributed a set of helper functions that perform a variety of common tasks. These will be useful for HTML templating packages, code analyzers, and similar tools that process Python code.

The `parse()` function takes an expression and returns an AST. The `dump()` function outputs a representation of a tree, suitable for debugging:

```python
import ast

t = ast.parse(""
    d = {}
    for i in 'abcdefghijklm':
        d[i + i] = ord(i) - ord('a') + 1
    print d
    """

print ast.dump(t)
```

This outputs a deeply nested tree:

```
Module(body=[
    Assign(targets=[
        Name(id='d', ctx=Store())
    ], value=Dict(keys=[], values=[]))
    For(target=Name(id='i', ctx=Store()),
        iter=Str(s='abcdefghijklm'), body=[
            Assign(targets=[
```

The `literal_eval()` method takes a string or an AST representing a literal expression, parses and evaluates it, and returns the resulting value. A literal expression is a Python expression containing only strings, numbers, dictionaries, etc. but no statements or function calls. If you need to evaluate an expression but cannot accept the security risk of using an `eval()` call, `literal_eval()` will handle it safely:

```python
>>> literal = '("a", "b", {2:4, 3:8, 1:2})'
>>> print ast.literal_eval(literal)
('a', 'b', {1: 2, 2: 4, 3: 8})
>>> print ast.literal_eval("a" + "b")
"ab"
```
The module also includes NodeVisitor and NodeTransformer classes for traversing and modifying an AST, and functions for common transformations such as changing line numbers.

The future_builtins module

Python 3.0 makes many changes to the repertoire of built-in functions, and most of the changes can’t be introduced in the Python 2.x series because they would break compatibility. The future_builtins module provides versions of these built-in functions that can be imported when writing 3.0-compatible code.

The functions in this module currently include:

- **ascii(obj)**: equivalent to **repr()**. In Python 3.0, **repr()** will return a Unicode string, while **ascii()** will return a pure ASCII bytestring.
- **filter(predicate, iterable)**, **map(func, iterable1, ...)**: the 3.0 versions return iterators, unlike the 2.x builtins which return lists.
- **hex(value)**, **oct(value)**: instead of calling the **__hex__()** or **__oct__()** methods, these versions will call the **__index__()** method and convert the result to hexadecimal or octal. **oct()** will use the new 0o notation for its result.

The **json** module: JavaScript Object Notation

The new **json** module supports the encoding and decoding of Python
types in JSON (Javascript Object Notation). JSON is a lightweight interchange format often used in web applications. For more information about JSON, see http://www.json.org.

`json` comes with support for decoding and encoding most built-in Python types. The following example encodes and decodes a dictionary:

```python
>>> import json
>>> data = {"spam": "foo", "parrot": 42}
>>> in_json = json.dumps(data) # Encode the data
>>> in_json
'{"parrot": 42, "spam": "foo"}"
>>> json.loads(in_json) # Decode into a Python object
{"spam": "foo", "parrot": 42}
```

It's also possible to write your own decoders and encoders to support more types. Pretty-printing of the JSON strings is also supported.

`json` (originally called simplejson) was written by Bob Ippolito.

**The plistlib module: A Property-List Parser**

The .plist format is commonly used on Mac OS X to store basic data types (numbers, strings, lists, and dictionaries) by serializing them into an XML-based format. It resembles the XML-RPC serialization of data types.

Despite being primarily used on Mac OS X, the format has nothing Mac-specific about it and the Python implementation works on any platform that Python supports, so the `plistlib` module has been promoted to the standard library.
Using the module is simple:

```python
import sys
import plistlib
import datetime

# Create data structure
data_struct = dict(lastAccessed=datetime.datetime.now(),
                 version=1,
                 categories=('Personal','Shared','

# Create string containing XML.
plist_str = plistlib.writePlistToDictionary(data_struct)
new_struct = plistlib.readPlistFromDictionary(plist_str)
print data_struct
print new_struct

# Write data structure to a file and read it back.
plistlib.writePlist(data_struct, '/tmp/customizations.plist')
new_struct = plistlib.readPlist('/tmp/customizations.plist')

# read/writePlist accepts file-like objects as well
plistlib.writePlist(data_struct, sys.stdout)
```

cypes Enhancements

Thomas Heller continued to maintain and enhance the cypes module.

cypes now supports a c_bool datatype that represents the C99 bool type. (Contributed by David Remahl; issue 1649190.)

The cypes string, buffer and array types have improved support for extended slicing syntax, where various combinations of (start,
stop, step) are supplied. (Implemented by Thomas Wouters.)

All ctypes data types now support from_buffer() and from_buffer_copy() methods that create a ctypes instance based on a provided buffer object. from_buffer_copy() copies the contents of the object, while from_buffer() will share the same memory area.

A new calling convention tells ctypes to clear the errno or Win32 LastError variables at the outset of each wrapped call. (Implemented by Thomas Heller; issue 1798.)

You can now retrieve the Unix errno variable after a function call. When creating a wrapped function, you can supply use_errno=True as a keyword parameter to the DLL() function and then call the module-level methods set_errno() and get_errno() to set and retrieve the error value.

The Win32 LastError variable is similarly supported by the DLL(), OleDLL(), and WinDLL() functions. You supply use_last_error=True as a keyword parameter and then call the module-level methods set_last_error() and get_last_error().

The byref() function, used to retrieve a pointer to a ctypes instance, now has an optional offset parameter that is a byte count that will be added to the returned pointer.

**Improved SSL Support**

Bill Janssen made extensive improvements to Python 2.6’s support for the Secure Sockets Layer by adding a new module, ssl, that's built
atop the OpenSSL library. This new module provides more control over the protocol negotiated, the X.509 certificates used, and has better support for writing SSL servers (as opposed to clients) in Python. The existing SSL support in the socket module hasn’t been removed and continues to work, though it will be removed in Python 3.0.

To use the new module, you must first create a TCP connection in the usual way and then pass it to the `ssl.wrap_socket()` function. It's possible to specify whether a certificate is required, and to obtain certificate info by calling the `getpeercert()` method.

**See also:** The documentation for the `ssl` module.
Deprecations and Removals

- String exceptions have been removed. Attempting to use them raises a `TypeError`.

- Changes to the `Exception` interface as dictated by PEP 352 continue to be made. For 2.6, the message attribute is being deprecated in favor of the args attribute.

- (3.0-warning mode) Python 3.0 will feature a reorganized standard library that will drop many outdated modules and rename others. Python 2.6 running in 3.0-warning mode will warn about these modules when they are imported.

  The list of deprecated modules is: audiodev, bgenlocations, buildtools, bundlebuilder, Canvas, compiler, dircache, dl, fpformat, gensuitemodule, ihooks, imageop, imgfile, linuxaudiodev, mhlib, mimetools, multifile, new, pure, statvfs, sunaudiodev, test.testall, and toaiff.

- The gopherlib module has been removed.

- The MimeWriter module and mimify module have been deprecated; use the `email` package instead.

- The md5 module has been deprecated; use the `hashlib` module instead.

- The posixfile module has been deprecated; `fcntl.lockf()` provides better locking.
- The popen2 module has been deprecated; use the subprocess module.

- The rgbimg module has been removed.

- The sets module has been deprecated; it’s better to use the built-in set and frozenset types.

- The sha module has been deprecated; use the hashlib module instead.
Build and C API Changes

Changes to Python’s build process and to the C API include:

- Python now must be compiled with C89 compilers (after 19 years!). This means that the Python source tree has dropped its own implementations of `memmove()` and `strerror()`, which are in the C89 standard library.

- Python 2.6 can be built with Microsoft Visual Studio 2008 (version 9.0), and this is the new default compiler. See the PCbuild directory for the build files. (Implemented by Christian Heimes.)

- On Mac OS X, Python 2.6 can be compiled as a 4-way universal build. The `configure` script can take a `--with-universal-archs=[32-bit|64-bit|all]` switch, controlling whether the binaries are built for 32-bit architectures (x86, PowerPC), 64-bit (x86-64 and PPC-64), or both. (Contributed by Ronald Oussoren.)

- The BerkeleyDB module now has a C API object, available as `bsddb.db.api`. This object can be used by other C extensions that wish to use the bsddb module for their own purposes. (Contributed by Duncan Grisby.)

- The new buffer interface, previously described in the PEP 3118 section, adds `PyObject_GetBuffer()` and `PyBuffer_Release()`, as well as a few other functions.

- Python's use of the C stdio library is now thread-safe, or at least as thread-safe as the underlying library is. A long-standing potential bug occurred if one thread closed a file object while another thread was reading from or writing to the object. In 2.6 file
objects have a reference count, manipulated by the PyFile_IncUseCount() and PyFile_DecUseCount() functions. File objects can't be closed unless the reference count is zero. PyFile_IncUseCount() should be called while the GIL is still held, before carrying out an I/O operation using the FILE * pointer, and PyFile_DecUseCount() should be called immediately after the GIL is re-acquired. (Contributed by Antoine Pitrou and Gregory P. Smith.)

- Importing modules simultaneously in two different threads no longer deadlocks; it will now raise an ImportError. A new API function, PyImport_ImportModuleNoBlock(), will look for a module in sys.modules first, then try to import it after acquiring an import lock. If the import lock is held by another thread, an ImportError is raised. (Contributed by Christian Heimes.)

- Several functions return information about the platform's floating-point support. PyFloat_GetMax() returns the maximum representable floating point value, and PyFloat_GetMin() returns the minimum positive value. PyFloat_GetInfo() returns an object containing more information from the float.h file, such as "mant_dig" (number of digits in the mantissa), "epsilon" (smallest difference between 1.0 and the next largest value representable), and several others. (Contributed by Christian Heimes; issue 1534.)

- C functions and methods that use PyComplex_AsCComplex() will now accept arguments that have a __complex__() method. In particular, the functions in the cmath module will now accept objects with this method. This is a backport of a Python 3.0 change. (Contributed by Mark Dickinson; issue 1675423.)
Python's C API now includes two functions for case-insensitive string comparisons, PyOS_stricmp(char*, char*) and PyOS_strnicmp(char*, char*, Py_ssize_t). (Contributed by Christian Heimes; issue 1635.)

Many C extensions define their own little macro for adding integers and strings to the module's dictionary in the init* function. Python 2.6 finally defines standard macros for adding values to a module, PyModule_AddStringMacro and PyModule_AddIntMacro(). (Contributed by Christian Heimes.)

Some macros were renamed in both 3.0 and 2.6 to make it clearer that they are macros, not functions. Py_Size() became Py_SIZE(), Py_Type() became Py_TYPE(), and Py_Refcnt() became Py_REFCT(). The mixed-case macros are still available in Python 2.6 for backward compatibility. (issue 1629)

Distutils now places C extensions it builds in a different directory when running on a debug version of Python. (Contributed by Collin Winter; issue 1530959.)

Several basic data types, such as integers and strings, maintain internal free lists of objects that can be re-used. The data structures for these free lists now follow a naming convention: the variable is always named free_list, the counter is always named numfree, and a macro Py<typename>_MAXFREELIST is always defined.

A new Makefile target, “make patchcheck”, prepares the Python source tree for making a patch: it fixes trailing whitespace in all modified .py files, checks whether the documentation has been
changed, and reports whether the Misc/ACKS and Misc/NEWS files have been updated. (Contributed by Brett Cannon.)

Another new target, “make profile-opt”, compiles a Python binary using GCC’s profile-guided optimization. It compiles Python with profiling enabled, runs the test suite to obtain a set of profiling results, and then compiles using these results for optimization. (Contributed by Gregory P. Smith.)

Port-Specific Changes: Windows

- The support for Windows 95, 98, ME and NT4 has been dropped. Python 2.6 requires at least Windows 2000 SP4.

- The new default compiler on Windows is Visual Studio 2008 (version 9.0). The build directories for Visual Studio 2003 (version 7.1) and 2005 (version 8.0) were moved into the PC/ directory. The new PCbuild directory supports cross compilation for X64, debug builds and Profile Guided Optimization (PGO). PGO builds are roughly 10% faster than normal builds. (Contributed by Christian Heimes with help from Amaury Forgeot d'Arc and Martin von Löwis.)

- The msvcrt module now supports both the normal and wide char variants of the console I/O API. The getwch() function reads a keypress and returns a Unicode value, as does the getwche() function. The putwch() function takes a Unicode character and writes it to the console. (Contributed by Christian Heimes.)

- os.path.expandvars() will now expand environment variables in the form “%var%”, and “~user” will be expanded into the user’s home directory path. (Contributed by Josiah Carlson;
issue 957650.)

- The socket module's socket objects now have an ioctl() method that provides a limited interface to the WSAIoctl() system interface.

- The _winreg module now has a function, ExpandEnvironmentStrings(), that expands environment variable references such as %NAME% in an input string. The handle objects provided by this module now support the context protocol, so they can be used in with statements. (Contributed by Christian Heimes.)

  _winreg also has better support for x64 systems, exposing the DisableReflectionKey(), EnableReflectionKey(), and QueryReflectionKey() functions, which enable and disable registry reflection for 32-bit processes running on 64-bit systems. (issue 1753245)

- The msilib module's Record object gained GetInteger() and GetString() methods that return field values as an integer or a string. (Contributed by Floris Bruynooghe; issue 2125.)

Port-Specific Changes: Mac OS X

- When compiling a framework build of Python, you can now specify the framework name to be used by providing the --with-framework-name= option to the configure script.
- The macfs module has been removed. This in turn required the macostools.touched() function to be removed because it depended on the macfs module. (issue 1490190)
- Many other Mac OS modules have been deprecated and will
removed in Python 3.0: _builtinSuites, aepack, aetools, aetypes, applesingle, appletrawmain, appletrunner, argvemulator, Audio_mac, autoGIL, Carbon, cfmfile, CodeWarrior, ColorPicker, EasyDialogs, Explorer, Finder, FrameWork, findertools, ic, icglue, icopen, macerrors, MacOS, macfs, macostools, macresource, MiniAEFrame, Nav, Netscape, OSATerminology, pimp, PixMapWrapper, StdSuites, SystemEvents, Terminal, and terminalcommand.

Port-Specific Changes: IRIX

A number of old IRIX-specific modules were deprecated and will be removed in Python 3.0: al and AL, cd, cddb, cdplayer, CL and cl, DEVICE, ERRNO, FILE, FL and fl, flp, fm, GET, GLWS, GL and gl, IN, IOCTL, jpeg, panelparser, readcd, SV and sv, torgb, videoreader, and WAIT.
Porting to Python 2.6

This section lists previously described changes and other bugfixes that may require changes to your code:

- Classes that aren’t supposed to be hashable should set `__hash__ = None` in their definitions to indicate the fact.

- String exceptions have been removed. Attempting to use them raises a `TypeError`.

- The `__init__()` method of `collections.deque` now clears any existing contents of the deque before adding elements from the iterable. This change makes the behavior match `list.__init__()`.

- `object.__init__()` previously accepted arbitrary arguments and keyword arguments, ignoring them. In Python 2.6, this is no longer allowed and will result in a `TypeError`. This will affect `__init__()` methods that end up calling the corresponding method on `object` (perhaps through using `super()`). See issue 1683368 for discussion.

- The Decimal constructor now accepts leading and trailing whitespace when passed a string. Previously it would raise an `InvalidOperation` exception. On the other hand, the `create_decimal()` method of Context objects now explicitly disallows extra whitespace, raising a `ConversionSyntax` exception.

- Due to an implementation accident, if you passed a file path to the built-in `__import__()` function, it would actually import the
specified file. This was never intended to work, however, and the implementation now explicitly checks for this case and raises an ImportError.

- C API: the `PyImport_Import()` and `PyImport_ImportModule()` functions now default to absolute imports, not relative imports. This will affect C extensions that import other modules.

- C API: extension data types that shouldn't be hashable should define their `tp_hash` slot to `PyObject_HashNotImplemented()`.

- The `socket` module exception `socket.error` now inherits from `IOError`. Previously it wasn't a subclass of `StandardError` but now it is, through `IOError`. (Implemented by Gregory P. Smith; issue 1706815.)

- The `xmlrpcclib` module no longer automatically converts `datetime.date` and `datetime.time` to the `xmlrpcclib.DateTime` type; the conversion semantics were not necessarily correct for all applications. Code using `xmlrpcclib` should convert date and `time` instances. (issue 1330538)

- (3.0-warning mode) The `Exception` class now warns when accessed using slicing or index access; having `Exception` behave like a tuple is being phased out.

- (3.0-warning mode) Inequality comparisons between two dictionaries or two objects that don't implement comparison methods are reported as warnings. `dict1 == dict2` still works, but `dict1 < dict2` is being phased out.
Comparisons between cells, which are an implementation detail of Python’s scoping rules, also cause warnings because such comparisons are forbidden entirely in 3.0.
Acknowledgements

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What’s New in Python 2.5

**Author:** A.M. Kuchling

This article explains the new features in Python 2.5. The final release of Python 2.5 is scheduled for August 2006; [PEP 356](#) describes the planned release schedule.

The changes in Python 2.5 are an interesting mix of language and library improvements. The library enhancements will be more important to Python’s user community, I think, because several widely-useful packages were added. New modules include ElementTree for XML processing (xml.etree), the SQLite database module (sqlite), and the ctypes module for calling C functions.

The language changes are of middling significance. Some pleasant new features were added, but most of them aren’t features that you'll use every day. Conditional expressions were finally added to the language using a novel syntax; see section [PEP 308: Conditional Expressions](#). The new ‘with’ statement will make writing cleanup code easier (section [PEP 343: The ‘with’ statement](#)). Values can now be passed into generators (section [PEP 342: New Generator Features](#)). Imports are now visible as either absolute or relative (section [PEP 328: Absolute and Relative Imports](#)). Some corner cases of exception handling are handled better (section [PEP 341: Unified try/except/finally](#)). All these improvements are worthwhile, but they’re improvements to one specific language feature or another; none of them are broad modifications to Python’s semantics.

As well as the language and library additions, other improvements and bugfixes were made throughout the source tree. A search through the
SVN change logs finds there were 353 patches applied and 458 bugs fixed between Python 2.4 and 2.5. (Both figures are likely to be underestimates.)

This article doesn’t try to be a complete specification of the new features; instead changes are briefly introduced using helpful examples. For full details, you should always refer to the documentation for Python 2.5 at https://docs.python.org. If you want to understand the complete implementation and design rationale, refer to the PEP for a particular new feature.

Comments, suggestions, and error reports for this document are welcome; please e-mail them to the author or open a bug in the Python bug tracker.
PEP 308: Conditional Expressions

For a long time, people have been requesting a way to write conditional expressions, which are expressions that return value A or value B depending on whether a Boolean value is true or false. A conditional expression lets you write a single assignment statement that has the same effect as the following:

```python
if condition:
    x = true_value
else:
    x = false_value
```

There have been endless tedious discussions of syntax on both python-dev and comp.lang.python. A vote was even held that found the majority of voters wanted conditional expressions in some form, but there was no syntax that was preferred by a clear majority. Candidates included C’s `cond ? true_v : false_v`, `if cond then true_v else false_v`, and 16 other variations.

Guido van Rossum eventually chose a surprising syntax:

```python
x = true_value if condition else false_value
```

Evaluation is still lazy as in existing Boolean expressions, so the order of evaluation jumps around a bit. The `condition` expression in the middle is evaluated first, and the `true_value` expression is evaluated only if the condition was true. Similarly, the `false_value` expression is only evaluated when the condition is false.

This syntax may seem strange and backwards; why does the condition go in the middle of the expression, and not in the front as in C’s `c ? x`
The decision was checked by applying the new syntax to the modules in the standard library and seeing how the resulting code read. In many cases where a conditional expression is used, one value seems to be the ‘common case’ and one value is an ‘exceptional case’, used only on rarer occasions when the condition isn’t met. The conditional syntax makes this pattern a bit more obvious:

```python
contents = ((doc + '\n') if doc else '')
```

I read the above statement as meaning “here contents is usually assigned a value of doc+'\n'; sometimes doc is empty, in which special case an empty string is returned.” I doubt I will use conditional expressions very often where there isn’t a clear common and uncommon case.

There was some discussion of whether the language should require surrounding conditional expressions with parentheses. The decision was made to not require parentheses in the Python language’s grammar, but as a matter of style I think you should always use them. Consider these two statements:

```python
# First version -- no parens
level = 1 if logging else 0

# Second version -- with parens
level = (1 if logging else 0)
```

In the first version, I think a reader’s eye might group the statement into ‘level = 1’, ‘if logging’, ‘else 0’, and think that the condition decides whether the assignment to level is performed. The second version reads better, in my opinion, because it makes it clear that the assignment is always performed and the choice is being made between two values.
Another reason for including the brackets: a few odd combinations of list comprehensions and lambdas could look like incorrect conditional expressions. See PEP 308 for some examples. If you put parentheses around your conditional expressions, you won’t run into this case.

See also:

PEP 308 - Conditional Expressions
PEP written by Guido van Rossum and Raymond D. Hettinger; implemented by Thomas Wouters.
PEP 309: Partial Function Application

The `functools` module is intended to contain tools for functional-style programming.

One useful tool in this module is the partial() function. For programs written in a functional style, you'll sometimes want to construct variants of existing functions that have some of the parameters filled in. Consider a Python function `f(a, b, c);` you could create a new function `g(b, c)` that was equivalent to `f(1, b, c).` This is called “partial function application”.

partial() takes the arguments `(function, arg1, arg2, ... kwarg1=value1, kwarg2=value2).` The resulting object is callable, so you can just call it to invoke `function` with the filled-in arguments.

Here's a small but realistic example:

```python
import functools

def log (message, subsystem):
    "Write the contents of 'message' to the specified subsystem."
    print '%s: %s' % (subsystem, message)
...

server_log = functools.partial(log, subsystem='server')
server_log('Unable to open socket')
```

Here's another example, from a program that uses PyGTK. Here a context-sensitive pop-up menu is being constructed dynamically. The callback provided for the menu option is a partially applied version of
the open_item() method, where the first argument has been provided.

```python
...  
class Application:
    def open_item(self, path):
        ...

def init (self):
    open_func = functools.partial(self.open_item)
popup_menu.append( ("Open", open_func, 1) )
```

Another function in the `functools` module is the `update_wrapper(wrapper, wrapped)` function that helps you write well-behaved decorators. `update_wrapper()` copies the name, module, and docstring attribute to a wrapper function so that tracebacks inside the wrapped function are easier to understand. For example, you might write:

```python
def my_decorator(f):
    def wrapper(*args, **kwd):
        print 'Calling decorated function'
        return f(*args, **kwd)
    functools.update_wrapper(wrapper, f)
    return wrapper
```

`wraps()` is a decorator that can be used inside your own decorators to copy the wrapped function’s information. An alternate version of the previous example would be:

```python
def my_decorator(f):
    @functools.wraps(f)
    def wrapper(*args, **kwd):
        print 'Calling decorated function'
        return f(*args, **kwd)
```
return wrapper

See also:

**PEP 309 - Partial Function Application**

PEP proposed and written by Peter Harris; implemented by Hye-Shik Chang and Nick Coghlan, with adaptations by Raymond Hettinger.
Some simple dependency support was added to Distutils. The setup() function now has requires, provides, and obsoletes keyword parameters. When you build a source distribution using the sdist command, the dependency information will be recorded in the PKG-INFO file.

Another new keyword parameter is download_url, which should be set to a URL for the package's source code. This means it's now possible to look up an entry in the package index, determine the dependencies for a package, and download the required packages.

```python
VERSION = '1.0'
setup(name='PyPackage',
    version=VERSION,
    requires=[['numarray', 'zlib (>=1.1.4)'],
    obsoletes=[['OldPackage']]
    download_url=('http://www.example.com/pypackage
    % VERSION'),
)
```

Another new enhancement to the Python package index at https://pypi.python.org is storing source and binary archives for a package. The new upload Distutils command will upload a package to the repository.

Before a package can be uploaded, you must be able to build a distribution using the sdist Distutils command. Once that works, you can run python setup.py upload to add your package to the
PyPI archive. Optionally you can GPG-sign the package by supplying the --sign and --identity options.

Package uploading was implemented by Martin von Löwis and Richard Jones.

See also:

**PEP 314 - Metadata for Python Software Packages v1.1**

PEP proposed and written by A.M. Kuchling, Richard Jones, and Fred Drake; implemented by Richard Jones and Fred Drake.
PEP 328: Absolute and Relative Imports

The simpler part of PEP 328 was implemented in Python 2.4: parentheses could now be used to enclose the names imported from a module using the from ... import ... statement, making it easier to import many different names.

The more complicated part has been implemented in Python 2.5: importing a module can be specified to use absolute or package-relative imports. The plan is to move toward making absolute imports the default in future versions of Python.

Let's say you have a package directory like this:

```
pkg/
pkg/__init__.py
pkg/main.py
pkg/string.py
```

This defines a package named pkg containing the pkg.main and pkg.string submodules.

Consider the code in the main.py module. What happens if it executes the statement import string? In Python 2.4 and earlier, it will first look in the package's directory to perform a relative import, finds pkg/string.py, imports the contents of that file as the pkg.string module, and that module is bound to the name string in the pkg.main module's namespace.

That's fine if pkg.string was what you wanted. But what if you wanted Python's standard string module? There's no clean way to ignore pkg.string and look for the standard module; generally you
had to look at the contents of sys.modules, which is slightly unclean. Holger Krekel's py.std package provides a tidier way to perform imports from the standard library, import py; py.std.string.join(), but that package isn't available on all Python installations.

Reading code which relies on relative imports is also less clear, because a reader may be confused about which module, string or pkg.string, is intended to be used. Python users soon learned not to duplicate the names of standard library modules in the names of their packages' submodules, but you can't protect against having your submodule's name being used for a new module added in a future version of Python.

In Python 2.5, you can switch import's behaviour to absolute imports using a from __future__ import absolute_import directive. This absolute-import behaviour will become the default in a future version (probably Python 2.7). Once absolute imports are the default, import string will always find the standard library's version. It's suggested that users should begin using absolute imports as much as possible, so it's preferable to begin writing from pkg import string in your code.

Relative imports are still possible by adding a leading period to the module name when using the from ... import form:

```python
# Import names from pkg.string
from .string import name1, name2
# Import pkg.string
from . import string
```

This imports the string module relative to the current package, so in
pkg.main this will import *name1* and *name2* from *pkg.string*. Additional leading periods perform the relative import starting from the parent of the current package. For example, code in the *A.B.C* module can do:

```
from . import D  # Imports A.B.D
from .. import E  # Imports A.E
from ..F import G  # Imports A.F.G
```

Leading periods cannot be used with the `import modname` form of the import statement, only the `from ... import` form.

**See also:**

**PEP 328 - Imports: Multi-Line and Absolute/Relative**

PEP written by Aahz; implemented by Thomas Wouters.

[http://codespeak.net/py/current/doc/index.html](http://codespeak.net/py/current/doc/index.html)

The *py* library by Holger Krekel, which contains the *py.std* package.
PEP 338: Executing Modules as Scripts

The -m switch added in Python 2.4 to execute a module as a script gained a few more abilities. Instead of being implemented in C code inside the Python interpreter, the switch now uses an implementation in a new module, runpy.

The runpy module implements a more sophisticated import mechanism so that it's now possible to run modules in a package such as pychecker.checker. The module also supports alternative import mechanisms such as the zipimport module. This means you can add a .zip archive's path to sys.path and then use the -m switch to execute code from the archive.

See also:

PEP 338 - Executing modules as scripts
PEP written and implemented by Nick Coghlan.
PEP 341: Unified try/except/finally

Until Python 2.5, the try statement came in two flavours. You could use a finally block to ensure that code is always executed, or one or more except blocks to catch specific exceptions. You couldn’t combine both except blocks and a finally block, because generating the right bytecode for the combined version was complicated and it wasn’t clear what the semantics of the combined statement should be.

Guido van Rossum spent some time working with Java, which does support the equivalent of combining except blocks and a finally block, and this clarified what the statement should mean. In Python 2.5, you can now write:

```python
try:
    block-1 ... 
except Exception1:
    handler-1 ... 
except Exception2:
    handler-2 ... 
else: 
    else-block
finally: 
    final-block
```

The code in block-1 is executed. If the code raises an exception, the various except blocks are tested: if the exception is of class Exception1, handler-1 is executed; otherwise if it’s of class Exception2, handler-2 is executed, and so forth. If no exception is raised, the else-block is executed.
No matter what happened previously, the final-block is executed once the code block is complete and any raised exceptions handled. Even if there’s an error in an exception handler or the else-block and a new exception is raised, the code in the final-block is still run.

See also:

**PEP 341 - Unifying try-except and try-finally**

PEP written by Georg Brandl; implementation by Thomas Lee.
PEP 342: New Generator Features

Python 2.5 adds a simple way to pass values into a generator. As introduced in Python 2.3, generators only produce output; once a generator's code was invoked to create an iterator, there was no way to pass any new information into the function when its execution is resumed. Sometimes the ability to pass in some information would be useful. Hackish solutions to this include making the generator's code look at a global variable and then changing the global variable's value, or passing in some mutable object that callers then modify.

To refresh your memory of basic generators, here's a simple example:

```python
def counter (maximum):
    i = 0
    while i < maximum:
        yield i
        i += 1
```

When you call `counter(10)`, the result is an iterator that returns the values from 0 up to 9. On encountering the `yield` statement, the iterator returns the provided value and suspends the function's execution, preserving the local variables. Execution resumes on the following call to the iterator's `next()` method, picking up after the `yield` statement.

In Python 2.3, `yield` was a statement; it didn’t return any value. In 2.5, `yield` is now an expression, returning a value that can be assigned to a variable or otherwise operated on:

```python
val = (yield i)
```
I recommend that you always put parentheses around a `yield` expression when you’re doing something with the returned value, as in the above example. The parentheses aren’t always necessary, but it’s easier to always add them instead of having to remember when they’re needed.

(PEP 342 explains the exact rules, which are that a `yield`-expression must always be parenthesized except when it occurs at the top-level expression on the right-hand side of an assignment. This means you can write `val = yield i` but have to use parentheses when there’s an operation, as in `val = (yield i) + 12`.)

Values are sent into a generator by calling its `send(value)` method. The generator’s code is then resumed and the `yield` expression returns the specified `value`. If the regular `next()` method is called, the `yield` returns `None`.

Here’s the previous example, modified to allow changing the value of the internal counter.

```python
def counter (maximum):
    i = 0
    while i < maximum:
        val = (yield i)
        # If value provided, change counter
        if val is not None:
            i = val
        else:
            i += 1
```

And here’s an example of changing the counter:

```python
>>> it = counter(10)
>>> print it.next()
```
yield will usually return None, so you should always check for this case. Don't just use its value in expressions unless you're sure that the send() method will be the only method used to resume your generator function.

In addition to send(), there are two other new methods on generators:

- **throw(type, value=None, traceback=None)** is used to raise an exception inside the generator; the exception is raised by the yield expression where the generator’s execution is paused.

- **close()** raises a new GeneratorExit exception inside the generator to terminate the iteration. On receiving this exception, the generator’s code must either raise GeneratorExit or StopIteration. Catching the GeneratorExit exception and returning a value is illegal and will trigger a RuntimeError; if the function raises some other exception, that exception is propagated to the caller. close() will also be called by Python’s garbage collector when the generator is garbage-collected.
If you need to run cleanup code when a `GeneratorExit` occurs, I suggest using a `try: ... finally:` suite instead of catching `GeneratorExit`.

The cumulative effect of these changes is to turn generators from one-way producers of information into both producers and consumers.

Generators also become *coroutines*, a more generalized form of subroutines. Subroutines are entered at one point and exited at another point (the top of the function, and a `return` statement), but coroutines can be entered, exited, and resumed at many different points (the `yield` statements). We'll have to figure out patterns for using coroutines effectively in Python.

The addition of the `close()` method has one side effect that isn't obvious. `close()` is called when a generator is garbage-collected, so this means the generator's code gets one last chance to run before the generator is destroyed. This last chance means that `try...finally` statements in generators can now be guaranteed to work; the `finally` clause will now always get a chance to run. The syntactic restriction that you couldn't mix `yield` statements with a `try...finally` suite has therefore been removed. This seems like a minor bit of language trivia, but using generators and `try...finally` is actually necessary in order to implement the `with` statement described by PEP 343. I'll look at this new statement in the following section.

Another even more esoteric effect of this change: previously, the `gi_frame` attribute of a generator was always a frame object. It's now possible for `gi_frame` to be `None` once the generator has been exhausted.
**See also:**

**PEP 342 - Coroutines via Enhanced Generators**
PEP written by Guido van Rossum and Phillip J. Eby; implemented by Phillip J. Eby. Includes examples of some fancier uses of generators as coroutines.

Earlier versions of these features were proposed in PEP 288 by Raymond Hettinger and PEP 325 by Samuele Pedroni.

**http://en.wikipedia.org/wiki/Coroutine**
The Wikipedia entry for coroutines.

**http://www.sidhe.org/~dan/blog/archives/000178.html**
An explanation of coroutines from a Perl point of view, written by Dan Sugalski.
PEP 343: The ‘with’ statement

The ‘with’ statement clarifies code that previously would use try...finally blocks to ensure that clean-up code is executed. In this section, I’ll discuss the statement as it will commonly be used. In the next section, I’ll examine the implementation details and show how to write objects for use with this statement.

The ‘with’ statement is a new control-flow structure whose basic structure is:

```python
with expression [as variable]:
   with-block
```

The expression is evaluated, and it should result in an object that supports the context management protocol (that is, has `__enter__()` and `__exit__()` methods).

The object’s `__enter__()` is called before `with-block` is executed and therefore can run set-up code. It also may return a value that is bound to the name `variable`, if given. (Note carefully that `variable` is not assigned the result of `expression`.)

After execution of the `with-block` is finished, the object’s `__exit__()` method is called, even if the block raised an exception, and can therefore run clean-up code.

To enable the statement in Python 2.5, you need to add the following directive to your module:

```python
from __future__ import with_statement
```
The statement will always be enabled in Python 2.6.

Some standard Python objects now support the context management protocol and can be used with the `with` statement. File objects are one example:

```python
with open('/etc/passwd', 'r') as f:
    for line in f:
        print line
...
more processing code ...
```

After this statement has executed, the file object in `f` will have been automatically closed, even if the `for` loop raised an exception part-way through the block.

**Note:** In this case, `f` is the same object created by `open()`, because `file.__enter__()` returns `self`.

The `threading` module's locks and condition variables also support the `with` statement:

```python
lock = threading.Lock()
with lock:
    # Critical section of code
...
```

The lock is acquired before the block is executed and always released once the block is complete.

The new `localcontext()` function in the `decimal` module makes it easy to save and restore the current decimal context, which encapsulates the desired precision and rounding characteristics for computations:
from decimal import Decimal, Context, localcontext

# Displays with default precision of 28 digits
v = Decimal('578')
print v.sqrt()

with localcontext(Context(prec=16)):
    # All code in this block uses a precision of 16
    # The original context is restored on exiting the block.
    print v.sqrt()

Writing Context Managers

Under the hood, the `with` statement is fairly complicated. Most people will only use `with` in company with existing objects and don’t need to know these details, so you can skip the rest of this section if you like. Authors of new objects will need to understand the details of the underlying implementation and should keep reading.

A high-level explanation of the context management protocol is:

- The expression is evaluated and should result in an object called a “context manager”. The context manager must have `__enter__()` and `__exit__()` methods.
- The context manager’s `__enter__()` method is called. The value returned is assigned to `VAR`. If no 'as `VAR' clause is present, the value is simply discarded.
- The code in `BLOCK` is executed.
- If `BLOCK` raises an exception, the `__exit__(type, value, traceback)` is called with the exception details, the same values returned by `sys.exc_info()`. The method’s return value controls whether the exception is re-raised: any false value re-raises the exception, and `True` will result in suppressing it. You'll
only rarely want to suppress the exception, because if you do the author of the code containing the `with` statement will never realize anything went wrong.

- If `BLOCK` didn’t raise an exception, the `__exit__()` method is still called, but `type`, `value`, and `traceback` are all `None`.

Let’s think through an example. I won’t present detailed code but will only sketch the methods necessary for a database that supports transactions.

(For people unfamiliar with database terminology: a set of changes to the database are grouped into a transaction. Transactions can be either committed, meaning that all the changes are written into the database, or rolled back, meaning that the changes are all discarded and the database is unchanged. See any database textbook for more information.)

Let’s assume there’s an object representing a database connection. Our goal will be to let the user write code like this:

```python
db_connection = DatabaseConnection()
with db_connection as cursor:
    cursor.execute('insert into ...')
    cursor.execute('delete from ...')
    # ... more operations ...
```

The transaction should be committed if the code in the block runs flawlessly or rolled back if there’s an exception. Here’s the basic interface for `DatabaseConnection` that I’ll assume:

```python
class DatabaseConnection:
    # Database interface
def cursor (self):
    "Returns a cursor object and starts a new tr
```
The `__enter__()` method is pretty easy, having only to start a new transaction. For this application the resulting cursor object would be a useful result, so the method will return it. The user can then add as `cursor` to their `with` statement to bind the cursor to a variable name.

```
class DatabaseConnection:
  ...
  def __enter__(self):
      # Code to start a new transaction
      cursor = self.cursor()
      return cursor
```

The `__exit__()` method is the most complicated because it's where most of the work has to be done. The method has to check if an exception occurred. If there was no exception, the transaction is committed. The transaction is rolled back if there was an exception.

In the code below, execution will just fall off the end of the function, returning the default value of None. None is false, so the exception will be re-raised automatically. If you wished, you could be more explicit and add a `return` statement at the marked location.

```
class DatabaseConnection:
  ...
  def __exit__(self, type, value, tb):
      if tb is None:
          # No exception, so commit
          self.commit()
```
The contextlib module

The new `contextlib` module provides some functions and a decorator that are useful for writing objects for use with the `with` statement.

The decorator is called `contextmanager()`, and lets you write a single generator function instead of defining a new class. The generator should yield exactly one value. The code up to the `yield` will be executed as the `__enter__()` method, and the value yielded will be the method's return value that will get bound to the variable in the `with` statement's `as` clause, if any. The code after the `yield` will be executed in the `__exit__()` method. Any exception raised in the block will be raised by the `yield` statement.

Our database example from the previous section could be written using this decorator as:

```python
from contextlib import contextmanager

@contextmanager
def db_transaction (connection):
    cursor = connection.cursor()
    try:
        yield cursor
    except:
        connection.rollback()
    raise
```
else:
    connection.commit()

db = DatabaseConnection()
with db_transaction(db) as cursor:
...

The `contextlib` module also has a nested(mgr1, mgr2, ...) function that combines a number of context managers so you don't need to write nested `with` statements. In this example, the single `with` statement both starts a database transaction and acquires a thread lock:

```python
lock = threading.Lock()
with nested (db_transaction(db), lock) as (cursor, locked):
...
```

Finally, the closing(object) function returns `object` so that it can be bound to a variable, and calls `object.close` at the end of the block.

```python
import urllib, sys
from contextlib import closing

with closing(urllib.urlopen('http://www.yahoo.com'))
    for line in f:
        sys.stdout.write(line)
```

See also:

**PEP 343 - The “with” statement**

PEP written by Guido van Rossum and Nick Coghlan; implemented by Mike Bland, Guido van Rossum, and Neal
Norwitz. The PEP shows the code generated for a 'with' statement, which can be helpful in learning how the statement works.

The documentation for the `contextlib` module.
PEP 352: Exceptions as New-Style Classes

Exception classes can now be new-style classes, not just classic classes, and the built-in Exception class and all the standard built-in exceptions (NameError, ValueError, etc.) are now new-style classes.

The inheritance hierarchy for exceptions has been rearranged a bit. In 2.5, the inheritance relationships are:

```
BaseException       # New in Python 2.5
 |- KeyboardInterrupt
 |- SystemExit
 |- Exception
    |- (all other current built-in exceptions)
```

This rearrangement was done because people often want to catch all exceptions that indicate program errors. KeyboardInterrupt and SystemExit aren’t errors, though, and usually represent an explicit action such as the user hitting Control-C or code calling `sys.exit()`. A bare except: will catch all exceptions, so you commonly need to list KeyboardInterrupt and SystemExit in order to re-raise them. The usual pattern is:

```
try:
    ...
except (KeyboardInterrupt, SystemExit):
    raise
except:
    # Log error...
    # Continue running program...
```
In Python 2.5, you can now write except Exception to achieve the same result, catching all the exceptions that usually indicate errors but leaving KeyboardInterrupt and SystemExit alone. As in previous versions, a bare except: still catches all exceptions.

The goal for Python 3.0 is to require any class raised as an exception to derive from BaseException or some descendant of BaseException, and future releases in the Python 2.x series may begin to enforce this constraint. Therefore, I suggest you begin making all your exception classes derive from Exception now. It’s been suggested that the bare except: form should be removed in Python 3.0, but Guido van Rossum hasn’t decided whether to do this or not.

Raising of strings as exceptions, as in the statement raise "Error occurred", is deprecated in Python 2.5 and will trigger a warning. The aim is to be able to remove the string-exception feature in a few releases.

See also:

PEP 352 - Required Superclass for Exceptions

PEP written by Brett Cannon and Guido van Rossum; implemented by Brett Cannon.
PEP 353: Using ssize_t as the index type

A wide-ranging change to Python’s C API, using a new Py_ssize_t type definition instead of int, will permit the interpreter to handle more data on 64-bit platforms. This change doesn’t affect Python’s capacity on 32-bit platforms.

Various pieces of the Python interpreter used C’s int type to store sizes or counts; for example, the number of items in a list or tuple were stored in an int. The C compilers for most 64-bit platforms still define int as a 32-bit type, so that meant that lists could only hold up to $2^{31} - 1 = 2147483647$ items. (There are actually a few different programming models that 64-bit C compilers can use – see http://www.unix.org/version2/whatsnew/lp64_wp.html for a discussion – but the most commonly available model leaves int as 32 bits.)

A limit of 2147483647 items doesn’t really matter on a 32-bit platform because you’ll run out of memory before hitting the length limit. Each list item requires space for a pointer, which is 4 bytes, plus space for a PyObject representing the item. $2147483647 \times 4$ is already more bytes than a 32-bit address space can contain.

It's possible to address that much memory on a 64-bit platform, however. The pointers for a list that size would only require 16 GiB of space, so it's not unreasonable that Python programmers might construct lists that large. Therefore, the Python interpreter had to be changed to use some type other than int, and this will be a 64-bit type on 64-bit platforms. The change will cause incompatibilities on 64-bit machines, so it was deemed worth making the transition now, while the number of 64-bit users is still relatively small. (In 5 or 10 years, we may all be on 64-bit machines, and the transition would be
more painful then.)

This change most strongly affects authors of C extension modules. Python strings and container types such as lists and tuples now use Py_ssize_t to store their size. Functions such as `PyList_Size()` now return Py_ssize_t. Code in extension modules may therefore need to have some variables changed to Py_ssize_t.

The `PyArg_ParseTuple()` and `Py_BuildValue()` functions have a new conversion code, n, for Py_ssize_t. `PyArg_ParseTuple()`'s s# and t# still output int by default, but you can define the macro PY_SSIZE_T_CLEAN before including Python.h to make them return Py_ssize_t.

**PEP 353** has a section on conversion guidelines that extension authors should read to learn about supporting 64-bit platforms.

See also:

**PEP 353 - Using ssize_t as the index type**

PEP written and implemented by Martin von Löwis.
PEP 357: The ‘__index__’ method

The NumPy developers had a problem that could only be solved by adding a new special method, `__index__()`. When using slice notation, as in `[start:stop:step]`, the values of the `start`, `stop`, and `step` indexes must all be either integers or long integers. NumPy defines a variety of specialized integer types corresponding to unsigned and signed integers of 8, 16, 32, and 64 bits, but there was no way to signal that these types could be used as slice indexes.

Slicing can’t just use the existing `__int__()` method because that method is also used to implement coercion to integers. If slicing used `__int__()`, floating-point numbers would also become legal slice indexes and that’s clearly an undesirable behaviour.

Instead, a new special method called `__index__()` was added. It takes no arguments and returns an integer giving the slice index to use. For example:

```python
class C:
    def __index__(self):
        return self.value
```

The return value must be either a Python integer or long integer. The interpreter will check that the type returned is correct, and raises a `TypeError` if this requirement isn’t met.

A corresponding `nb_index` slot was added to the C-level `PyNumberMethods` structure to let C extensions implement this protocol. `PyNumber_Index(obj)` can be used in extension code to call the `__index__()` function and retrieve its result.
See also:

**PEP 357 - Allowing Any Object to be Used for Slicing**
PEP written and implemented by Travis Oliphant.
Other Language Changes

Here are all of the changes that Python 2.5 makes to the core Python language.

- The `dict` type has a new hook for letting subclasses provide a default value when a key isn’t contained in the dictionary. When a key isn’t found, the dictionary’s `__missing__(key)` method will be called. This hook is used to implement the new `defaultdict` class in the `collections` module. The following example defines a dictionary that returns zero for any missing key:

  ```python
class zerodict (dict):
    def __missing__ (self, key):
      return 0

d = zerodict({1:1, 2:2})
print d[1], d[2]  # Prints 1, 2
print d[3], d[4]  # Prints 0, 0
```

- Both 8-bit and Unicode strings have new `partition(sep)` and `rpartition(sep)` methods that simplify a common use case.

  The `find(S)` method is often used to get an index which is then used to slice the string and obtain the pieces that are before and after the separator. `partition(sep)` condenses this pattern into a single method call that returns a 3-tuple containing the substring before the separator, the separator itself, and the substring after the separator. If the separator isn’t found, the first element of the tuple is the entire string and the other two elements are empty. `rpartition(sep)` also returns a 3-tuple but starts searching from the end of the string; the `r` stands for ‘reverse’.
Some examples:

```python
>>> ('http://www.python.org').partition(':/'
('http', ':', 'www.python.org')
>>> ('file:/usr/share/doc/index.html').partition(
('file:/usr/share/doc/index.html', '', '')
>>> (u'Subject: a quick question').partition(':'
(u'Subject', ':', u'a quick question')
>>> 'www.python.org'.rpartition('.'
('www.python', '.', 'org')
>>> 'www.python.org'.rpartition(':'
('', '', 'www.python.org')
```

(Implemented by Fredrik Lundh following a suggestion by Raymond Hettinger.)

- The `startswith()` and `endswith()` methods of string types now accept tuples of strings to check for.

```python
def is_image_file (filename):
    return filename.endswith(('.gif', '.jpg', '.
```

(Implemented by Georg Brandl following a suggestion by Tom Lynn.)

- The `min()` and `max()` built-in functions gained a key keyword parameter analogous to the key argument for `sort()`. This parameter supplies a function that takes a single argument and is called for every value in the list; `min()/max()` will return the element with the smallest/largest return value from this function. For example, to find the longest string in a list, you can do:

```python
L = ['medium', 'longest', 'short']
```
Two new built-in functions, `any()` and `all()`, evaluate whether an iterator contains any true or false values. `any()` returns `True` if any value returned by the iterator is true; otherwise it will return `False`. `all()` returns `True` only if all of the values returned by the iterator evaluate as true. (Suggested by Guido van Rossum, and implemented by Raymond Hettinger.)

The result of a class's `__hash__()` method can now be either a long integer or a regular integer. If a long integer is returned, the hash of that value is taken. In earlier versions the hash value was required to be a regular integer, but in 2.5 the `id()` built-in was changed to always return non-negative numbers, and users often seem to use `id(self)` in `__hash__()` methods (though this is discouraged).

ASCII is now the default encoding for modules. It’s now a syntax error if a module contains string literals with 8-bit characters but doesn’t have an encoding declaration. In Python 2.4 this triggered a warning, not a syntax error. See PEP 263 for how to declare a module’s encoding; for example, you might add a line like this near the top of the source file:

```python
# -*- coding: latin1 -*-
```

A new warning, `UnicodeWarning`, is triggered when you attempt
to compare a Unicode string and an 8-bit string that can't be converted to Unicode using the default ASCII encoding. The result of the comparison is false:

```python
chr(128) == unichr(128)  # Can't convert chr(128)
__main__:1: UnicodeWarning: Unicode equal comparison failed to convert both arguments to Unicode - interpreting them as being unequal
False
```  
```python
chr(127) == unichr(127)  # chr(127) can be converted
True
```  
Previously this would raise a `UnicodeDecodeError` exception, but in 2.5 this could result in puzzling problems when accessing a dictionary. If you looked up `unichr(128)` and `chr(128)` was being used as a key, you'd get a `UnicodeDecodeError` exception. Other changes in 2.5 resulted in this exception being raised instead of suppressed by the code in `dictobject.c` that implements dictionaries.

Raising an exception for such a comparison is strictly correct, but the change might have broken code, so instead `UnicodeWarning` was introduced.

(Implemented by Marc-André Lemburg.)

- One error that Python programmers sometimes make is forgetting to include an `__init__.py` module in a package directory. Debugging this mistake can be confusing, and usually requires running Python with the `-v` switch to log all the paths searched. In Python 2.5, a new `ImportWarning` warning is triggered when an import would have picked up a directory as a package but no
__init__.py was found. This warning is silently ignored by default; provide the -wd option when running the Python executable to display the warning message. (Implemented by Thomas Wouters.)

- The list of base classes in a class definition can now be empty. As an example, this is now legal:

```python
class C():
    pass
```

(Implemented by Brett Cannon.)

Interactive Interpreter Changes

In the interactive interpreter, quit and exit have long been strings so that new users get a somewhat helpful message when they try to quit:

```python
>>> quit
'Use Ctrl-D (i.e. EOF) to exit.'
```

In Python 2.5, quit and exit are now objects that still produce string representations of themselves, but are also callable. Newbies who try quit() or exit() will now exit the interpreter as they expect. (Implemented by Georg Brandl.)

The Python executable now accepts the standard long options --help and --version; on Windows, it also accepts the /? option for displaying a help message. (Implemented by Georg Brandl.)

Optimizations
Several of the optimizations were developed at the NeedForSpeed sprint, an event held in Reykjavik, Iceland, from May 21–28 2006. The sprint focused on speed enhancements to the CPython implementation and was funded by EWT LLC with local support from CCP Games. Those optimizations added at this sprint are specially marked in the following list.

- When they were introduced in Python 2.4, the built-in set and frozenset types were built on top of Python’s dictionary type. In 2.5 the internal data structure has been customized for implementing sets, and as a result sets will use a third less memory and are somewhat faster. (Implemented by Raymond Hettinger.)
- The speed of some Unicode operations, such as finding substrings, string splitting, and character map encoding and decoding, has been improved. (Substring search and splitting improvements were added by Fredrik Lundh and Andrew Dalke at the NeedForSpeed sprint. Character maps were improved by Walter Dörwald and Martin von Löwis.)
- The long(str, base) function is now faster on long digit strings because fewer intermediate results are calculated. The peak is for strings of around 800–1000 digits where the function is 6 times faster. (Contributed by Alan McIntyre and committed at the NeedForSpeed sprint.)
- It’s now illegal to mix iterating over a file with for line in file and calling the file object’s read()/readline()/readlines() methods. Iteration uses an internal buffer and the read*() methods don’t use that buffer. Instead they would return the data following the buffer, causing the data to appear out of order. Mixing iteration and these methods will now trigger a ValueError from the read*() method. (Implemented by Thomas Wouters.)
- The struct module now compiles structure format strings into an
internal representation and caches this representation, yielding a 20% speedup. (Contributed by Bob Ippolito at the NeedForSpeed sprint.)

- The `re` module got a 1 or 2% speedup by switching to Python’s allocator functions instead of the system’s `malloc()` and `free()`. (Contributed by Jack Diederich at the NeedForSpeed sprint.)

- The code generator’s peephole optimizer now performs simple constant folding in expressions. If you write something like `a = 2+3`, the code generator will do the arithmetic and produce code corresponding to `a = 5`. (Proposed and implemented by Raymond Hettinger.)

- Function calls are now faster because code objects now keep the most recently finished frame (a “zombie frame”) in an internal field of the code object, reusing it the next time the code object is invoked. (Original patch by Michael Hudson, modified by Armin Rigo and Richard Jones; committed at the NeedForSpeed sprint.)

- Frame objects are also slightly smaller, which may improve cache locality and reduce memory usage a bit. (Contributed by Neal Norwitz.)

- Python’s built-in exceptions are now new-style classes, a change that speeds up instantiation considerably. Exception handling in Python 2.5 is therefore about 30% faster than in 2.4. (Contributed by Richard Jones, Georg Brandl and Sean Reifschneider at the NeedForSpeed sprint.)

- Importing now caches the paths tried, recording whether they exist or not so that the interpreter makes fewer `open()` and `stat()` calls on startup. (Contributed by Martin von Löwis and Georg Brandl.)
New, Improved, and Removed Modules

The standard library received many enhancements and bug fixes in Python 2.5. Here's a partial list of the most notable changes, sorted alphabetically by module name. Consult the Misc/NEWS file in the source tree for a more complete list of changes, or look through the SVN logs for all the details.

- The `audioop` module now supports the a-LAW encoding, and the code for u-LAW encoding has been improved. (Contributed by Lars Immisch.)

- The `codecs` module gained support for incremental codecs. The `codec.lookup()` function now returns a `CodecInfo` instance instead of a tuple. `CodecInfo` instances behave like a 4-tuple to preserve backward compatibility but also have the attributes `encode`, `decode`, `incrementalencoder`, `incrementaldecoder`, `streamwriter`, and `streamreader`. Incremental codecs can receive input and produce output in multiple chunks; the output is the same as if the entire input was fed to the non-incremental codec. See the `codecs` module documentation for details. (Designed and implemented by Walter Dörwald.)

- The `collections` module gained a new type, `defaultdict`, that subclasses the standard `dict` type. The new type mostly behaves like a dictionary but constructs a default value when a key isn't present, automatically adding it to the dictionary for the requested key value.

The first argument to `defaultdict`'s constructor is a factory
function that gets called whenever a key is requested but not found. This factory function receives no arguments, so you can use built-in type constructors such as `list()` or `int()`. For example, you can make an index of words based on their initial letter like this:

```python
words = """Nel mezzo del cammin di nostra vita mi ritrovoi per una selva oscura che la diritta via era smarrita"").lower().split()

index = defaultdict(list)
for w in words:
    init_letter = w[0]
    index[init_letter].append(w)
```

Printing index results in the following output:

```python
defaultdict(<type 'list'>, {'c': ['cammin', 'che', 'd': ['del', 'di', 'diritta'], 'm': ['mezzo', 'l': ['la'], 'o': ['oscura'], 'n': ['nel', 'p': ['per'], 's': ['selva', 'smarrita'], 'r': ['ritrovai'], 'u': ['una'], 'v': ['vita']})
```

(Contributed by Guido van Rossum.)

- The deque double-ended queue type supplied by the `collections` module now has a `remove(value)` method that removes the first occurrence of `value` in the queue, raising `ValueError` if the value isn’t found. (Contributed by Raymond Hettinger.)

- New module: The `contextlib` module contains helper functions
for use with the new `with` statement. See section The contextlib module for more about this module.

- New module: The cProfile module is a C implementation of the existing profile module that has much lower overhead. The module's interface is the same as profile: you run cProfile.run('main()') to profile a function, can save profile data to a file, etc. It's not yet known if the Hotshot profiler, which is also written in C but doesn't match the profile module's interface, will continue to be maintained in future versions of Python. (Contributed by Armin Rigo.)

Also, the pstats module for analyzing the data measured by the profiler now supports directing the output to any file object by supplying a stream argument to the Stats constructor. (Contributed by Skip Montanaro.)

- The csv module, which parses files in comma-separated value format, received several enhancements and a number of bugfixes. You can now set the maximum size in bytes of a field by calling the csv.field_size_limit(new_limit) function; omitting the new_limit argument will return the currently-set limit. The reader class now has a line_num attribute that counts the number of physical lines read from the source; records can span multiple physical lines, so line_num is not the same as the number of records read.

The CSV parser is now stricter about multi-line quoted fields. Previously, if a line ended within a quoted field without a terminating newline character, a newline would be inserted into the returned field. This behavior caused problems when reading files that contained carriage return characters within fields, so the
code was changed to return the field without inserting newlines. As a consequence, if newlines embedded within fields are important, the input should be split into lines in a manner that preserves the newline characters.

(Contributed by Skip Montanaro and Andrew McNamara.)

- The **datetime** class in the **datetime** module now has a `strptime(string, format)` method for parsing date strings, contributed by Josh Spoerri. It uses the same format characters as `time.strptime()` and `time.strftime()`:

  ```python
  from datetime import datetime
  ts = datetime.strptime('10:13:15 2006-03-07', '%H:%M:%S %Y-%m-%d')
  ```

- The `SequenceMatcher.get_matching_blocks()` method in the **difflib** module now guarantees to return a minimal list of blocks describing matching subsequences. Previously, the algorithm would occasionally break a block of matching elements into two list entries. (Enhancement by Tim Peters.)

- The **doctest** module gained a **SKIP** option that keeps an example from being executed at all. This is intended for code snippets that are usage examples intended for the reader and aren’t actually test cases.

  An **encoding** parameter was added to the `testfile()` function and the `DocFileSuite` class to specify the file's encoding. This makes it easier to use non-ASCII characters in tests contained within a docstring. (Contributed by Bjorn Tillenius.)
- The **email** package has been updated to version 4.0. (Contributed by Barry Warsaw.)

- The **fileinput** module was made more flexible. Unicode filenames are now supported, and a *mode* parameter that defaults to "r" was added to the `input()` function to allow opening files in binary or universal newlines mode. Another new parameter, `openhook`, lets you use a function other than `open()` to open the input files. Once you're iterating over the set of files, the `FileInput` object's new `fileno()` returns the file descriptor for the currently opened file. (Contributed by Georg Brandl.)

- In the **gc** module, the new `get_count()` function returns a 3-tuple containing the current collection counts for the three GC generations. This is accounting information for the garbage collector; when these counts reach a specified threshold, a garbage collection sweep will be made. The existing `gc.collect()` function now takes an optional *generation* argument of 0, 1, or 2 to specify which generation to collect. (Contributed by Barry Warsaw.)

- The `nsmallest()` and `nlargest()` functions in the **heapq** module now support a key keyword parameter similar to the one provided by the `min()`/`max()` functions and the `sort()` methods. For example:

```python
>>> import heapq
>>> L = ['short', 'medium', 'longest', 'longer still']
>>> heapq.nsmallest(2, L)  # Return two lowest elements
['longer still', 'longest']
>>> heapq.nsmallest(2, L, key=len)  # Return two shortest elements
['short', 'medium']
```
(Contributed by Raymond Hettinger.)

- The `itertools.islice()` function now accepts None for the start and step arguments. This makes it more compatible with the attributes of slice objects, so that you can now write the following:

```python
s = slice(5)  # Create slice object
itertools.islice(iterable, s.start, s.stop, s.step)
```

(Contributed by Raymond Hettinger.)

- The `format()` function in the `locale` module has been modified and two new functions were added, `format_string()` and `currency()`.

  The `format()` function’s `val` parameter could previously be a string as long as no more than one `%char` specifier appeared; now the parameter must be exactly one `%char` specifier with no surrounding text. An optional `monetary` parameter was also added which, if True, will use the locale’s rules for formatting currency in placing a separator between groups of three digits.

  To format strings with multiple `%char` specifiers, use the new `format_string()` function that works like `format()` but also supports mixing `%char` specifiers with arbitrary text.

  A new `currency()` function was also added that formats a number according to the current locale’s settings.

  (Contributed by Georg Brandl.)

- The `mailbox` module underwent a massive rewrite to add the capability to modify mailboxes in addition to reading them. A new
set of classes that include mbox, MH, and Maildir are used to read mailboxes, and have an add(message) method to add messages, remove(key) to remove messages, and lock()/unlock() to lock/unlock the mailbox. The following example converts a maildir-format mailbox into an mbox-format one:

```python
import mailbox

# 'factory=None' uses email.Message.Message as the class representing individual messages.
src = mailbox.Maildir('maildir', factory=None)
dest = mailbox.mbox('/tmp/mbox')

for msg in src:
    dest.add(msg)
```

(Contributed by Gregory K. Johnson. Funding was provided by Google's 2005 Summer of Code.)

- New module: the msilib module allows creating Microsoft Installer .msi files and CAB files. Some support for reading the .msi database is also included. (Contributed by Martin von Löwis.)

- The nis module now supports accessing domains other than the system default domain by supplying a domain argument to the nis.match() and nis.maps() functions. (Contributed by Ben Bell.)

- The operator module's itemgetter() and attrgetter() functions now support multiple fields. A call such as operator.attrgetter('a', 'b') will return a function that
retrieves the a and b attributes. Combining this new feature with the sort() method's key parameter lets you easily sort lists using multiple fields. (Contributed by Raymond Hettinger.)

- The optparse module was updated to version 1.5.1 of the Optik library. The OptionParser class gained an epilog attribute, a string that will be printed after the help message, and a destroy() method to break reference cycles created by the object. (Contributed by Greg Ward.)

- The os module underwent several changes. The stat_float_times variable now defaults to true, meaning that os.stat() will now return time values as floats. (This doesn't necessarily mean that os.stat() will return times that are precise to fractions of a second; not all systems support such precision.)

  Constants named os.SEEK_SET, os.SEEK_CUR, and os.SEEK_END have been added; these are the parameters to the os.lseek() function. Two new constants for locking are os.O_SHLOCK and os.O_EXLOCK.

  Two new functions, wait3() and wait4(), were added. They're similar the waitpid() function which waits for a child process to exit and returns a tuple of the process ID and its exit status, but wait3() and wait4() return additional information. wait3() doesn't take a process ID as input, so it waits for any child process to exit and returns a 3-tuple of process-id, exit-status, resource-usage as returned from the resource.getrusage() function. wait4(pid) does take a process ID. (Contributed by Chad J. Schroeder.)
On FreeBSD, the `os.stat()` function now returns times with nanosecond resolution, and the returned object now has `st_gen` and `st_birthtime`. The `st_flags` attribute is also available, if the platform supports it. (Contributed by Antti Louko and Diego Pettenò.)

- The Python debugger provided by the `pdb` module can now store lists of commands to execute when a breakpoint is reached and execution stops. Once breakpoint #1 has been created, enter commands 1 and enter a series of commands to be executed, finishing the list with `end`. The command list can include commands that resume execution, such as `continue` or `next`. (Contributed by Grégoire Dooms.)

- The `pickle` and `cPickle` modules no longer accept a return value of `None` from the `__reduce__()` method; the method must return a tuple of arguments instead. The ability to return `None` was deprecated in Python 2.4, so this completes the removal of the feature.

- The `pkgutil` module, containing various utility functions for finding packages, was enhanced to support PEP 302's import hooks and now also works for packages stored in ZIP-format archives. (Contributed by Phillip J. Eby.)

- The `pybench` benchmark suite by Marc-André Lemburg is now included in the `Tools/pybench` directory. The `pybench` suite is an improvement on the commonly used `pystone.py` program because `pybench` provides a more detailed measurement of the interpreter's speed. It times particular operations such as function calls, tuple slicing, method lookups, and numeric operations, instead of performing many different operations and reducing the
result to a single number as pystone.py does.

- The pyexpat module now uses version 2.0 of the Expat parser. (Contributed by Trent Mick.)

- The Queue class provided by the Queue module gained two new methods. `join()` blocks until all items in the queue have been retrieved and all processing work on the items have been completed. Worker threads call the other new method, `task_done()`, to signal that processing for an item has been completed. (Contributed by Raymond Hettinger.)

- The old regex and regsub modules, which have been deprecated ever since Python 2.0, have finally been deleted. Other deleted modules: statcache, tzparse, whrandom.

- Also deleted: the lib-old directory, which includes ancient modules such as dircmp and ni, was removed. lib-old wasn't on the default sys.path, so unless your programs explicitly added the directory to sys.path, this removal shouldn't affect your code.

- The rlcompleter module is no longer dependent on importing the readline module and therefore now works on non-Unix platforms. (Patch from Robert Kiendl.)

- The SimpleXMLRPCServer and DocXMLRPCServer classes now have a `rpc_paths` attribute that constrains XML-RPC operations to a limited set of URL paths; the default is to allow only '/-' and '/RPC2'. Setting `rpc_paths` to None or an empty tuple disables this path checking.
The `socket` module now supports AF_NETLINK sockets on Linux, thanks to a patch from Philippe Biondi. Netlink sockets are a Linux-specific mechanism for communications between a user-space process and kernel code; an introductory article about them is at [http://www.linuxjournal.com/article/7356](http://www.linuxjournal.com/article/7356). In Python code, netlink addresses are represented as a tuple of 2 integers, `(pid, group_mask)`.

Two new methods on socket objects, `recv_into(buffer)` and `recvfrom_into(buffer)`, store the received data in an object that supports the buffer protocol instead of returning the data as a string. This means you can put the data directly into an array or a memory-mapped file.

Socket objects also gained `getfamily()`, `gettype()`, and `getproto()` accessor methods to retrieve the family, type, and protocol values for the socket.

New module: the `spwd` module provides functions for accessing the shadow password database on systems that support shadow passwords.

The `struct` is now faster because it compiles format strings into `Struct` objects with `pack()` and `unpack()` methods. This is similar to how the `re` module lets you create compiled regular expression objects. You can still use the module-level `pack()` and `unpack()` functions; they'll create `Struct` objects and cache them. Or you can use `Struct` instances directly:

```python
s = struct.Struct('ih3s')
data = s.pack(1972, 187, 'abc')
```
You can also pack and unpack data to and from buffer objects directly using the `pack_into(buffer, offset, v1, v2, ...) and unpack_from(buffer, offset)` methods. This lets you store data directly into an array or a memory-mapped file.

(Struct objects were implemented by Bob Ippolito at the NeedForSpeed sprint. Support for buffer objects was added by Martin Blais, also at the NeedForSpeed sprint.)

- The Python developers switched from CVS to Subversion during the 2.5 development process. Information about the exact build version is available as the `sys.subversion` variable, a 3-tuple of `(interpreter-name, branch-name, revision-range)`. For example, at the time of writing my copy of 2.5 was reporting ('CPython', 'trunk', '45313:45315').

  This information is also available to C extensions via the `Py_GetBuildInfo()` function that returns a string of build information like this: "trunk:45355:45356M, Apr 13 2006, 07:42:19". (Contributed by Barry Warsaw.)

- Another new function, `sys._current_frames()`, returns the current stack frames for all running threads as a dictionary mapping thread identifiers to the topmost stack frame currently active in that thread at the time the function is called. (Contributed by Tim Peters.)

- The `TarFile` class in the `tarfile` module now has an `extractall()` method that extracts all members from the archive into the current working directory. It's also possible to set
a different directory as the extraction target, and to unpack only a subset of the archive's members.

The compression used for a tarfile opened in stream mode can now be autodetected using the mode 'r|*'. (Contributed by Lars Gustäbel.)

- The `threading` module now lets you set the stack size used when new threads are created. The `stack_size([*size*])` function returns the currently configured stack size, and supplying the optional `size` parameter sets a new value. Not all platforms support changing the stack size, but Windows, POSIX threading, and OS/2 all do. (Contributed by Andrew MacIntyre.)

- The `unicodedata` module has been updated to use version 4.1.0 of the Unicode character database. Version 3.2.0 is required by some specifications, so it's still available as `unicodedata.ucd_3_2_0`.

- New module: the `uuid` module generates universally unique identifiers (UUIDs) according to RFC 4122. The RFC defines several different UUID versions that are generated from a starting string, from system properties, or purely randomly. This module contains a UUID class and functions named `uuid1()`, `uuid3()`, `uuid4()`, and `uuid5()` to generate different versions of UUID. (Version 2 UUIDs are not specified in RFC 4122 and are not supported by this module.)

```python
>>> import uuid
>>> # make a UUID based on the host ID and current time
>>> uuid.uuid1()
UUID('a8098c1a-f86e-11da-bd1a-00112444be1e')
```
The *weakref* module's *WeakKeyDictionary* and *WeakValueDictionary* types gained new methods for iterating over the weak references contained in the dictionary. *iterkeyrefs()* and *keyrefs()* methods were added to *WeakKeyDictionary*, and *itervaluerefs()* and *valuerefs()* were added to *WeakValueDictionary*.

(Contributed by Fred L. Drake, Jr.)

The *webbrowser* module received a number of enhancements. It's now usable as a script with *python -m webbrowser*, taking a URL as the argument; there are a number of switches to control the behaviour (*-n* for a new browser window, *-t* for a new tab). New module-level functions, *open_new()* and *open_new_tab()* were added to support this. The module's *open()* function supports an additional feature, an *autoraise* parameter that signals whether to raise the open window when possible. A number of additional browsers were added to the supported list such as Firefox, Opera, Konqueror, and elinks.

(Contributed by Oleg Broytmann and Georg Brandl.)
• The xmlrpcLib module now supports returning `datetime` objects for the XML-RPC date type. Supply `use_datetime=True` to the `loads()` function or the Unmarshaller class to enable this feature. (Contributed by Skip Montanaro.)

• The `zipfile` module now supports the ZIP64 version of the format, meaning that a .zip archive can now be larger than 4 GiB and can contain individual files larger than 4 GiB. (Contributed by Ronald Oussoren.)

• The `zlib` module's Compress and Decompress objects now support a `copy()` method that makes a copy of the object's internal state and returns a new Compress or Decompress object. (Contributed by Chris AtLee.)

The ctypes package

The `ctypes` package, written by Thomas Heller, has been added to the standard library. `ctypes` lets you call arbitrary functions in shared libraries or DLLs. Long-time users may remember the `dl` module, which provides functions for loading shared libraries and calling functions in them. The `ctypes` package is much fancier.

To load a shared library or DLL, you must create an instance of the CDLL class and provide the name or path of the shared library or DLL. Once that's done, you can call arbitrary functions by accessing them as attributes of the CDLL object.

```python
import ctypes
```
```python
libc = ctypes.CDLL('libc.so.6')
result = libc.printf("Line of output\n")
```

Type constructors for the various C types are provided: c_int(), c_float(), c_double(), c_char_p() (equivalent to char *), and so forth. Unlike Python’s types, the C versions are all mutable; you can assign to their value attribute to change the wrapped value. Python integers and strings will be automatically converted to the corresponding C types, but for other types you must call the correct type constructor. (And I mean must; getting it wrong will often result in the interpreter crashing with a segmentation fault.)

You shouldn’t use c_char_p() with a Python string when the C function will be modifying the memory area, because Python strings are supposed to be immutable; breaking this rule will cause puzzling bugs. When you need a modifiable memory area, use create_string_buffer():

```python
s = "this is a string"
buf = ctypes.create_string_buffer(s)
libc.strfry(buf)
```

C functions are assumed to return integers, but you can set the restype attribute of the function object to change this:

```python
>>> libc.atof('2.71828')
-1783957616
>>> libc.atof.retype = ctypes.c_double
>>> libc.atof('2.71828')
2.71828
```

c types also provides a wrapper for Python’s C API as the ctypes.pythonapi object. This object does not release the global
interpreter lock before calling a function, because the lock must be held when calling into the interpreter’s code. There's a py_object() type constructor that will create a *PyObject* pointer. A simple usage:

```python
import ctypes

d = {}
ctypes.pythonapi.PyObject_SetItem(ctypes.py_object(d),
        ctypes.py_object("abc"),
        ctypes.py_object(1))

# d is now {'abc': 1}.
```

Don’t forget to use py_object(); if it’s omitted you end up with a segmentation fault.

*ctypes* has been around for a while, but people still write and distribution hand-coded extension modules because you can’t rely on *ctypes* being present. Perhaps developers will begin to write Python wrappers atop a library accessed through *ctypes* instead of extension modules, now that *ctypes* is included with core Python.

See also:

[http://starship.python.net/crew/theller/ctypes/](http://starship.python.net/crew/theller/ctypes/)

The ctypes web page, with a tutorial, reference, and FAQ.

The documentation for the ctypes module.

The ElementTree package

A subset of Fredrik Lundh’s ElementTree library for processing XML has been added to the standard library as `xml.etree`. The available
modules are ElementTree, ElementPath, and ElementInclude from ElementTree 1.2.6. The cElementTree accelerator module is also included.

The rest of this section will provide a brief overview of using ElementTree. Full documentation for ElementTree is available at http://effbot.org/zone/element-index.htm.

ElementTree represents an XML document as a tree of element nodes. The text content of the document is stored as the text and tail attributes of (This is one of the major differences between ElementTree and the Document Object Model; in the DOM there are many different types of node, including TextNode.)

The most commonly used parsing function is parse(), that takes either a string (assumed to contain a filename) or a file-like object and returns an ElementTree instance:

```python
from xml.etree import ElementTree as ET

tree = ET.parse('ex-1.xml')

feed = urllib.urlopen('http://planet.python.org/rss10.xml')
tree = ET.parse(feed)
```

Once you have an ElementTree instance, you can call its getroot() method to get the root Element node.

There's also an XML() function that takes a string literal and returns an Element node (not an ElementTree). This function provides a tidy way to incorporate XML fragments, approaching the convenience of an XML literal:
Each XML element supports some dictionary-like and some list-like access methods. Dictionary-like operations are used to access attribute values, and list-like operations are used to access child nodes.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>elem[n]</td>
<td>Returns n'th child element.</td>
</tr>
<tr>
<td>elem[m:n]</td>
<td>Returns list of m'th through n'th child elements.</td>
</tr>
<tr>
<td>len(elem)</td>
<td>Returns number of child elements.</td>
</tr>
<tr>
<td>list(elem)</td>
<td>Returns list of child elements.</td>
</tr>
<tr>
<td>elem.append(elem2)</td>
<td>Adds elem2 as a child.</td>
</tr>
<tr>
<td>elem.insert(index, elem2)</td>
<td>Inserts elem2 at the specified location.</td>
</tr>
<tr>
<td>del elem[n]</td>
<td>Deletes n'th child element.</td>
</tr>
<tr>
<td>elem.keys()</td>
<td>Returns list of attribute names.</td>
</tr>
<tr>
<td>elem.get(name)</td>
<td>Returns value of attribute name.</td>
</tr>
<tr>
<td>elem.set(name, value)</td>
<td>Sets new value for attribute name.</td>
</tr>
<tr>
<td>elem.attrib</td>
<td>Retrieves the dictionary containing attributes.</td>
</tr>
<tr>
<td>del elem.attrib[name]</td>
<td>Deletes attribute name.</td>
</tr>
</tbody>
</table>

Comments and processing instructions are also represented as
Element nodes. To check if a node is a comment or processing instructions:

```python
if elem.tag is ET.Comment:
    ...
elif elem.tag is ET.ProcessingInstruction:
    ...
```

To generate XML output, you should call the `ElementTree.write()` method. Like `parse()`, it can take either a string or a file-like object:

```python
# Encoding is US-ASCII
tree.write('output.xml')

# Encoding is UTF-8
f = open('output.xml', 'w')
tree.write(f, encoding='utf-8')
```

(Caution: the default encoding used for output is ASCII. For general XML work, where an element’s name may contain arbitrary Unicode characters, ASCII isn’t a very useful encoding because it will raise an exception if an element’s name contains any characters with values greater than 127. Therefore, it’s best to specify a different encoding such as UTF-8 that can handle any Unicode character.)

This section is only a partial description of the `ElementTree` interfaces. Please read the package’s official documentation for more details.

**See also:**

[http://effbot.org/zone/element-index.htm](http://effbot.org/zone/element-index.htm)

Official documentation for `ElementTree`. 
The hashlib package

A new `hashlib` module, written by Gregory P. Smith, has been added to replace the md5 and sha modules. `hashlib` adds support for additional secure hashes (SHA-224, SHA-256, SHA-384, and SHA-512). When available, the module uses OpenSSL for fast platform optimized implementations of algorithms.

The old md5 and sha modules still exist as wrappers around hashlib to preserve backwards compatibility. The new module's interface is very close to that of the old modules, but not identical. The most significant difference is that the constructor functions for creating new hashing objects are named differently.

```python
# Old versions
h = md5.md5()
h = md5.new()

# New version
h = hashlib.md5()

# Old versions
h = sha.sha()
h = sha.new()

# New version
h = hashlib.sha1()

# Hash that weren't previously available
h = hashlib.sha224()
h = hashlib.sha256()
h = hashlib.sha384()
h = hashlib.sha512()
```
# Alternative form

```python
h = hashlib.new('md5')  # Provide algorithm
```

Once a hash object has been created, its methods are the same as before: `update(string)` hashes the specified string into the current digest state, `digest()` and `hexdigest()` return the digest value as a binary string or a string of hex digits, and `copy()` returns a new hashing object with the same digest state.

See also: The documentation for the `hashlib` module.

**The sqlite3 package**

The `pysqlite` module ([http://www.pysqlite.org](http://www.pysqlite.org)), a wrapper for the SQLite embedded database, has been added to the standard library under the package name `sqlite3`.

SQLite is a C library that provides a lightweight disk-based database that doesn’t require a separate server process and allows accessing the database using a nonstandard variant of the SQL query language. Some applications can use SQLite for internal data storage. It's also possible to prototype an application using SQLite and then port the code to a larger database such as PostgreSQL or Oracle.

`pysqlite` was written by Gerhard Häring and provides a SQL interface compliant with the DB-API 2.0 specification described by [PEP 249](https://www.python.org/dev/peps/pep-0249/).

If you're compiling the Python source yourself, note that the source tree doesn't include the SQLite code, only the wrapper module. You'll need to have the SQLite libraries and headers installed before compiling Python, and the build process will compile the module when the necessary headers are available.
To use the module, you must first create a Connection object that represents the database. Here the data will be stored in the /tmp/example file:

```python
conn = sqlite3.connect('/tmp/example')
```

You can also supply the special name :memory: to create a database in RAM.

Once you have a Connection, you can create a Cursor object and call its `execute()` method to perform SQL commands:

```python
c = conn.cursor()

# Create table
c.execute('''create table stocks
    (date text, trans text, symbol text,
    qty real, price real)''')

# Insert a row of data
c.execute('''insert into stocks
    values ('2006-01-05','BUY','RHAT',100,35.14)''')
```

Usually your SQL operations will need to use values from Python variables. You shouldn’t assemble your query using Python’s string operations because doing so is insecure; it makes your program vulnerable to an SQL injection attack.

Instead, use the DB-API’s parameter substitution. Put ? as a placeholder wherever you want to use a value, and then provide a tuple of values as the second argument to the cursor's `execute()` method. (Other database modules may use a different placeholder, such as %s or :1.) For example:
# Never do this -- insecure!
symbol = 'IBM'
c.execute("... where symbol = '%s'" % symbol)

# Do this instead
t = (symbol,)
c.execute('select * from stocks where symbol=?', t)

# Larger example
for t in (('2006-03-28', 'BUY', 'IBM', 1000, 45.00),
          ('2006-04-05', 'BUY', 'MSOFT', 1000, 72.00),
          ('2006-04-06', 'SELL', 'IBM', 500, 53.00),
         ):
    c.execute('insert into stocks values (?,?,?,?,?)

To retrieve data after executing a SELECT statement, you can either treat the cursor as an iterator, call the cursor's fetchone() method to retrieve a single matching row, or call fetchall() to get a list of the matching rows.

This example uses the iterator form:

```python
>>> c = conn.cursor()
>>> c.execute('select * from stocks order by price')
>>> for row in c:
...     print row
...
(u'2006-01-05', u'Buy', u'RHAT', 100, 35.140000000000001)
(u'2006-03-28', u'Buy', u'IBM', 1000, 45.0)
(u'2006-04-06', u'Sell', u'IBM', 500, 53.0)
(u'2006-04-05', u'Buy', u'MSOFT', 1000, 72.0)

For more information about the SQL dialect supported by SQLite, see

See also:

http://www.pysqlite.org
   The pysqlite web page.

http://www.sqlite.org
   The SQLite web page; the documentation describes the syntax
   and the available data types for the supported SQL dialect.

The documentation for the sqlite3 module.

PEP 249 - Database API Specification 2.0
   PEP written by Marc-André Lemburg.

The wsgiref package

The Web Server Gateway Interface (WSGI) v1.0 defines a standard
interface between web servers and Python web applications and is
described in PEP 333. The wsgiref package is a reference
implementation of the WSGI specification.

The package includes a basic HTTP server that will run a WSGI
application; this server is useful for debugging but isn't intended for
production use. Setting up a server takes only a few lines of code:

```python
from wsgiref import simple_server

wsgi_app = ...

host = ''
port = 8000
httpd = simple_server.make_server(host, port, wsgi_app)
httpd.serve_forever()
```
See also:

http://www.wsgi.org
A central web site for WSGI-related resources.

PEP 333 - Python Web Server Gateway Interface v1.0
PEP written by Phillip J. Eby.
Build and C API Changes

Changes to Python’s build process and to the C API include:

- The Python source tree was converted from CVS to Subversion, in a complex migration procedure that was supervised and flawlessly carried out by Martin von Löwis. The procedure was developed as PEP 347.

- Coverity, a company that markets a source code analysis tool called Prevent, provided the results of their examination of the Python source code. The analysis found about 60 bugs that were quickly fixed. Many of the bugs were refcounting problems, often occurring in error-handling code. See http://scan.coverity.com for the statistics.

- The largest change to the C API came from PEP 353, which modifies the interpreter to use a Py_ssize_t type definition instead of int. See the earlier section PEP 353: Using ssize_t as the index type for a discussion of this change.

- The design of the bytecode compiler has changed a great deal, no longer generating bytecode by traversing the parse tree. Instead the parse tree is converted to an abstract syntax tree (or AST), and it is the abstract syntax tree that’s traversed to produce the bytecode.

It’s possible for Python code to obtain AST objects by using the compile() built-in and specifying _ast.PyCF_ONLY_AST as the value of the flags parameter:

```python
from _ast import PyCF_ONLY_AST
```
No official documentation has been written for the AST code yet, but PEP 339 discusses the design. To start learning about the code, read the definition of the various AST nodes in Parser/Python.asdl. A Python script reads this file and generates a set of C structure definitions in Include/Python-ast.h. The PyParser_ASTFromString() and PyParser_ASTFromFile(), defined in Include/pythonrun.h, take Python source as input and return the root of an AST representing the contents. This AST can then be turned into a code object by PyAST_Compile(). For more information, read the source code, and then ask questions on python-dev.

The AST code was developed under Jeremy Hylton's management, and implemented by (in alphabetical order) Brett Cannon, Nick Coghlan, Grant Edwards, John Ehresman, Kurt Kaiser, Neal Norwitz, Tim Peters, Armin Rigo, and Neil Schemenauer, plus the participants in a number of AST sprints at conferences such as PyCon.

- Evan Jones's patch to obmalloc, first described in a talk at PyCon DC 2005, was applied. Python 2.4 allocated small objects in 256K-sized arenas, but never freed arenas. With this patch, Python will free arenas when they're empty. The net effect is that on some platforms, when you allocate many objects, Python's
memory usage may actually drop when you delete them and the memory may be returned to the operating system. (Implemented by Evan Jones, and reworked by Tim Peters.)

Note that this change means extension modules must be more careful when allocating memory. Python's API has many different functions for allocating memory that are grouped into families. For example, `PyMem_Malloc()`, `PyMem_Realloc()`, and `PyMem_Free()` are one family that allocates raw memory, while `PyObject_Malloc()`, `PyObject_Realloc()`, and `PyObject_Free()` are another family that's supposed to be used for creating Python objects.

Previously these different families all reduced to the platform's `malloc()` and `free()` functions. This meant it didn't matter if you got things wrong and allocated memory with the `PyMem()` function but freed it with the `PyObject()` function. With 2.5's changes to obmalloc, these families now do different things and mismatches will probably result in a segfault. You should carefully test your C extension modules with Python 2.5.

- The built-in set types now have an official C API. Call `PySet_New()` and `PyFrozenSet_New()` to create a new set, `PySet_Add()` and `PySet_Discard()` to add and remove elements, and `PySet_Contains()` and `PySet_Size()` to examine the set's state. (Contributed by Raymond Hettinger.)

- C code can now obtain information about the exact revision of the Python interpreter by calling the `Py_GetBuildInfo()` function that returns a string of build information like this: "trunk:45355:45356M, Apr 13 2006, 07:42:19". (Contributed by Barry Warsaw.)
• Two new macros can be used to indicate C functions that are local to the current file so that a faster calling convention can be used. `Py_LOCAL(type)` declares the function as returning a value of the specified type and uses a fast-calling qualifier. `Py_LOCAL_INLINE(type)` does the same thing and also requests the function be inlined. If `PY_LOCAL_AGGRESSIVE()` is defined before `python.h` is included, a set of more aggressive optimizations are enabled for the module; you should benchmark the results to find out if these optimizations actually make the code faster. (Contributed by Fredrik Lundh at the NeedForSpeed sprint.)

• `PyErr_NewException(name, base, dict)` can now accept a tuple of base classes as its base argument. (Contributed by Georg Brandl.)

• The `PyErr_Warn()` function for issuing warnings is now deprecated in favour of `PyErr_WarnEx(category, message, stacklevel)` which lets you specify the number of stack frames separating this function and the caller. A `stacklevel` of 1 is the function calling `PyErr_WarnEx()`, 2 is the function above that, and so forth. (Added by Neal Norwitz.)

• The CPython interpreter is still written in C, but the code can now be compiled with a C++ compiler without errors. (Implemented by Anthony Baxter, Martin von Löwis, Skip Montanaro.)

• The `PyRange_New()` function was removed. It was never documented, never used in the core code, and had dangerously lax error checking. In the unlikely case that your extensions were using it, you can replace it by something like the following:
Port-Specific Changes

- MacOS X (10.3 and higher): dynamic loading of modules now uses the dlopen() function instead of MacOS-specific functions.
- MacOS X: an --enable-universalsdk switch was added to the configure script that compiles the interpreter as a universal binary able to run on both PowerPC and Intel processors. (Contributed by Ronald Oussoren; issue 2573.)
- Windows: .dll is no longer supported as a filename extension for extension modules. .pyd is now the only filename extension that will be searched for.
Porting to Python 2.5

This section lists previously described changes that may require changes to your code:

- ASCII is now the default encoding for modules. It's now a syntax error if a module contains string literals with 8-bit characters but doesn't have an encoding declaration. In Python 2.4 this triggered a warning, not a syntax error.
- Previously, the `gi_frame` attribute of a generator was always a frame object. Because of the PEP 342 changes described in section PEP 342: New Generator Features, it's now possible for `gi_frame` to be `None`.
- A new warning, `UnicodeWarning`, is triggered when you attempt to compare a Unicode string and an 8-bit string that can't be converted to Unicode using the default ASCII encoding. Previously such comparisons would raise a `UnicodeDecodeError` exception.
- Library: the `csv` module is now stricter about multi-line quoted fields. If your files contain newlines embedded within fields, the input should be split into lines in a manner which preserves the newline characters.
- Library: the `locale` module's `format()` function's would previously accept any string as long as no more than one `%char` specifier appeared. In Python 2.5, the argument must be exactly one `%char` specifier with no surrounding text.
- Library: The `pickle` and cPickle modules no longer accept a return value of `None` from the `__reduce__()` method; the method must return a tuple of arguments instead. The modules also no longer accept the deprecated `bin` keyword parameter.
- Library: The `SimpleXMLRPCServer` and `DocXMLRPCServer` classes now have a `rpc_paths` attribute that constrains XML-
RPC operations to a limited set of URL paths; the default is to allow only '/' and '/RPC2'. Setting `rpc_paths` to `None` or an empty tuple disables this path checking.

- **C API:** Many functions now use `Py_ssize_t` instead of `int` to allow processing more data on 64-bit machines. Extension code may need to make the same change to avoid warnings and to support 64-bit machines. See the earlier section PEP 353: Using `ssize_t` as the index type for a discussion of this change.

- **C API:** The obmalloc changes mean that you must be careful to not mix usage of the `PyMem_*()` and `PyObject_*()` families of functions. Memory allocated with one family's `*_Malloc()` must be freed with the corresponding family's `*_Free()` function.
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This article explains the new features in Python 2.4.1, released on March 30, 2005.

Python 2.4 is a medium-sized release. It doesn’t introduce as many changes as the radical Python 2.2, but introduces more features than the conservative 2.3 release. The most significant new language features are function decorators and generator expressions; most other changes are to the standard library.

According to the CVS change logs, there were 481 patches applied and 502 bugs fixed between Python 2.3 and 2.4. Both figures are likely to be underestimates.

This article doesn’t attempt to provide a complete specification of every single new feature, but instead provides a brief introduction to each feature. For full details, you should refer to the documentation for Python 2.4, such as the Python Library Reference and the Python Reference Manual. Often you will be referred to the PEP for a particular new feature for explanations of the implementation and design rationale.
PEP 218: Built-In Set Objects

Python 2.3 introduced the sets module. C implementations of set data types have now been added to the Python core as two new built-in types, `set(iterable)` and `frozenset(iterable)`. They provide high speed operations for membership testing, for eliminating duplicates from sequences, and for mathematical operations like unions, intersections, differences, and symmetric differences.

```python
>>> a = set('abracadabra')  # form a set
>>> 'z' in a  # fast membership testing
False
>>> a
set(['a', 'r', 'b', 'c', 'd'])
>>> ''.join(a)  # convert back into a string
'arbcd'

>>> b = set('alacazam')  # form a second set
>>> a - b  # letters in a but not in b
set(['r', 'd', 'b'])
>>> a | b  # letters in either a or b
set(['a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'])
>>> a & b  # letters in both a and b
set(['a', 'c'])
>>> a ^ b  # letters in a or b but not both
set(['r', 'd', 'b', 'm', 'z', 'l'])

>>> a.add('z')  # add a new element
>>> a
set(['a', 'c', 'b', 'd', 'r', 'w', 'y', 'x', 'z'])
>>> a.remove('x')  # take one element out
>>> a
set(['a', 'c', 'b', 'd', 'r', 'w', 'y', 'z'])
```
The `frozenset()` type is an immutable version of `set()`. Since it is immutable and hashable, it may be used as a dictionary key or as a member of another set.

The `sets` module remains in the standard library, and may be useful if you wish to subclass the `Set` or `ImmutableSet` classes. There are currently no plans to deprecate the module.

**See also:**

**PEP 218 - Adding a Built-In Set Object Type**

Originally proposed by Greg Wilson and ultimately implemented by Raymond Hettinger.
PEP 237: Unifying Long Integers and Integers

The lengthy transition process for this PEP, begun in Python 2.2, takes another step forward in Python 2.4. In 2.3, certain integer operations that would behave differently after int/long unification triggered `FutureWarning` warnings and returned values limited to 32 or 64 bits (depending on your platform). In 2.4, these expressions no longer produce a warning and instead produce a different result that's usually a long integer.

The problematic expressions are primarily left shifts and lengthy hexadecimal and octal constants. For example, `2 << 32` results in a warning in 2.3, evaluating to 0 on 32-bit platforms. In Python 2.4, this expression now returns the correct answer, 8589934592.

See also:

**PEP 237 - Unifying Long Integers and Integers**
Original PEP written by Moshe Zadka and GvR. The changes for 2.4 were implemented by Kalle Svensson.
PEP 289: Generator Expressions

The iterator feature introduced in Python 2.2 and the `itertools` module make it easier to write programs that loop through large data sets without having the entire data set in memory at one time. List comprehensions don’t fit into this picture very well because they produce a Python list object containing all of the items. This unavoidably pulls all of the objects into memory, which can be a problem if your data set is very large. When trying to write a functionally-styled program, it would be natural to write something like:

```python
links = [link for link in get_all_links() if not link]
for link in links:
    ...
```

instead of

```python
for link in get_all_links():
    if link.followed:
        continue
    ...
```

The first form is more concise and perhaps more readable, but if you’re dealing with a large number of link objects you’d have to write the second form to avoid having all link objects in memory at the same time.

Generator expressions work similarly to list comprehensions but don’t materialize the entire list; instead they create a generator that will return elements one by one. The above example could be written as:

```python
links = (link for link in get_all_links() if not link)
```
for link in links:
    ... 

Generator expressions always have to be written inside parentheses, as in the above example. The parentheses signalling a function call also count, so if you want to create an iterator that will be immediately passed to a function you could write:

```python
print sum(obj.count for obj in list_all_objects())
```

Generator expressions differ from list comprehensions in various small ways. Most notably, the loop variable (obj in the above example) is not accessible outside of the generator expression. List comprehensions leave the variable assigned to its last value; future versions of Python will change this, making list comprehensions match generator expressions in this respect.

See also:

**PEP 289 - Generator Expressions**

- Proposed by Raymond Hettinger and implemented by Jiwon Seo with early efforts steered by Hye-Shik Chang.
PEP 292: Simpler String Substitutions

Some new classes in the standard library provide an alternative mechanism for substituting variables into strings; this style of substitution may be better for applications where untrained users need to edit templates.

The usual way of substituting variables by name is the % operator:

```python
>>> '%(page)i: %(title)s' % {'page':2, 'title': 'The Best of Times'}
'2: The Best of Times'
```

When writing the template string, it can be easy to forget the i or s after the closing parenthesis. This isn’t a big problem if the template is in a Python module, because you run the code, get an “Unsupported format character” `ValueError`, and fix the problem. However, consider an application such as Mailman where template strings or translations are being edited by users who aren’t aware of the Python language. The format string’s syntax is complicated to explain to such users, and if they make a mistake, it’s difficult to provide helpful feedback to them.

PEP 292 adds a Template class to the `string` module that uses $ to indicate a substitution:

```python
>>> import string
>>> t = string.Template('$page: $title')
>>> t.substitute({'page':2, 'title': 'The Best of Times'})
'2: The Best of Times'
```

If a key is missing from the dictionary, the substitute() method will
raise a **KeyError**. There's also a `safe_substitute()` method that ignores missing keys:

```python
>>> t = string.Template('$page: $title')
>>> t.safe_substitute({'page':3})
'3: $title'
```

**See also:**

**PEP 292 - Simpler String Substitutions**

Written and implemented by Barry Warsaw.
PEP 318: Decorators for Functions and Methods

Python 2.2 extended Python’s object model by adding static methods and class methods, but it didn’t extend Python’s syntax to provide any new way of defining static or class methods. Instead, you had to write a `def` statement in the usual way, and pass the resulting method to a `staticmethod()` or `classmethod()` function that would wrap up the function as a method of the new type. Your code would look like this:

```python
class C:
    def meth (cls):
        ...

    meth = classmethod(meth)  # Rebind name to wrapped-up class method
```

If the method was very long, it would be easy to miss or forget the `classmethod()` invocation after the function body.

The intention was always to add some syntax to make such definitions more readable, but at the time of 2.2’s release a good syntax was not obvious. Today a good syntax still isn’t obvious but users are asking for easier access to the feature; a new syntactic feature has been added to meet this need.

The new feature is called “function decorators”. The name comes from the idea that `classmethod()`, `staticmethod()`, and friends are storing additional information on a function object; they’re *decorating* functions with more details.
The notation borrows from Java and uses the '@' character as an indicator. Using the new syntax, the example above would be written:

```python
class C:
    @classmethod
    def meth(cls):
        ...
```

The `@classmethod` is shorthand for the `meth=classmethod(meth)` assignment. More generally, if you have the following:

```python
@A
@B
@C
def f():
    ...
```

It's equivalent to the following pre-decorator code:

```python
def f(): ...
f = A(B(C(f)))
```

Decorators must come on the line before a function definition, one decorator per line, and can't be on the same line as the def statement, meaning that `@A def f(): ...` is illegal. You can only decorate function definitions, either at the module level or inside a class; you can't decorate class definitions.

A decorator is just a function that takes the function to be decorated as an argument and returns either the same function or some new object. The return value of the decorator need not be callable (though it typically is), unless further decorators will be applied to the result. It's
easy to write your own decorators. The following simple example just sets an attribute on the function object:

```python
>>> def deco(func):
...     func.attr = 'decorated'
...     return func
...
>>> @deco
...     def f(): pass
...
>>> f
<function f at 0x402ef0d4>
>>> f.attr
'decorated'

As a slightly more realistic example, the following decorator checks that the supplied argument is an integer:

```python
def require_int (func):
    def wrapper (arg):
        assert isinstance(arg, int)
        return func(arg)
    return wrapper

@require_int
def p1 (arg):
    print arg

@require_int
def p2 (arg):
    print arg*2
```

An example in PEP 318 contains a fancier version of this idea that lets you both specify the required type and check the returned type.
Decorator functions can take arguments. If arguments are supplied, your decorator function is called with only those arguments and must return a new decorator function; this function must take a single function and return a function, as previously described. In other words, \texttt{@A @B @C(args)} becomes:

\begin{verbatim}
def f(): ...  
_deco = C(args)  
f = A(B(_deco(f)))
\end{verbatim}

Getting this right can be slightly brain-bending, but it's not too difficult.

A small related change makes the \texttt{func\_name} attribute of functions writable. This attribute is used to display function names in tracebacks, so decorators should change the name of any new function that's constructed and returned.

**See also:**

**PEP 318 - Decorators for Functions, Methods and Classes**

Written by Kevin D. Smith, Jim Jewett, and Skip Montanaro. Several people wrote patches implementing function decorators, but the one that was actually checked in was patch \#979728, written by Mark Russell.

**https://www.python.org/moin/PythonDecoratorLibrary**

This Wiki page contains several examples of decorators.
PEP 322: Reverse Iteration

A new built-in function, `reversed(seq)`, takes a sequence and returns an iterator that loops over the elements of the sequence in reverse order.

```python
>>> for i in reversed(xrange(1,4)):
...     print i
...
3
2
1
```

Compared to extended slicing, such as `range(1,4)[::-1]`, `reversed()` is easier to read, runs faster, and uses substantially less memory.

Note that `reversed()` only accepts sequences, not arbitrary iterators. If you want to reverse an iterator, first convert it to a list with `list()`.

```python
>>> input = open('/etc/passwd', 'r')
>>> for line in reversed(list(input)):
...     print line
...
root:*:0:0:System Administrator:/var/root:/bin/tcsh
...n
```

See also:

PEP 322 - Reverse Iteration

Written and implemented by Raymond Hettinger.
PEP 324: New subprocess Module

The standard library provides a number of ways to execute a subprocess, offering different features and different levels of complexity. `os.system(command)` is easy to use, but slow (it runs a shell process which executes the command) and dangerous (you have to be careful about escaping the shell's metacharacters). The popen2 module offers classes that can capture standard output and standard error from the subprocess, but the naming is confusing. The `subprocess` module cleans this up, providing a unified interface that offers all the features you might need.

Instead of popen2's collection of classes, `subprocess` contains a single class called Popen whose constructor supports a number of different keyword arguments.

```python
class Popen(args, bufsize=0, executable=None, stdin=None, stdout=None, stderr=None, preexec_fn=None, close_fds=False, shell=False, cwd=None, env=None, universal_newlines=False, startupinfo=None, creationflags=0):
```

`args` is commonly a sequence of strings that will be the arguments to the program executed as the subprocess. (If the `shell` argument is true, `args` can be a string which will then be passed on to the shell for interpretation, just as `os.system()` does.)

`stdin`, `stdout`, and `stderr` specify what the subprocess's input, output, and error streams will be. You can provide a file object or a file descriptor, or you can use the constant `subprocess.PIPE` to create a pipe between the subprocess and the parent.
The constructor has a number of handy options:

- `close_fds` requests that all file descriptors be closed before running the subprocess.
- `cwd` specifies the working directory in which the subprocess will be executed (defaulting to whatever the parent’s working directory is).
- `env` is a dictionary specifying environment variables.
- `preexec_fn` is a function that gets called before the child is started.
- `universal_newlines` opens the child’s input and output using Python’s universal newlines feature.

Once you’ve created the Popen instance, you can call its wait() method to pause until the subprocess has exited, poll() to check if it’s exited without pausing, or communicate(data) to send the string data to the subprocess’s standard input. communicate(data) then reads any data that the subprocess has sent to its standard output or standard error, returning a tuple (stdout_data, stderr_data).

`call()` is a shortcut that passes its arguments along to the Popen constructor, waits for the command to complete, and returns the status code of the subprocess. It can serve as a safer analog to `os.system()`:

```python
sts = subprocess.call(['dpkg', '-i', '/tmp/new-package.deb'])
if sts == 0:
    # Success
...
else:
    # dpkg returned an error
...
```

The command is invoked without use of the shell. If you really do want
to use the shell, you can add `shell=True` as a keyword argument and provide a string instead of a sequence:

```python
sts = subprocess.call('dpkg -i /tmp/new-package.deb'
```

The PEP takes various examples of shell and Python code and shows how they’d be translated into Python code that uses `subprocess`. Reading this section of the PEP is highly recommended.

See also:

**PEP 324 - subprocess - New process module**

Written and implemented by Peter Åstrand, with assistance from Fredrik Lundh and others.
PEP 327: Decimal Data Type

Python has always supported floating-point (FP) numbers, based on the underlying C double type, as a data type. However, while most programming languages provide a floating-point type, many people (even programmers) are unaware that floating-point numbers don’t represent certain decimal fractions accurately. The new Decimal type can represent these fractions accurately, up to a user-specified precision limit.

Why is Decimal needed?

The limitations arise from the representation used for floating-point numbers. FP numbers are made up of three components:

- The sign, which is positive or negative.
- The mantissa, which is a single-digit binary number followed by a fractional part. For example, 1.01 in base-2 notation is 1 + 0/2 + 1/4, or 1.25 in decimal notation.
- The exponent, which tells where the decimal point is located in the number represented.

For example, the number 1.25 has positive sign, a mantissa value of 1.01 (in binary), and an exponent of 0 (the decimal point doesn’t need to be shifted). The number 5 has the same sign and mantissa, but the exponent is 2 because the mantissa is multiplied by 4 (2 to the power of the exponent 2); 1.25 * 4 equals 5.

Modern systems usually provide floating-point support that conforms to a standard called IEEE 754. C’s double type is usually implemented as a 64-bit IEEE 754 number, which uses 52 bits of space for the mantissa. This means that numbers can only be
specified to 52 bits of precision. If you’re trying to represent numbers whose expansion repeats endlessly, the expansion is cut off after 52 bits. Unfortunately, most software needs to produce output in base 10, and common fractions in base 10 are often repeating decimals in binary. For example, 1.1 decimal is binary 1.0001100110011...; 
\[ .1 = \frac{1}{16} + \frac{1}{32} + \frac{1}{256} \text{ plus an infinite number of additional terms.} \]
IEEE 754 has to chop off that infinitely repeated decimal after 52 digits, so the representation is slightly inaccurate.

Sometimes you can see this inaccuracy when the number is printed:

```python
>>> 1.1
1.1000000000000001
```

The inaccuracy isn’t always visible when you print the number because the FP-to-decimal-string conversion is provided by the C library, and most C libraries try to produce sensible output. Even if it’s not displayed, however, the inaccuracy is still there and subsequent operations can magnify the error.

For many applications this doesn’t matter. If I’m plotting points and displaying them on my monitor, the difference between 1.1 and 1.1000000000000001 is too small to be visible. Reports often limit output to a certain number of decimal places, and if you round the number to two or three or even eight decimal places, the error is never apparent. However, for applications where it does matter, it’s a lot of work to implement your own custom arithmetic routines.

Hence, the Decimal type was created.

The Decimal type
A new module, `decimal`, was added to Python's standard library. It contains two classes, `Decimal` and `Context`. `Decimal` instances represent numbers, and `Context` instances are used to wrap up various settings such as the precision and default rounding mode.

`Decimal` instances are immutable, like regular Python integers and FP numbers; once it's been created, you can't change the value an instance represents. `Decimal` instances can be created from integers or strings:

```python
>>> import decimal
>>> decimal.Decimal(1972)
Decimal("1972")
>>> decimal.Decimal("1.1")
Decimal("1.1")
```

You can also provide tuples containing the sign, the mantissa represented as a tuple of decimal digits, and the exponent:

```python
>>> decimal.Decimal((1, (1, 4, 7, 5), -2))
Decimal("-14.75")
```

Cautionary note: the sign bit is a Boolean value, so 0 is positive and 1 is negative.

Converting from floating-point numbers poses a bit of a problem: should the FP number representing 1.1 turn into the decimal number for exactly 1.1, or for 1.1 plus whatever inaccuracies are introduced? The decision was to dodge the issue and leave such a conversion out of the API. Instead, you should convert the floating-point number into a string using the desired precision and pass the string to the `Decimal` constructor:
Once you have Decimal instances, you can perform the usual mathematical operations on them. One limitation: exponentiation requires an integer exponent:

```python
>>> a = decimal.Decimal('35.72')
>>> b = decimal.Decimal('1.73')
>>> a+b
Decimal("37.45")
>>> a-b
Decimal("33.99")
>>> a*b
Decimal("61.7956")
>>> a/b
Decimal("20.64739884393063583815028902")
>>> a ** 2
Decimal("1275.9184")
>>> a**b
Traceback (most recent call last):
  ...  
decimal.InvalidOperation: x ** (non-integer)
```

You can combine Decimal instances with integers, but not with floating-point numbers:

```python
>>> a + 4
Decimal("39.72")
>>> a + 4.5
Traceback (most recent call last):
  ...  
```

```
Decimal numbers can be used with the `math` and `cmath` modules, but note that they'll be immediately converted to floating-point numbers before the operation is performed, resulting in a possible loss of precision and accuracy. You'll also get back a regular floating-point number and not a Decimal.

```python
>>> import math, cmath
>>> d = decimal.Decimal('123456789012.345')
>>> math.sqrt(d)
351364.18288201344
>>> cmath.sqrt(-d)
351364.18288201344j
```

Decimal instances have a `sqrt()` method that returns a Decimal, but if you need other things such as trigonometric functions you'll have to implement them.

```python
>>> d.sqrt()
Decimal("351364.1828820134592177245001")
```

### The Context type

Instances of the Context class encapsulate several settings for decimal operations:

- `prec` is the precision, the number of decimal places.
- `rounding` specifies the rounding mode. The `decimal` module has constants for the various possibilities: `ROUND_DOWN`, `ROUND_CEILING`, `ROUND_HALF_EVEN`, and various others.
- traps is a dictionary specifying what happens on encountering certain error conditions: either an exception is raised or a value is returned. Some examples of error conditions are division by zero, loss of precision, and overflow.

There's a thread-local default context available by calling getcontext(); you can change the properties of this context to alter the default precision, rounding, or trap handling. The following example shows the effect of changing the precision of the default context:

```python
>>> decimal.getcontext().prec
28
>>> decimal.Decimal(1) / decimal.Decimal(7)
Decimal("0.1428571428571428571428571429")
>>> decimal.getcontext().prec = 9
>>> decimal.Decimal(1) / decimal.Decimal(7)
Decimal("0.142857143")
```

The default action for error conditions is selectable; the module can either return a special value such as infinity or not-a-number, or exceptions can be raised:

```python
>>> decimal.Decimal(1) / decimal.Decimal(0)
Traceback (most recent call last):
 ...
decimal.DivisionByZero: x / 0
>>> decimal.getcontext().traps[decimal.DivisionByZero]
>>> decimal.Decimal(1) / decimal.Decimal(0)
Decimal("Infinity")
```

The Context instance also has various methods for formatting numbers such as to_eng_string() and to_sci_string().
For more information, see the documentation for the `decimal` module, which includes a quick-start tutorial and a reference.

See also:

**PEP 327 - Decimal Data Type**
Written by Facundo Batista and implemented by Facundo Batista, Eric Price, Raymond Hettinger, Aahz, and Tim Peters.

[http://www.lahey.com/float.htm](http://www.lahey.com/float.htm)
The article uses Fortran code to illustrate many of the problems that floating-point inaccuracy can cause.

A description of a decimal-based representation. This representation is being proposed as a standard, and underlies the new Python decimal type. Much of this material was written by Mike Cowlishaw, designer of the Rexx language.
PEP 328: Multi-line Imports

One language change is a small syntactic tweak aimed at making it easier to import many names from a module. In a `from module import names` statement, `names` is a sequence of names separated by commas. If the sequence is very long, you can either write multiple imports from the same module, or you can use backslashes to escape the line endings like this:

```python
from SimpleXMLRPCServer import SimpleXMLRPCServer,
    SimpleXMLRPCRequestHandler,
    CGIXMLRPCRequestHandler,
    resolve_dotted_attribute
```

The syntactic change in Python 2.4 simply allows putting the names within parentheses. Python ignores newlines within a parenthesized expression, so the backslashes are no longer needed:

```python
from SimpleXMLRPCServer import (SimpleXMLRPCServer,
    SimpleXMLRPCRequestHandler,
    CGIXMLRPCRequestHandler,
    resolve_dotted_attribute)
```

The PEP also proposes that all `import` statements be absolute imports, with a leading `.` character to indicate a relative import. This part of the PEP was not implemented for Python 2.4, but was completed for Python 2.5.

See also:

PEP 328 - Imports: Multi-Line and Absolute/Relative
Written by Aahz. Multi-line imports were implemented by Dima
Dorfman.
PEP 331: Locale-Independent Float/String Conversions

The `locale` modules lets Python software select various conversions and display conventions that are localized to a particular country or language. However, the module was careful to not change the numeric locale because various functions in Python's implementation required that the numeric locale remain set to the 'C' locale. Often this was because the code was using the C library's `atof()` function.

Not setting the numeric locale caused trouble for extensions that used third-party C libraries, however, because they wouldn’t have the correct locale set. The motivating example was GTK+, whose user interface widgets weren’t displaying numbers in the current locale.

The solution described in the PEP is to add three new functions to the Python API that perform ASCII-only conversions, ignoring the locale setting:

- `PyOS_ascii_strtod(str, ptr)` and `PyOS_ascii_atof(str, ptr)` both convert a string to a C double.
- `PyOS_ascii_formatd(buffer, buf_len, format, d)` converts a double to an ASCII string.

The code for these functions came from the GLib library ([http://library.gnome.org/devel/glib/stable/](http://library.gnome.org/devel/glib/stable/)), whose developers kindly relicensed the relevant functions and donated them to the Python Software Foundation. The `locale` module can now change the numeric locale, letting extensions such as GTK+ produce the correct results.
See also:

**PEP 331 - Locale-Independent Float/String Conversions**
Written by Christian R. Reis, and implemented by Gustavo Carneiro.
Other Language Changes

Here are all of the changes that Python 2.4 makes to the core Python language.

- Decorators for functions and methods were added (PEP 318).

- Built-in `set()` and `frozenset()` types were added (PEP 218). Other new built-ins include the `reversed(seq)` function (PEP 322).

- Generator expressions were added (PEP 289).

- Certain numeric expressions no longer return values restricted to 32 or 64 bits (PEP 237).

- You can now put parentheses around the list of names in a from module import names statement (PEP 328).

- The `dict.update()` method now accepts the same argument forms as the `dict` constructor. This includes any mapping, any iterable of key/value pairs, and keyword arguments. (Contributed by Raymond Hettinger.)

- The string methods `ljust()`, `rjust()`, and `center()` now take an optional argument for specifying a fill character other than a space. (Contributed by Raymond Hettinger.)

- Strings also gained an `rsplit()` method that works like the `split()` method but splits from the end of the string. (Contributed by Sean Reifschneider.)

```python
>>> 'www.python.org'.split('.', 1)
```
Three keyword parameters, `cmp`, `key`, and `reverse`, were added to the `sort()` method of lists. These parameters make some common usages of `sort()` simpler. All of these parameters are optional.

For the `cmp` parameter, the value should be a comparison function that takes two parameters and returns -1, 0, or +1 depending on how the parameters compare. This function will then be used to sort the list. Previously this was the only parameter that could be provided to `sort()`.

`key` should be a single-parameter function that takes a list element and returns a comparison key for the element. The list is then sorted using the comparison keys. The following example sorts a list case-insensitively:

```python
>>> L = ['A', 'b', 'c', 'D']
>>> L.sort()  # Case-sensitive sort
>>> L
['A', 'D', 'b', 'c']
>>> # Using 'key' parameter to sort list
>>> L.sort(key=lambda x: x.lower())
>>> L
['A', 'b', 'c', 'D']
>>> # Old-fashioned way
>>> L.sort(cmp=lambda x,y: cmp(x.lower(), y.lower))
>>> L
['A', 'b', 'c', 'D']
```

The last example, which uses the `cmp` parameter, is the old way...
to perform a case-insensitive sort. It works but is slower than using a key parameter. Using key calls lower() method once for each element in the list while using cmp will call it twice for each comparison, so using key saves on invocations of the lower() method.

For simple key functions and comparison functions, it is often possible to avoid a lambda expression by using an unbound method instead. For example, the above case-insensitive sort is best written as:

```python
>>> L.sort(key=str.lower)
>>> L
['A', 'b', 'c', 'D']
```

Finally, the reverse parameter takes a Boolean value. If the value is true, the list will be sorted into reverse order. Instead of L.sort(); L.reverse(), you can now write L.sort(reverse=True).

The results of sorting are now guaranteed to be stable. This means that two entries with equal keys will be returned in the same order as they were input. For example, you can sort a list of people by name, and then sort the list by age, resulting in a list sorted by age where people with the same age are in namesorted order.

(All changes to sort() contributed by Raymond Hettinger.)

- There is a new built-in function sorted(iterable) that works like the in-place list.sort() method but can be used in expressions. The differences are:
the input may be any iterable;

- a newly formed copy is sorted, leaving the original intact; and

- the expression returns the new sorted copy

```python
>>> L = [9, 7, 8, 3, 2, 4, 1, 6, 5]
>>> [10+i for i in sorted(L)]  # usable in a list comprehension
[11, 12, 13, 14, 15, 16, 17, 18, 19]
>>> L  # original is left intact
[9,7,8,3,2,4,1,6,5]
>>> sorted('Monty Python')  # any iterable may be an input
[' ', 'M', 'P', 'h', 'n', 'o', 'o', 't', 'y']
>>> # List the contents of a dict sorted by key values
>>> colormap = dict(red=1, blue=2, green=3, black=4)
>>> for k, v in sorted(colormap.items()):
...     print(k, v)
...
black 4
blue 2
green 3
red 1
yellow 5
```

(Contributed by Raymond Hettinger.)

- Integer operations will no longer trigger an OverflowWarning. The OverflowWarning warning will disappear in Python 2.5.

- The interpreter gained a new switch, `-m`, that takes a name, searches for the corresponding module on `sys.path`, and runs the module as a script. For example, you can now run the Python profiler with `python -m profile`. (Contributed by Nick Coghlan.)
• The `eval(expr, globals, locals)` and `execfile(filename, globals, locals)` functions and the `exec` statement now accept any mapping type for the `locals` parameter. Previously this had to be a regular Python dictionary. (Contributed by Raymond Hettinger.)

• The `zip()` built-in function and `itertools.izip()` now return an empty list if called with no arguments. Previously they raised a `TypeError` exception. This makes them more suitable for use with variable length argument lists:

```python
>>> def transpose(array):
...     return zip(*array)
...
>>> transpose([(1,2,3), (4,5,6)])
[(1, 4), (2, 5), (3, 6)]
>>> transpose([])
[]
```

(Contributed by Raymond Hettinger.)

• Encountering a failure while importing a module no longer leaves a partially-initialized module object in `sys.modules`. The incomplete module object left behind would fool further imports of the same module into succeeding, leading to confusing errors. (Fixed by Tim Peters.)

• `None` is now a constant; code that binds a new value to the name `None` is now a syntax error. (Contributed by Raymond Hettinger.)

**Optimizations**

• The inner loops for list and tuple slicing were optimized and now
run about one-third faster. The inner loops for dictionaries were also optimized, resulting in performance boosts for keys(), values(), items(), iterkeys(), itervalues(), and iteritems(). (Contributed by Raymond Hettinger.)

- The machinery for growing and shrinking lists was optimized for speed and for space efficiency. Appending and popping from lists now runs faster due to more efficient code paths and less frequent use of the underlying system realloc(). List comprehensions also benefit. list.extend() was also optimized and no longer converts its argument into a temporary list before extending the base list. (Contributed by Raymond Hettinger.)

- list(), tuple(), map(), filter(), and zip() now run several times faster with non-sequence arguments that supply a __len__() method. (Contributed by Raymond Hettinger.)

- The methods list.__getitem__(), dict.__getitem__(), and dict.__contains__() are now implemented as method_descriptor objects rather than wrapper_descriptor objects. This form of access doubles their performance and makes them more suitable for use as arguments to functionals: map(mydict.__getitem__, keylist). (Contributed by Raymond Hettinger.)

- Added a new opcode, LIST_APPEND, that simplifies the generated bytecode for list comprehensions and speeds them up by about a third. (Contributed by Raymond Hettinger.)

- The peephole bytecode optimizer has been improved to produce shorter, faster bytecode; remarkably, the resulting bytecode is more readable. (Enhanced by Raymond Hettinger.)

- String concatenations in statements of the form s = s + "abc" and s += "abc" are now performed more efficiently in certain circumstances. This optimization won't be present in other Python implementations such as Jython, so you shouldn't rely on it; using the join() method of strings is still recommended when you want to efficiently glue a large number of strings together.
(Contributed by Armin Rigo.)

The net result of the 2.4 optimizations is that Python 2.4 runs the pystone benchmark around 5% faster than Python 2.3 and 35% faster than Python 2.2. (pystone is not a particularly good benchmark, but it's the most commonly used measurement of Python's performance. Your own applications may show greater or smaller benefits from Python 2.4.)
New, Improved, and Deprecated Modules

As usual, Python’s standard library received a number of enhancements and bug fixes. Here’s a partial list of the most notable changes, sorted alphabetically by module name. Consult the Misc/NEWS file in the source tree for a more complete list of changes, or look through the CVS logs for all the details.

- The **asyncore** module’s `loop()` function now has a `count` parameter that lets you perform a limited number of passes through the polling loop. The default is still to loop forever.

- The **base64** module now has more complete RFC 3548 support for Base64, Base32, and Base16 encoding and decoding, including optional case folding and optional alternative alphabets. (Contributed by Barry Warsaw.)

- The **bisect** module now has an underlying C implementation for improved performance. (Contributed by Dmitry Vasiliev.)

- The CJKCodecs collections of East Asian codecs, maintained by Hye-Shik Chang, was integrated into 2.4. The new encodings are:
  - Chinese (PRC): gb2312, gbk, gb18030, big5hkscs, hz
  - Chinese (ROC): big5, cp950
Some other new encodings were added: HP Roman8, ISO_8859-11, ISO_8859-16, PCTP-154, and TIS-620.

The UTF-8 and UTF-16 codecs now cope better with receiving partial input. Previously the StreamReader class would try to read more data, making it impossible to resume decoding from the stream. The read() method will now return as much data as it can and future calls will resume decoding where previous ones left off. (Implemented by Walter Dörwald.)

There is a new collections module for various specialized collection datatypes. Currently it contains just one type, deque, a double-ended queue that supports efficiently adding and removing elements from either end:

```python
>>> from collections import deque
>>> d = deque('ghi')     # make a new deque with three items
>>> d.append('j')        # add a new entry to the right side
>>> d.appendleft('f')   # add a new entry to the left side
>>> d                   # show the representation
deque(['f', 'g', 'h', 'i', 'j'])
>>> d.pop()              # return and remove the rightmost item
'j'
>>> d.popleft()          # return and remove the leftmost item
'f'
>>> list(d)              # list the contents of the deque
['g', 'h', 'i']
>>> 'h' in d             # search the deque
True
```

Several modules, such as the Queue and threading modules, now take advantage of collections.deque for improved performance. (Contributed by Raymond Hettinger.)
• The ConfigParser classes have been enhanced slightly. The read() method now returns a list of the files that were successfully parsed, and the set() method raises TypeError if passed a value argument that isn’t a string. (Contributed by John Belmonte and David Goodger.)

• The curses module now supports the ncurses extension use_default_colors(). On platforms where the terminal supports transparency, this makes it possible to use a transparent background. (Contributed by Jörg Lehmann.)

• The difflib module now includes an HtmlDiff class that creates an HTML table showing a side by side comparison of two versions of a text. (Contributed by Dan Gass.)

• The email package was updated to version 3.0, which dropped various deprecated APIs and removes support for Python versions earlier than 2.3. The 3.0 version of the package uses a new incremental parser for MIME messages, available in the email.FeedParser module. The new parser doesn't require reading the entire message into memory, and doesn't raise exceptions if a message is malformed; instead it records any problems in the defect attribute of the message. (Developed by Anthony Baxter, Barry Warsaw, Thomas Wouters, and others.)

• The heapq module has been converted to C. The resulting tenfold improvement in speed makes the module suitable for handling high volumes of data. In addition, the module has two new functions nlargest() and nsmallest() that use heaps to find the N largest or smallest values in a dataset without the expense of a full sort. (Contributed by Raymond Hettinger.)
- The `httplib` module now contains constants for HTTP status codes defined in various HTTP-related RFC documents. Constants have names such as `OK`, `CREATED`, `CONTINUE`, and `MOVED_PERMANENTLY`; use `pydoc` to get a full list. (Contributed by Andrew Eland.)

- The `imaplib` module now supports IMAP’s THREAD command (contributed by Yves Dionne) and new `deleteacl()` and `myrights()` methods (contributed by Arnaud Mazin).

- The `itertools` module gained a `groupby(iterable[, *func*])` function. `iterable` is something that can be iterated over to return a stream of elements, and the optional `func` parameter is a function that takes an element and returns a key value; if omitted, the key is simply the element itself. `groupby()` then groups the elements into subsequences which have matching values of the key, and returns a series of 2-tuples containing the key value and an iterator over the subsequence.

Here’s an example to make this clearer. The `key` function simply returns whether a number is even or odd, so the result of `groupby()` is to return consecutive runs of odd or even numbers.

```python
>>> import itertools
>>> L = [2, 4, 6, 7, 8, 9, 11, 12, 14]
>>> for key_val, it in itertools.groupby(L, lambda x: x % 2):
...     print(key_val, list(it))
0 [2, 4, 6]
1 [7]
0 [8]
1 [9, 11]
0 [12, 14]
```
groupby() is typically used with sorted input. The logic for groupby() is similar to the Unix uniq filter which makes it handy for eliminating, counting, or identifying duplicate elements:

```python
>>> word = 'abracadabra'
>>> letters = sorted(word)   # Turn string into a list
>>> letters
['a', 'a', 'a', 'a', 'b', 'b', 'c', 'd', 'r']
>>> for k, g in itertools.groupby(letters):
...     print k, list(g)
...
'a', ['a', 'a', 'a', 'a']
'b', ['b', 'b']
c ['c']
d ['d']
r ['r', 'r']
>>> # List unique letters
>>> [k for k, g in itertools.groupby(letters)]
['a', 'b', 'c', 'd', 'r']
>>> # Count letter occurrences
>>> [(k, len(list(g))) for k, g in itertools.groupby(letters)]
[('a', 4), ('b', 2), ('c', 1), ('d', 1), ('r', 2)]
```

(Contributed by Hye-Shik Chang.)

- `itertools` also gained a function named `tee(iterator, N)` that returns $N$ independent iterators that replicate `iterator`. If $N$ is omitted, the default is 2.

```python
>>> L = [1, 2, 3]
>>> i1, i2 = itertools.tee(L)
>>> i1, i2
([1, 2, 3], [1, 2, 3])
```
Note that `tee()` has to keep copies of the values returned by the iterator; in the worst case, it may need to keep all of them. This should therefore be used carefully if the leading iterator can run far ahead of the trailing iterator in a long stream of inputs. If the separation is large, then you might as well use `list()` instead. When the iterators track closely with one another, `tee()` is ideal. Possible applications include bookmarking, windowing, or lookahead iterators. (Contributed by Raymond Hettinger.)

- A number of functions were added to the `locale` module, such as `bind_textdomain_codeset()` to specify a particular encoding and a family of `gettext()` functions that return messages in the chosen encoding. (Contributed by Gustavo Niemeyer.)

- Some keyword arguments were added to the `logging` package's `basicConfig()` function to simplify log configuration. The default behavior is to log messages to standard error, but various keyword arguments can be specified to log to a particular file, change the logging format, or set the logging level. For example:

```python
import logging
logging.basicConfig(filename='/var/log/application.log', level=0,  # Log all messages
                    format='%(levelname):%(process):%(thread):%(message)'
```
Other additions to the `logging` package include a `log(level, msg)` convenience method, as well as a `TimedRotatingFileHandler` class that rotates its log files at a timed interval. The module already had `RotatingFileHandler`, which rotated logs once the file exceeded a certain size. Both classes derive from a new `BaseRotatingHandler` class that can be used to implement other rotating handlers.

(Changes implemented by Vinay Sajip.)

- The `marshal` module now shares interned strings on unpacking a data structure. This may shrink the size of certain pickle strings, but the primary effect is to make `.pyc` files significantly smaller. (Contributed by Martin von Löwis.)

- The `nntplib` module's NNTP class gained `description()` and `descriptions()` methods to retrieve newsgroup descriptions for a single group or for a range of groups. (Contributed by Jürgen A. Erhard.)

- Two new functions were added to the `operator` module, `attrgetter(attr)` and `itemgetter(index)`. Both functions return callables that take a single argument and return the corresponding attribute or item; these callables make excellent data extractors when used with `map()` or `sorted()`. For example:

```python
>>> L = [('c', 2), ('d', 1), ('a', 4), ('b', 3)]
>>> map(operator.itemgetter(0), L)
['c', 'd', 'a', 'b']
>>> map(operator.itemgetter(1), L)
[2, 1, 4, 3]
>>> sorted(L, key=operator.itemgetter(1))  # Sort
[('a', 4), ('b', 3), ('c', 2), ('d', 1)]
```
The `optparse` module was updated in various ways. The module now passes its messages through `gettext.gettext()`, making it possible to internationalize Optik's help and error messages. Help messages for options can now include the string 'default', which will be replaced by the option's default value. (Contributed by Greg Ward.)

The long-term plan is to deprecate the `rfc822` module in some future Python release in favor of the `email` package. To this end, the `email.Utils.formatdate()` function has been changed to make it usable as a replacement for `rfc822.formatdate()`. You may want to write new e-mail processing code with this in mind. (Change implemented by Anthony Baxter.)

A new `urandom(n)` function was added to the `os` module, returning a string containing `n` bytes of random data. This function provides access to platform-specific sources of randomness such as `/dev/urandom` on Linux or the Windows CryptoAPI. (Contributed by Trevor Perrin.)

Another new function: `os.path.lexists(path)` returns true if the file specified by `path` exists, whether or not it's a symbolic link. This differs from the existing `os.path.exists(path)` function, which returns false if `path` is a symlink that points to a destination that doesn't exist. (Contributed by Beni Cherniavsky.)

A new `getsid()` function was added to the `posix` module that underlies the `os` module. (Contributed by J. Raynor.)
- The `poplib` module now supports POP over SSL. (Contributed by Hector Urtubia.)

- The `profile` module can now profile C extension functions. (Contributed by Nick Bastin.)

- The `random` module has a new method called `getrandbits(N)` that returns a long integer of length $N$ bits in length. The existing `randrange()` method now uses `getrandbits()` where appropriate, making generation of arbitrarily large random numbers more efficient. (Contributed by Raymond Hettinger.)

- The regular expression language accepted by the `re` module was extended with simple conditional expressions, written as `(? (group)A|B)`. `group` is either a numeric group ID or a group name defined with `(?P<group>...)` earlier in the expression. If the specified group matched, the regular expression pattern $A$ will be tested against the string; if the group didn't match, the pattern $B$ will be used instead. (Contributed by Gustavo Niemeyer.)

- The `re` module is also no longer recursive, thanks to a massive amount of work by Gustavo Niemeyer. In a recursive regular expression engine, certain patterns result in a large amount of C stack space being consumed, and it was possible to overflow the stack. For example, if you matched a 30000-byte string of a characters against the expression `(a|b)+`, one stack frame was consumed per character. Python 2.3 tried to check for stack overflow and raise a `RuntimeError` exception, but certain patterns could sidestep the checking and if you were unlucky Python could segfault. Python 2.4’s regular expression engine can match this pattern without problems.
• The **signal** module now performs tighter error-checking on the parameters to the **signal.signal()** function. For example, you can’t set a handler on the SIGKILL signal; previous versions of Python would quietly accept this, but 2.4 will raise a **RuntimeError** exception.

• Two new functions were added to the **socket** module. **socketpair()** returns a pair of connected sockets and **getservbyport(port)** looks up the service name for a given port number. (Contributed by Dave Cole and Barry Warsaw.)

• The **sys.exitfunc()** function has been deprecated. Code should be using the existing **atexit** module, which correctly handles calling multiple exit functions. Eventually **sys.exitfunc()** will become a purely internal interface, accessed only by **atexit**.

• The **tarfile** module now generates GNU-format tar files by default. (Contributed by Lars Gustäbel.)

• The **threading** module now has an elegantly simple way to support thread-local data. The module contains a **local** class whose attribute values are local to different threads.

```python
import threading

data = threading.local()
data.number = 42
data.url = ('www.python.org', 80)
```

Other threads can assign and retrieve their own values for the number and url attributes. You can subclass **local** to initialize attributes or to add methods. (Contributed by Jim Fulton.)
• The **timeit** module now automatically disables periodic garbage collection during the timing loop. This change makes consecutive timings more comparable. (Contributed by Raymond Hettinger.)

• The **weakref** module now supports a wider variety of objects including Python functions, class instances, sets, frozensets, deques, arrays, files, sockets, and regular expression pattern objects. (Contributed by Raymond Hettinger.)

• The **xmlrpclib** module now supports a multi-call extension for transmitting multiple XML-RPC calls in a single HTTP operation. (Contributed by Brian Quinlan.)

• The **mpz**, **rotor**, and **xreadlines** modules have been removed.

**cookielib**

The **cookielib** library supports client-side handling for HTTP cookies, mirroring the **Cookie** module's server-side cookie support. Cookies are stored in cookie jars; the library transparently stores cookies offered by the web server in the cookie jar, and fetches the cookie from the jar when connecting to the server. As in web browsers, policy objects control whether cookies are accepted or not.

In order to store cookies across sessions, two implementations of cookie jars are provided: one that stores cookies in the Netscape format so applications can use the Mozilla or Lynx cookie files, and one that stores cookies in the same format as the Perl **libwww** library.

**urllib2** has been changed to interact with **cookielib**: **HTTPCookieProcessor** manages a cookie jar that is used when accessing URLs.
This module was contributed by John J. Lee.

**doctest**

The *doctest* module underwent considerable refactoring thanks to Edward Loper and Tim Peters. Testing can still be as simple as running `doctest.testmod()`, but the refactorings allow customizing the module's operation in various ways.

The new `DocTestFinder` class extracts the tests from a given object's docstrings:

```python
def f(x, y):
    """"">>> f(2,2)
4
>>> f(3,2)
6
    """
    return x*y

finder = doctest.DocTestFinder()

# Get list of DocTest instances
tests = finder.find(f)
```

The new `DocTestRunner` class then runs individual tests and can produce a summary of the results:

```python
runner = doctest.DocTestRunner()
for t in tests:
    tried, failed = runner.run(t)

runner.summarize(verbos=1)
```
The above example produces the following output:

```
1 items passed all tests:
    2 tests in f
2 tests in 1 items.
2 passed and 0 failed.
Test passed.
```

DocTestRunner uses an instance of the OutputChecker class to compare the expected output with the actual output. This class takes a number of different flags that customize its behaviour; ambitious users can also write a completely new subclass of OutputChecker.

The default output checker provides a number of handy features. For example, with the `doctest.ELLIPSIS` option flag, an ellipsis (…) in the expected output matches any substring, making it easier to accommodate outputs that vary in minor ways:

```
def o(n):
    """"""""""""""""""""""
    >> o(1)
<__main__.C instance at 0x...>
""""""""""""""
```

Another special string, `<BLANKLINE>`, matches a blank line:

```
def p(n):
    """""""""""""""""""""
    >> p(1)
<BLANKLINE>
""""""""""
```

Another new capability is producing a diff-style display of the output by specifying the `doctest.REPORT_UDIFF` (unified diffs),
doctest.REPORT_CDIFF (context diffs), or doctest.REPORT_NDIFF (delta-style) option flags. For example:

```python
def g(n):
    """>> g(4)

here
is
a
lengthy

>>>"

L = 'here is a rather lengthy list of words'.split
for word in L[:n]:
    print word
```

Running the above function's tests with `doctest.REPORT_UDIFF` specified, you get the following output:

```plaintext
**********************************************************************
File "t.py", line 15, in g
Failed example:
    g(4)
Differences (unified diff with -expected +actual):
@@ -2,3 +2,3 @@
    is
    a
    -lengthy
+rather
**********************************************************************
```
Build and C API Changes

Some of the changes to Python’s build process and to the C API are:

- Three new convenience macros were added for common return values from extension functions: `Py_RETURN_NONE`, `Py_RETURN_TRUE`, and `Py_RETURN_FALSE`. (Contributed by Brett Cannon.)
- Another new macro, `Py_CLEAR(obj)`, decreases the reference count of `obj` and sets `obj` to the null pointer. (Contributed by Jim Fulton.)
- A new function, `PyTuple_Pack(N, obj1, obj2, ..., objN)`, constructs tuples from a variable length argument list of Python objects. (Contributed by Raymond Hettinger.)
- A new function, `PyDict_Contains(d, k)`, implements fast dictionary lookups without masking exceptions raised during the look-up process. (Contributed by Raymond Hettinger.)
- The `Py_IS_NAN(X)` macro returns 1 if its float or double argument `X` is a NaN. (Contributed by Tim Peters.)
- C code can avoid unnecessary locking by using the new `PyEval_ThreadsInitialized()` function to tell if any thread operations have been performed. If this function returns false, no lock operations are needed. (Contributed by Nick Coghlan.)
- A new function, `PyArg_VaParseTupleAndKeywords()`, is the same as `PyArg_ParseTupleAndKeywords()` but takes a `va_list` instead of a number of arguments. (Contributed by Greg Chapman.)
- A new method flag, `METH_COEXISTS`, allows a function defined in slots to co-exist with a `PyCFunction` having the same name. This can halve the access time for a method such as `set.__contains__()`. (Contributed by Raymond Hettinger.)
- Python can now be built with additional profiling for the interpreter.
itself, intended as an aid to people developing the Python core. Providing `--enable-profiling` to the `configure` script will let you profile the interpreter with `gprof`, and providing the `--with-tsc` switch enables profiling using the Pentium’s Time-Stamp-Counter register. Note that the `--with-tsc` switch is slightly misnamed, because the profiling feature also works on the PowerPC platform, though that processor architecture doesn’t call that register “the TSC register”. (Contributed by Jeremy Hylton.)

- The `tracebackobject` type has been renamed to `PyTracebackObject`.

**Port-Specific Changes**

- The Windows port now builds under MSVC++ 7.1 as well as version 6. (Contributed by Martin von Löwis.)
Porting to Python 2.4

This section lists previously described changes that may require changes to your code:

- Left shifts and hexadecimal/octal constants that are too large no longer trigger a `FutureWarning` and return a value limited to 32 or 64 bits; instead they return a long integer.
- Integer operations will no longer trigger an `OverflowWarning`. The `OverflowWarning` warning will disappear in Python 2.5.
- The `zip()` built-in function and `itertools.izip()` now return an empty list instead of raising a `TypeError` exception if called with no arguments.
- You can no longer compare the date and `datetime` instances provided by the `datetime` module. Two instances of different classes will now always be unequal, and relative comparisons (<, >) will raise a `TypeError`.
- `dircache.listdir()` now passes exceptions to the caller instead of returning empty lists.
- `LexicalHandler.startDTD()` used to receive the public and system IDs in the wrong order. This has been corrected; applications relying on the wrong order need to be fixed.
- `fcntl.ioctl()` now warns if the `mutate` argument is omitted and relevant.
- The `tarfile` module now generates GNU-format tar files by default.
- Encountering a failure while importing a module no longer leaves a partially-initialized module object in `sys.modules`.
- `None` is now a constant; code that binds a new value to the name `None` is now a syntax error.
- The `signals.signal()` function now raises a `RuntimeError` exception for certain illegal values; previously these errors would
pass silently. For example, you can no longer set a handler on the SIGKILL signal.
Acknowledgements

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What’s New in Python 2.3

Author: A.M. Kuchling

This article explains the new features in Python 2.3. Python 2.3 was released on July 29, 2003.

The main themes for Python 2.3 are polishing some of the features added in 2.2, adding various small but useful enhancements to the core language, and expanding the standard library. The new object model introduced in the previous version has benefited from 18 months of bugfixes and from optimization efforts that have improved the performance of new-style classes. A few new built-in functions have been added such as `sum()` and `enumerate()`. The `in` operator can now be used for substring searches (e.g. "ab" in "abc" returns `True`).

Some of the many new library features include Boolean, set, heap, and date/time data types, the ability to import modules from ZIP-format archives, metadata support for the long-awaited Python catalog, an updated version of IDLE, and modules for logging messages, wrapping text, parsing CSV files, processing command-line options, using BerkeleyDB databases... the list of new and enhanced modules is lengthy.

This article doesn’t attempt to provide a complete specification of the new features, but instead provides a convenient overview. For full details, you should refer to the documentation for Python 2.3, such as the Python Library Reference and the Python Reference Manual. If you want to understand the complete implementation and design rationale, refer to the PEP for a particular new feature.
PEP 218: A Standard Set Datatype

The new sets module contains an implementation of a set datatype. The Set class is for mutable sets, sets that can have members added and removed. The ImmutableSet class is for sets that can't be modified, and instances of ImmutableSet can therefore be used as dictionary keys. Sets are built on top of dictionaries, so the elements within a set must be hashable.

Here's a simple example:

```python
>>> import sets
>>> S = sets.Set([1,2,3])
>>> S
Set([1, 2, 3])
>>> 1 in S
True
>>> 0 in S
False
>>> S.add(5)
>>> S.remove(3)
>>> S
Set([1, 2, 5])
```

The union and intersection of sets can be computed with the union() and intersection() methods; an alternative notation uses the bitwise operators & and |. Mutable sets also have in-place versions of these methods, union_update() and intersection_update().

```python
>>> S1 = sets.Set([1,2,3])
>>> S2 = sets.Set([4,5,6])
>>> S1.union(S2)
```
It's also possible to take the symmetric difference of two sets. This is the set of all elements in the union that aren't in the intersection. Another way of putting it is that the symmetric difference contains all elements that are in exactly one set. Again, there's an alternative notation (^), and an in-place version with the ungainly name symmetric_difference_update().

There are also issubset() and issuperset() methods for checking whether one set is a subset or superset of another:
False
>>> S1.issuperset(S2)
True

See also:

**PEP 218 - Adding a Built-In Set Object Type**

PEP written by Greg V. Wilson. Implemented by Greg V. Wilson, Alex Martelli, and GvR.
PEP 255: Simple Generators

In Python 2.2, generators were added as an optional feature, to be enabled by a `from __future__ import generators` directive. In 2.3 generators no longer need to be specially enabled, and are now always present; this means that `yield` is now always a keyword. The rest of this section is a copy of the description of generators from the “What’s New in Python 2.2” document; if you read it back when Python 2.2 came out, you can skip the rest of this section.

You’re doubtless familiar with how function calls work in Python or C. When you call a function, it gets a private namespace where its local variables are created. When the function reaches a `return` statement, the local variables are destroyed and the resulting value is returned to the caller. A later call to the same function will get a fresh new set of local variables. But, what if the local variables weren’t thrown away on exiting a function? What if you could later resume the function where it left off? This is what generators provide; they can be thought of as resumable functions.

Here’s the simplest example of a generator function:

```python
def generate_ints(N):
    for i in range(N):
        yield i
```

A new keyword, `yield`, was introduced for generators. Any function containing a `yield` statement is a generator function; this is detected by Python’s bytecode compiler which compiles the function specially as a result.

When you call a generator function, it doesn’t return a single value;
instead it returns a generator object that supports the iterator protocol. On executing the `yield` statement, the generator outputs the value of `i`, similar to a `return` statement. The big difference between `yield` and a `return` statement is that on reaching a `yield` the generator’s state of execution is suspended and local variables are preserved. On the next call to the generator’s `.next()` method, the function will resume executing immediately after the `yield` statement. (For complicated reasons, the `yield` statement isn’t allowed inside the `try` block of a `try...finally` statement; read PEP 255 for a full explanation of the interaction between `yield` and exceptions.)

Here’s a sample usage of the `generate_ints()` generator:

```python
>>> gen = generate_ints(3)
>>> gen
<generator object at 0x8117f90>
>>> gen.next()
0
>>> gen.next()
1
>>> gen.next()
2
>>> gen.next()
Traceback (most recent call last):
  File "stdin", line 1, in ?
  File "stdin", line 2, in generate_ints
StopIteration
```

You could equally write for `i` in `generate_ints(5)`, or `a,b,c = generate_ints(3)`.

Inside a generator function, the `return` statement can only be used without a value, and signals the end of the procession of values;
afterwards the generator cannot return any further values. return with a value, such as return 5, is a syntax error inside a generator function. The end of the generator’s results can also be indicated by raising StopIteration manually, or by just letting the flow of execution fall off the bottom of the function.

You could achieve the effect of generators manually by writing your own class and storing all the local variables of the generator as instance variables. For example, returning a list of integers could be done by setting self.count to 0, and having the next() method increment self.count and return it. However, for a moderately complicated generator, writing a corresponding class would be much messier. Lib/test/test_generators.py contains a number of more interesting examples. The simplest one implements an in-order traversal of a tree using generators recursively.

```python
# A recursive generator that generates Tree leaves in order.
def inorder(t):
    if t:
        for x in inorder(t.left):
            yield x
        yield t.label
        for x in inorder(t.right):
            yield x
```

Two other examples in Lib/test/test_generators.py produce solutions for the N-Queens problem (placing $N$ queens on an $NxN$ chess board so that no queen threatens another) and the Knight’s Tour (a route that takes a knight to every square of an $NxN$ chessboard without visiting any square twice).

The idea of generators comes from other programming languages,
especially Icon (http://www.cs.arizona.edu/icon/), where the idea of
generators is central. In Icon, every expression and function call
behaves like a generator. One example from “An Overview of the Icon
Programming Language” at http://www.cs.arizona.edu/icon/docs/ipd266.htm gives an idea of what
this looks like:

```python
sentence := "Store it in the neighboring harbor"
if (i := find("or", sentence)) > 5 then write(i)
```

In Icon the find() function returns the indexes at which the substring
“or” is found: 3, 23, 33. In the if statement, i is first assigned a value
of 3, but 3 is less than 5, so the comparison fails, and Icon retries it
with the second value of 23. 23 is greater than 5, so the comparison
now succeeds, and the code prints the value 23 to the screen.

Python doesn’t go nearly as far as Icon in adopting generators as a
central concept. Generators are considered part of the core Python
language, but learning or using them isn’t compulsory; if they don’t
solve any problems that you have, feel free to ignore them. One novel
feature of Python’s interface as compared to Icon’s is that a
generator’s state is represented as a concrete object (the iterator) that
can be passed around to other functions or stored in a data structure.

See also:

**PEP 255 - Simple Generators**
Written by Neil Schemenauer, Tim Peters, Magnus Lie Hetland.
Implemented mostly by Neil Schemenauer and Tim Peters, with
other fixes from the Python Labs crew.
PEP 263: Source Code Encodings

Python source files can now be declared as being in different character set encodings. Encodings are declared by including a specially formatted comment in the first or second line of the source file. For example, a UTF-8 file can be declared with:

```
#!/usr/bin/env python
#
# -*- coding: UTF-8 -*-
```

Without such an encoding declaration, the default encoding used is 7-bit ASCII. Executing or importing modules that contain string literals with 8-bit characters and have no encoding declaration will result in a `DeprecationWarning` being signalled by Python 2.3; in 2.4 this will be a syntax error.

The encoding declaration only affects Unicode string literals, which will be converted to Unicode using the specified encoding. Note that Python identifiers are still restricted to ASCII characters, so you can’t have variable names that use characters outside of the usual alphanumerics.

See also:

**PEP 263 - Defining Python Source Code Encodings**

Written by Marc-André Lemburg and Martin von Löwis; implemented by Suzuki Hisao and Martin von Löwis.
PEP 273: Importing Modules from ZIP Archives

The new `zipimport` module adds support for importing modules from a ZIP-format archive. You don't need to import the module explicitly; it will be automatically imported if a ZIP archive's filename is added to `sys.path`. For example:

```
amk@nyman:~/src/python$ unzip -l /tmp/example.zip
Archive: /tmp/example.zip
  Length    Date     Time  Name
--------  ----      ----  ----
  8467  11-26-02 22:30  jwzthreading.py
--------  ----      ----  ----
  8467

amk@nyman:~/src/python$ ./python
Python 2.3 (#1, Aug 1 2003, 19:54:32)
>>> import sys
>>> sys.path.insert(0, '/tmp/example.zip')  # Add .zip file to front of path
>>> import jwzthreading
>>> jwzthreading.__file__
'/tmp/example.zip/jwzthreading.py'
```

An entry in `sys.path` can now be the filename of a ZIP archive. The ZIP archive can contain any kind of files, but only files named `*.py`, `*.pyc`, or `*.pyo` can be imported. If an archive only contains `*.py` files, Python will not attempt to modify the archive by adding the corresponding `*.pyc` file, meaning that if a ZIP archive doesn't contain `*.pyc` files, importing may be rather slow.

A path within the archive can also be specified to only import from a
subdirectory; for example, the path /tmp/example.zip/lib/ would only import from the lib/ subdirectory within the archive.

See also:

**PEP 273 - Import Modules from Zip Archives**
Written by James C. Ahlstrom, who also provided an implementation. Python 2.3 follows the specification in **PEP 273**, but uses an implementation written by Just van Rossum that uses the import hooks described in **PEP 302**. See section **PEP 302: New Import Hooks** for a description of the new import hooks.
PEP 277: Unicode file name support for Windows NT

On Windows NT, 2000, and XP, the system stores file names as Unicode strings. Traditionally, Python has represented file names as byte strings, which is inadequate because it renders some file names inaccessible.

Python now allows using arbitrary Unicode strings (within the limitations of the file system) for all functions that expect file names, most notably the `open()` built-in function. If a Unicode string is passed to `os.listdir()`, Python now returns a list of Unicode strings. A new function, `os.getcwd()`, returns the current directory as a Unicode string.

Byte strings still work as file names, and on Windows Python will transparently convert them to Unicode using the mbcs encoding.

Other systems also allow Unicode strings as file names but convert them to byte strings before passing them to the system, which can cause a `UnicodeError` to be raised. Applications can test whether arbitrary Unicode strings are supported as file names by checking `os.path.supports_unicode_filenames`, a Boolean value.

Under MacOS, `os.listdir()` may now return Unicode filenames.

See also:

**PEP 277 - Unicode file name support for Windows NT**

Written by Neil Hodgson; implemented by Neil Hodgson, Martin von Löwis, and Mark Hammond.
PEP 278: Universal Newline Support

The three major operating systems used today are Microsoft Windows, Apple's Macintosh OS, and the various Unix derivatives. A minor irritation of cross-platform work is that these three platforms all use different characters to mark the ends of lines in text files. Unix uses the linefeed (ASCII character 10), MacOS uses the carriage return (ASCII character 13), and Windows uses a two-character sequence of a carriage return plus a newline.

Python's file objects can now support end of line conventions other than the one followed by the platform on which Python is running. Opening a file with the mode 'u' or 'rU' will open a file for reading in universal newlines mode. All three line ending conventions will be translated to a '\n' in the strings returned by the various file methods such as read() and readline().

Universal newline support is also used when importing modules and when executing a file with the execfile() function. This means that Python modules can be shared between all three operating systems without needing to convert the line-endings.

This feature can be disabled when compiling Python by specifying the --without-universal-newlines switch when running Python's configure script.

See also:

PEP 278 - Universal Newline Support
Written and implemented by Jack Jansen.
PEP 279: enumerate()

A new built-in function, `enumerate()`, will make certain loops a bit clearer. `enumerate(thing)`, where `thing` is either an iterator or a sequence, returns an iterator that will return `(0, thing[0]), (1, thing[1]), (2, thing[2])`, and so forth.

A common idiom to change every element of a list looks like this:

```python
for i in range(len(L)):
    item = L[i]
    # ... compute some result based on item ...
    L[i] = result
```

This can be rewritten using `enumerate()` as:

```python
for i, item in enumerate(L):
    # ... compute some result based on item ...
    L[i] = result
```

See also:

**PEP 279 - The `enumerate()` built-in function**

Written and implemented by Raymond D. Hettinger.
PEP 282: The logging Package

A standard package for writing logs, `logging`, has been added to Python 2.3. It provides a powerful and flexible mechanism for generating logging output which can then be filtered and processed in various ways. A configuration file written in a standard format can be used to control the logging behavior of a program. Python includes handlers that will write log records to standard error or to a file or socket, send them to the system log, or even e-mail them to a particular address; of course, it’s also possible to write your own handler classes.

The Logger class is the primary class. Most application code will deal with one or more Logger objects, each one used by a particular subsystem of the application. Each Logger is identified by a name, and names are organized into a hierarchy using . as the component separator. For example, you might have Logger instances named server, server.auth and server.network. The latter two instances are below server in the hierarchy. This means that if you turn up the verbosity for server or direct server messages to a different handler, the changes will also apply to records logged to server.auth and server.network. There’s also a root Logger that’s the parent of all other loggers.

For simple uses, the `logging` package contains some convenience functions that always use the root log:

```python
import logging
logging.debug('Debugging information')
logging.info('Informational message')
```
logging.warning('Warning:config file %s not found')
logging.error('Error occurred')
logging.critical('Critical error -- shutting down')

This produces the following output:

```
WARNING:root:Warning:config file server.conf not found
ERROR:root:Error occurred
CRITICAL:root:Critical error -- shutting down
```

In the default configuration, informational and debugging messages are suppressed and the output is sent to standard error. You can enable the display of informational and debugging messages by calling the `setLevel()` method on the root logger.

Notice the `warning()` call's use of string formatting operators; all of the functions for logging messages take the arguments `(msg, arg1, arg2, ...)` and log the string resulting from `msg % (arg1, arg2, ...)`. 

There's also an `exception()` function that records the most recent traceback. Any of the other functions will also record the traceback if you specify a true value for the keyword argument `exc_info`.

```python
def f():
    try:
        1/0
    except:
        logging.exception('Problem recorded')
f()
```

This produces the following output:

```
ERROR:root:Problem recorded
```
Slightly more advanced programs will use a logger other than the root logger. The `getLogger(name)` function is used to get a particular log, creating it if it doesn't exist yet. `getLogger(None)` returns the root logger.

```python
log = logging.getLogger('server')
...  
log.info('Listening on port %i', port)
...
log.critical('Disk full')
...  
```

Log records are usually propagated up the hierarchy, so a message logged to `server.auth` is also seen by `server` and `root`, but a Logger can prevent this by setting its `propagate` attribute to `False`.

There are more classes provided by the `logging` package that can be customized. When a Logger instance is told to log a message, it creates a LogRecord instance that is sent to any number of different Handler instances. Loggers and handlers can also have an attached list of filters, and each filter can cause the LogRecord to be ignored or can modify the record before passing it along. When they're finally output, LogRecord instances are converted to text by a Formatter class. All of these classes can be replaced by your own specially-written classes.

With all of these features the `logging` package should provide enough flexibility for even the most complicated applications. This is
only an incomplete overview of its features, so please see the package’s reference documentation for all of the details. Reading PEP 282 will also be helpful.

See also:

**PEP 282 - A Logging System**
Written by Vinay Sajip and Trent Mick; implemented by Vinay Sajip.
PEP 285: A Boolean Type

A Boolean type was added to Python 2.3. Two new constants were added to the __builtin__ module, True and False. (True and False constants were added to the built-ins in Python 2.2.1, but the 2.2.1 versions are simply set to integer values of 1 and 0 and aren’t a different type.)

The type object for this new type is named bool; the constructor for it takes any Python value and converts it to True or False.

```python
>>> bool(1)
True
>>> bool(0)
False
>>> bool([])
False
>>> bool((1,))
True
```

Most of the standard library modules and built-in functions have been changed to return Booleans.

```python
>>> obj = []
>>> hasattr(obj, 'append')
True
>>> isinstance(obj, list)
True
>>> isinstance(obj, tuple)
False
```

Python’s Booleans were added with the primary goal of making code clearer. For example, if you’re reading a function and encounter the
statement return 1, you might wonder whether the 1 represents a Boolean truth value, an index, or a coefficient that multiplies some other quantity. If the statement is return True, however, the meaning of the return value is quite clear.

Python’s Booleans were not added for the sake of strict type-checking. A very strict language such as Pascal would also prevent you performing arithmetic with Booleans, and would require that the expression in an if statement always evaluate to a Boolean result. Python is not this strict and never will be, as PEP 285 explicitly says. This means you can still use any expression in an if statement, even ones that evaluate to a list or tuple or some random object. The Boolean type is a subclass of the int class so that arithmetic using a Boolean still works.

```
>>> True + 1
2
>>> False + 1
1
>>> False * 75
0
>>> True * 75
75
```

To sum up True and False in a sentence: they’re alternative ways to spell the integer values 1 and 0, with the single difference that str() and repr() return the strings 'True' and 'False' instead of '1' and '0'.

See also:

PEP 285 - Adding a bool type
Written and implemented by GvR.
PEP 293: Codec Error Handling Callbacks

When encoding a Unicode string into a byte string, unencodable characters may be encountered. So far, Python has allowed specifying the error processing as either “strict” (raising `UnicodeError`), “ignore” (skipping the character), or “replace” (using a question mark in the output string), with “strict” being the default behavior. It may be desirable to specify alternative processing of such errors, such as inserting an XML character reference or HTML entity reference into the converted string.

Python now has a flexible framework to add different processing strategies. New error handlers can be added with `codecs.register_error()`, and codecs then can access the error handler with `codecs.lookup_error()`. An equivalent C API has been added for codecs written in C. The error handler gets the necessary state information such as the string being converted, the position in the string where the error was detected, and the target encoding. The handler can then either raise an exception or return a replacement string.

Two additional error handlers have been implemented using this framework: “backslashreplace” uses Python backslash quoting to represent unencodable characters and “xmlcharrefreplace” emits XML character references.

See also:

PEP 293 - Codec Error Handling Callbacks

Written and implemented by Walter Dörwald.
PEP 301: Package Index and Metadata for Distutils

Support for the long-requested Python catalog makes its first appearance in 2.3.

The heart of the catalog is the new Distutils register command. Running python setup.py register will collect the metadata describing a package, such as its name, version, maintainer, description, &c., and send it to a central catalog server. The resulting catalog is available from https://pypi.python.org/pypi.

To make the catalog a bit more useful, a new optional classifiers keyword argument has been added to the Distutils setup() function. A list of Trove-style strings can be supplied to help classify the software.

Here’s an example setup.py with classifiers, written to be compatible with older versions of the Distutils:

```python
from distutils import core
kw = {'name': 'Quixote',
      'version': '0.5.1',
      'description': 'A highly Pythonic Web application
# ...'
}

if (hasattr(core, 'setup_keywords') and
    'classifiers' in core.setup_keywords):
    kw['classifiers'] = ['
        [ 'Topic :: Internet :: WwW/HTTP :: Dynamic Content',
          'Environment :: No Input/Output (Daemon)',
          'Intended Audience :: Developers'],
```
core.setup(**kw)

The full list of classifiers can be obtained by running python setup.py register --list-classifiers.

See also:

PEP 301 - Package Index and Metadata for Distutils
Written and implemented by Richard Jones.
PEP 302: New Import Hooks

While it's been possible to write custom import hooks ever since the ihooks module was introduced in Python 1.3, no one has ever been really happy with it because writing new import hooks is difficult and messy. There have been various proposed alternatives such as the imutil and iu modules, but none of them has ever gained much acceptance, and none of them were easily usable from C code.

PEP 302 borrows ideas from its predecessors, especially from Gordon McMillan's iu module. Three new items are added to the sys module:

- sys.path_hooks is a list of callable objects; most often they'll be classes. Each callable takes a string containing a path and either returns an importer object that will handle imports from this path or raises an ImportError exception if it can't handle this path.
- sys.path_importer_cache caches importer objects for each path, so sys.path_hooks will only need to be traversed once for each path.
- sys.meta_path is a list of importer objects that will be traversed before sys.path is checked. This list is initially empty, but user code can add objects to it. Additional built-in and frozen modules can be imported by an object added to this list.

Importer objects must have a single method, find_module(fullname, path=None). fullname will be a module or package name, e.g. string or distutils.core. find_module() must return a loader object that has a single method, load_module(fullname), that creates and returns the corresponding module object.
Pseudo-code for Python’s new import logic, therefore, looks something like this (simplified a bit; see PEP 302 for the full details):

```python
for mp in sys.meta_path:
    loader = mp(fullname)
    if loader is not None:
        <module> = loader.load_module(fullname)

for path in sys.path:
    for hook in sys.path_hooks:
        try:
            importer = hook(path)
        except ImportError:
            # ImportError, so try the other path hooks
            pass
        else:
            loader = importer.find_module(fullname)
            <module> = loader.load_module(fullname)

# Not found!
raise ImportError
```

See also:

**PEP 302 - New Import Hooks**

Written by Just van Rossum and Paul Moore. Implemented by Just van Rossum.
PEP 305: Comma-separated Files

Comma-separated files are a format frequently used for exporting data from databases and spreadsheets. Python 2.3 adds a parser for comma-separated files.

Comma-separated format is deceptively simple at first glance:

```
Costs,150,200,3.95
```

Read a line and call line.split(','): what could be simpler? But toss in string data that can contain commas, and things get more complicated:

```
"Costs",150,200,3.95,"Includes taxes, shipping, and
```

A big ugly regular expression can parse this, but using the new csv package is much simpler:

```
import csv

input = open('datafile', 'rb')
reader = csv.reader(input)
for line in reader:
    print line
```

The reader() function takes a number of different options. The field separator isn't limited to the comma and can be changed to any character, and so can the quoting and line-ending characters.

Different dialects of comma-separated files can be defined and registered; currently there are two dialects, both used by Microsoft
Excel. A separate `csv.writer` class will generate comma-separated files from a succession of tuples or lists, quoting strings that contain the delimiter.

**See also:**

**PEP 305 - CSV File API**

Written and implemented by Kevin Altis, Dave Cole, Andrew McNamara, Skip Montanaro, Cliff Wells.
PEP 307: Pickle Enhancements

The `pickle` and `cPickle` modules received some attention during the 2.3 development cycle. In 2.2, new-style classes could be pickled without difficulty, but they weren’t pickled very compactly; PEP 307 quotes a trivial example where a new-style class results in a pickled string three times longer than that for a classic class.

The solution was to invent a new pickle protocol. The `pickle.dumps()` function has supported a text-or-binary flag for a long time. In 2.3, this flag is redefined from a Boolean to an integer: 0 is the old text-mode pickle format, 1 is the old binary format, and now 2 is a new 2.3-specific format. A new constant, `pickle.HIGHEST_PROTOCOL`, can be used to select the fanciest protocol available.

Unpickling is no longer considered a safe operation. 2.2’s `pickle` provided hooks for trying to prevent unsafe classes from being unpickled (specifically, a `__safe_for_unpickling__` attribute), but none of this code was ever audited and therefore it’s all been ripped out in 2.3. You should not unpickle untrusted data in any version of Python.

To reduce the pickling overhead for new-style classes, a new interface for customizing pickling was added using three special methods: `__getstate__()`, `__setstate__()`, and `__getnewargs__()`. Consult PEP 307 for the full semantics of these methods.

As a way to compress pickles yet further, it’s now possible to use integer codes instead of long strings to identify pickled classes. The Python Software Foundation will maintain a list of standardized codes; there’s also a range of codes for private use. Currently no codes have
been specified.

See also:

**PEP 307 - Extensions to the pickle protocol**

Written and implemented by Guido van Rossum and Tim Peters.
Extended Slices

Ever since Python 1.4, the slicing syntax has supported an optional third “step” or “stride” argument. For example, these are all legal Python syntax: \( \text{L}[1:10:2], \text{L}[\cdot-1:1], \text{L}[\cdot-1] \). This was added to Python at the request of the developers of Numerical Python, which uses the third argument extensively. However, Python’s built-in list, tuple, and string sequence types have never supported this feature, raising a `TypeError` if you tried it. Michael Hudson contributed a patch to fix this shortcoming.

For example, you can now easily extract the elements of a list that have even indexes:

```python
>>> L = range(10)
>>> L[::2]
[0, 2, 4, 6, 8]
```

Negative values also work to make a copy of the same list in reverse order:

```python
>>> L[::-1]
[9, 8, 7, 6, 5, 4, 3, 2, 1, 0]
```

This also works for tuples, arrays, and strings:

```python
>>> s='abcd'
>>> s[::2]
'ac'
>>> s[::1]
'dcba'
```

If you have a mutable sequence such as a list or an array you can
assign to or delete an extended slice, but there are some differences between assignment to extended and regular slices. Assignment to a regular slice can be used to change the length of the sequence:

```python
>>> a = range(3)
>>> a
[0, 1, 2]
>>> a[1:3] = [4, 5, 6]
>>> a
[0, 4, 5, 6]
```

Extended slices aren't this flexible. When assigning to an extended slice, the list on the right hand side of the statement must contain the same number of items as the slice it is replacing:

```python
>>> a = range(4)
>>> a
[0, 1, 2, 3]
>>> a[:2]
[0, 2]
>>> a[:2] = [0, -1]
>>> a
[0, 1, -1, 3]
>>> a[:2] = [0, 1, 2]
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: attempt to assign sequence of size 3 to extended slice of size 2
```

Deletion is more straightforward:

```python
>>> a = range(4)
>>> a
[0, 1, 2, 3]
>>> a[:2]
[0, 2]
```
One can also now pass slice objects to the \_\_getitem\_\_(\) methods of the built-in sequences:

```python
>>> range(10).\_\_getitem\_\_(slice(0, 5, 2))
[0, 2, 4]
```

Or use slice objects directly in subscripts:

```python
>>> range(10)[slice(0, 5, 2)]
[0, 2, 4]
```

To simplify implementing sequences that support extended slicing, slice objects now have a method `indices(length)` which, given the length of a sequence, returns a `(start, stop, step)` tuple that can be passed directly to `range().indices()` handles omitted and out-of-bounds indices in a manner consistent with regular slices (and this innocuous phrase hides a welter of confusing details!). The method is intended to be used like this:

```python
class FakeSeq:
...
    def calc_item(self, i):
        ...
    def \_\_getitem\_\_(self, item):
        if isinstance(item, slice):
            indices = item.indices(len(self))
            return FakeSeq([self.calc_item(i) for i
        else:
            return self.calc_item(i)
```
From this example you can also see that the built-in `slice` object is now the type object for the slice type, and is no longer a function. This is consistent with Python 2.2, where `int`, `str`, etc., underwent the same change.
Other Language Changes

Here are all of the changes that Python 2.3 makes to the core Python language.

- The `yield` statement is now always a keyword, as described in section PEP 255: Simple Generators of this document.

- A new built-in function `enumerate()` was added, as described in section PEP 279: enumerate() of this document.

- Two new constants, `True` and `False` were added along with the built-in `bool` type, as described in section PEP 285: A Boolean Type of this document.

- The `int()` type constructor will now return a long integer instead of raising an `OverflowError` when a string or floating-point number is too large to fit into an integer. This can lead to the paradoxical result that `isinstance(int(expression), int)` is false, but that seems unlikely to cause problems in practice.

- Built-in types now support the extended slicing syntax, as described in section Extended Slices of this document.

- A new built-in function, `sum(iterable, start=0)`, adds up the numeric items in the iterable object and returns their sum. `sum()` only accepts numbers, meaning that you can’t use it to concatenate a bunch of strings. (Contributed by Alex Martelli.)

- `list.insert(pos, value)` used to insert `value` at the front of the list when `pos` was negative. The behaviour has now been changed to be consistent with slice indexing, so when `pos` is -1
the value will be inserted before the last element, and so forth.

- `list.index(value)`, which searches for `value` within the list and returns its index, now takes optional `start` and `stop` arguments to limit the search to only part of the list.

- Dictionaries have a new method, `pop(key[, *default*])`, that returns the value corresponding to `key` and removes that key/value pair from the dictionary. If the requested key isn't present in the dictionary, `default` is returned if it's specified and `KeyError` raised if it isn't.

```
>>> d = {1:2}
>>> d
{1: 2}
>>> d.pop(4)
Traceback (most recent call last):
  File "stdin", line 1, in ?
KeyError: 4
>>> d.pop(1)
2
>>> d.pop(1)
Traceback (most recent call last):
  File "stdin", line 1, in ?
KeyError: 'pop(): dictionary is empty'
>>> d
{}
```  

There's also a new class method, `dict.fromkeys(iterable, value)`, that creates a dictionary with keys taken from the supplied iterator `iterable` and all values set to `value`, defaulting to None.

(Patches contributed by Raymond Hettinger.)
Also, the `dict()` constructor now accepts keyword arguments to simplify creating small dictionaries:

```python
>>> dict(red=1, blue=2, green=3, black=4)
{'blue': 2, 'black': 4, 'green': 3, 'red': 1}
```

(Contributed by Just van Rossum.)

- The `assert` statement no longer checks the `__debug__` flag, so you can no longer disable assertions by assigning to `__debug__`. Running Python with the `-O` switch will still generate code that doesn't execute any assertions.

- Most type objects are now callable, so you can use them to create new objects such as functions, classes, and modules. (This means that the new module can be deprecated in a future Python version, because you can now use the type objects available in the `types` module.) For example, you can create a new module object with the following code:

```python
>>> import types
>>> m = types.ModuleType('abc', 'docstring')
>>> m
<module 'abc' (built-in)>
>>> m.__doc__
'docstring'
```

- A new warning, `PendingDeprecationWarning` was added to indicate features which are in the process of being deprecated. The warning will *not* be printed by default. To check for use of features that will be deprecated in the future, supply `-Walways::PendingDeprecationWarning::` on the
command line or use `warnings.filterwarnings()`.

- The process of deprecating string-based exceptions, as in `raise "Error occurred"`, has begun. Raising a string will now trigger `PendingDeprecationWarning`.

- Using `None` as a variable name will now result in a `SyntaxWarning` warning. In a future version of Python, `None` may finally become a keyword.

- The `xreadlines()` method of file objects, introduced in Python 2.1, is no longer necessary because files now behave as their own iterator. `xreadlines()` was originally introduced as a faster way to loop over all the lines in a file, but now you can simply write `for line in file_obj`. File objects also have a new read-only encoding attribute that gives the encoding used by the file; Unicode strings written to the file will be automatically converted to bytes using the given encoding.

- The method resolution order used by new-style classes has changed, though you'll only notice the difference if you have a really complicated inheritance hierarchy. Classic classes are unaffected by this change. Python 2.2 originally used a topological sort of a class's ancestors, but 2.3 now uses the C3 algorithm as described in the paper “A Monotonic Superclass Linearization for Dylan”. To understand the motivation for this change, read Michele Simionato's article “Python 2.3 Method Resolution Order”, or read the thread on python-dev starting with the message at https://mail.python.org/pipermail/python-dev/2002-October/029035.html. Samuele Pedroni first pointed out the problem and also implemented the fix by coding the C3 algorithm.
- Python runs multithreaded programs by switching between threads after executing N bytecodes. The default value for N has been increased from 10 to 100 bytecodes, speeding up single-threaded applications by reducing the switching overhead. Some multithreaded applications may suffer slower response time, but that's easily fixed by setting the limit back to a lower number using `sys.setcheckinterval(N)`. The limit can be retrieved with the new `sys.getcheckinterval()` function.

- One minor but far-reaching change is that the names of extension types defined by the modules included with Python now contain the module and a '.' in front of the type name. For example, in Python 2.2, if you created a socket and printed its `__class__`, you'd get this output:

  ```
  >>> s = socket.socket()
  >>> s.__class__
  <type 'socket'>
  ```

  In 2.3, you get this:

  ```
  >>> s.__class__
  <type '_socket.socket'>
  ```

- One of the noted incompatibilities between old- and new-style classes has been removed: you can now assign to the `__name__` and `__bases__` attributes of new-style classes. There are some restrictions on what can be assigned to `__bases__` along the lines of those relating to assigning to an instance's `__class__` attribute.

String Changes
• The `in` operator now works differently for strings. Previously, when evaluating `X in Y` where `X` and `Y` are strings, `X` could only be a single character. That's now changed; `X` can be a string of any length, and `X in Y` will return `True` if `X` is a substring of `Y`. If `X` is the empty string, the result is always `True`.

```python
>>> 'ab' in 'abcd'
True
>>> 'ad' in 'abcd'
False
>>> '' in 'abcd'
True
```

Note that this doesn't tell you where the substring starts; if you need that information, use the `find()` string method.

• The `strip()`, `lstrip()`, and `rstrip()` string methods now have an optional argument for specifying the characters to strip. The default is still to remove all whitespace characters:

```python
>>> '   abc '.strip()
'abc'
>>> '><<abc><><>'.strip('<> ')
'abc'
>>> '><<abc><><>\n'.strip('<> ')
'abc><><>\n'
>>> u'\u4000\u4001abc\u4000'.strip(u'\u4000')
u'\u4001abc'
```

(Suggested by Simon Brunning and implemented by Walter Dörwald.)

• The `startswith()` and `endswith()` string methods now
accept negative numbers for the start and end parameters.

- Another new string method is zfill(), originally a function in the string module. zfill() pads a numeric string with zeros on the left until it's the specified width. Note that the % operator is still more flexible and powerful than zfill().

```python
>>> '45'.zfill(4)
'0045'
>>> '12345'.zfill(4)
'12345'
>>> 'goofy'.zfill(6)
'0goofy'
```

(Contributed by Walter Dörwald.)

- A new type object, basestring, has been added. Both 8-bit strings and Unicode strings inherit from this type, so isinstance(obj, basestring) will return True for either kind of string. It's a completely abstract type, so you can't create basestring instances.

- Interned strings are no longer immortal and will now be garbage-collected in the usual way when the only reference to them is from the internal dictionary of interned strings. (Implemented by Oren Tirosh.)

**Optimizations**

- The creation of new-style class instances has been made much faster; they're now faster than classic classes!
- The sort() method of list objects has been extensively rewritten by Tim Peters, and the implementation is significantly faster.
Multiplication of large long integers is now much faster thanks to an implementation of Karatsuba multiplication, an algorithm that scales better than the O(n*n) required for the grade-school multiplication algorithm. (Original patch by Christopher A. Craig, and significantly reworked by Tim Peters.)

The SET_LINENO opcode is now gone. This may provide a small speed increase, depending on your compiler’s idiosyncrasies. See section Other Changes and Fixes for a longer explanation. (Removed by Michael Hudson.)

xrange() objects now have their own iterator, making for i in xrange(n) slightly faster than for i in range(n). (Patch by Raymond Hettinger.)

A number of small rearrangements have been made in various hotspots to improve performance, such as inlining a function or removing some code. (Implemented mostly by GvR, but lots of people have contributed single changes.)

The net result of the 2.3 optimizations is that Python 2.3 runs the pystone benchmark around 25% faster than Python 2.2.
New, Improved, and Deprecated Modules

As usual, Python’s standard library received a number of enhancements and bug fixes. Here’s a partial list of the most notable changes, sorted alphabetically by module name. Consult the Misc/NEWS file in the source tree for a more complete list of changes, or look through the CVS logs for all the details.

- The `array` module now supports arrays of Unicode characters using the 'u' format character. Arrays also now support using the `+=` assignment operator to add another array’s contents, and the `*=` assignment operator to repeat an array. (Contributed by Jason Orendorff.)

- The `bsddb` module has been replaced by version 4.1.6 of the PyBSDDB package, providing a more complete interface to the transactional features of the BerkeleyDB library.

The old version of the module has been renamed to `bsdddb185` and is no longer built automatically; you’ll have to edit `Modules/Setup` to enable it. Note that the new `bsddb` package is intended to be compatible with the old module, so be sure to file bugs if you discover any incompatibilities. When upgrading to Python 2.3, if the new interpreter is compiled with a new version of the underlying BerkeleyDB library, you will almost certainly have to convert your database files to the new version. You can do this fairly easily with the new scripts `db2pickle.py` and `pickle2db.py` which you will find in the distribution’s Tools/scripts directory. If you’ve already been using the PyBSDDB package and importing it as `bsdddb3`, you will have to change your import statements to import it as `bsddb`.
• The new **bz2** module is an interface to the bz2 data compression library. bz2-compressed data is usually smaller than corresponding **zlib**-compressed data. (Contributed by Gustavo Niemeyer.)

• A set of standard date/time types has been added in the new **datetime** module. See the following section for more details.

• The Distutils Extension class now supports an extra constructor argument named `depends` for listing additional source files that an extension depends on. This lets Distutils recompile the module if any of the dependency files are modified. For example, if `sampmodule.c` includes the header file `sample.h`, you would create the Extension object like this:

```
ext = Extension("samp",
               sources=["sampmodule.c"],
               depends=["sample.h"])
```

Modifying `sample.h` would then cause the module to be recompiled. (Contributed by Jeremy Hylton.)

• Other minor changes to Distutils: it now checks for the CC, CFLAGS, CPP, LDFLAGS, and CPPFLAGS environment variables, using them to override the settings in Python’s configuration (contributed by Robert Weber).

• Previously the **doctest** module would only search the docstrings of public methods and functions for test cases, but it now also examines private ones as well. The DocTestSuite() function creates a `unittest.TestSuite` object from a set of **doctest** tests.
The new `gc.get_referents(object)` function returns a list of all the objects referenced by `object`.

The `getopt` module gained a new function, `gnu_getopt()`, that supports the same arguments as the existing `getopt()` function but uses GNU-style scanning mode. The existing `getopt()` stops processing options as soon as a non-option argument is encountered, but in GNU-style mode processing continues, meaning that options and arguments can be mixed. For example:

```python
>>> getopt.getopt([['-f', 'filename', 'output', '','output', 'output', 'output']], ['output'], [('-f', 'filename'), ('-v', '')])
```

(Contributed by Peter Åstrand.)

The `grp`, `pwd`, and `resource` modules now return enhanced tuples:

```python
>>> import grp
>>> g = grp.getgrnam('amk')
>>> g.gr_name, g.gr_gid
('amk', 500)
```

The `gzip` module can now handle files exceeding 2 GiB.

The new `heapq` module contains an implementation of a heap queue algorithm. A heap is an array-like data structure that keeps items in a partially sorted order such that, for every index \( k \), \( \text{heap}[k] \leq \text{heap}[2k+1] \) and \( \text{heap}[k] \leq \text{heap}[2k+2] \). This makes it quick to remove the smallest item, and inserting a new item while maintaining the heap property is \( O(\lg n) \). (See
The `heapq` module provides `heappush()` and `heappop()` functions for adding and removing items while maintaining the heap property on top of some other mutable Python sequence type. Here's an example that uses a Python list:

```python
>>> import heapq
>>> heap = []
>>> for item in [3, 7, 5, 11, 1]:
...    heapq.heappush(heap, item)
...
>>> heap
[1, 3, 5, 11, 7]
>>> heapq.heappop(heap)
1
>>> heapq.heappop(heap)
3
>>> heap
[5, 7, 11]
```

(Contributed by Kevin O'Connor.)

- The IDLE integrated development environment has been updated using the code from the IDLEfork project (http://idlefork.sourceforge.net). The most notable feature is that the code being developed is now executed in a subprocess, meaning that there's no longer any need for manual `reload()` operations. IDLE's core code has been incorporated into the standard library as the `idlelib` package.

- The `imaplib` module now supports IMAP over SSL. (Contributed by Piers Lauder and Tino Lange.)
• The **itertools** contains a number of useful functions for use with iterators, inspired by various functions provided by the ML and Haskell languages. For example, `itertools.ifilter(predicate, iterator)` returns all elements in the iterator for which the function `predicate()` returns `True`, and `itertools.repeat(obj, N)` returns `obj` `N` times. There are a number of other functions in the module; see the package’s reference documentation for details. (Contributed by Raymond Hettinger.)

• Two new functions in the **math** module, `degrees(rads)` and `radians(degs)`, convert between radians and degrees. Other functions in the **math** module such as `math.sin()` and `math.cos()` have always required input values measured in radians. Also, an optional `base` argument was added to `math.log()` to make it easier to compute logarithms for bases other than `e` and `10`. (Contributed by Raymond Hettinger.)

• Several new POSIX functions (`getpgid()`, `killpg()`, `lchown()`, `loadavg()`, `major()`, `makedev()`, `minor()`, and `mknod()`) were added to the **posix** module that underlies the **os** module. (Contributed by Gustavo Niemeyer, Geert Jansen, and Denis S. Otkidach.)

• In the **os** module, the `*stat()` family of functions can now report fractions of a second in a timestamp. Such time stamps are represented as floats, similar to the value returned by `time.time()`.

    During testing, it was found that some applications will break if time stamps are floats. For compatibility, when using the tuple interface of the `stat_result` time stamps will be represented as
integers. When using named fields (a feature first introduced in Python 2.2), time stamps are still represented as integers, unless `os.stat_float_times()` is invoked to enable float return values:

```python
>>> os.stat("/tmp").st_mtime
1034791200
>>> os.stat_float_times(True)
>>> os.stat("/tmp").st_mtime
1034791200.6335014
```

In Python 2.4, the default will change to always returning floats.

Application developers should enable this feature only if all their libraries work properly when confronted with floating point time stamps, or if they use the tuple API. If used, the feature should be activated on an application level instead of trying to enable it on a per-use basis.

- The `optparse` module contains a new parser for command-line arguments that can convert option values to a particular Python type and will automatically generate a usage message. See the following section for more details.

- The old and never-documented `linuxaudiodev` module has been deprecated, and a new version named `ossaudiodev` has been added. The module was renamed because the OSS sound drivers can be used on platforms other than Linux, and the interface has also been tidied and brought up to date in various ways. (Contributed by Greg Ward and Nicholas FitzRoy-Dale.)

- The new `platform` module contains a number of functions that try to determine various properties of the platform you're running
on. There are functions for getting the architecture, CPU type, the Windows OS version, and even the Linux distribution version. (Contributed by Marc-André Lemburg.)

- The parser objects provided by the pyexpat module can now optionally buffer character data, resulting in fewer calls to your character data handler and therefore faster performance. Setting the parser object's buffer_text attribute to True will enable buffering.

- The sample(population, k) function was added to the random module. population is a sequence or xrange object containing the elements of a population, and sample() chooses k elements from the population without replacing chosen elements. k can be any value up to len(population). For example:

```python
>>> days = ['Mo', 'Tu', 'We', 'Th', 'Fr', 'St', 'Sn']
>>> random.sample(days, 3)  # Choose 3 elements
['St', 'Sn', 'Th']
>>> random.sample(days, 7)  # Choose 7 elements
['Tu', 'Th', 'Mo', 'We', 'St', 'Fr', 'Sn']
>>> random.sample(days, 7)  # Choose 7 again
['We', 'Mo', 'Sn', 'Fr', 'Tu', 'St', 'Th']
>>> random.sample(days, 8)  # Can't choose 8 elements
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "random.py", line 414, in sample
    raise ValueError, "sample larger than population"
ValueError: sample larger than population
>>> random.sample(xrange(1,10000,2), 10)  # Choose 10 odd numbers
[3407, 3805, 1505, 7023, 2401, 2267, 9733, 3151, 7935, 533]```
The `random` module now uses a new algorithm, the Mersenne Twister, implemented in C. It's faster and more extensively studied than the previous algorithm.

(All changes contributed by Raymond Hettinger.)

- The `readline` module also gained a number of new functions: `get_history_item()`, `get_current_history_length()`, and `redisplay()`.

- The `rexec` and `Bastion` modules have been declared dead, and attempts to import them will fail with a `RuntimeError`. New-style classes provide new ways to break out of the restricted execution environment provided by `rexec`, and no one has interest in fixing them or time to do so. If you have applications using `rexec`, rewrite them to use something else.

(Sticking with Python 2.2 or 2.1 will not make your applications any safer because there are known bugs in the `rexec` module in those versions. To repeat: if you're using `rexec`, stop using it immediately.)

- The `rotor` module has been deprecated because the algorithm it uses for encryption is not believed to be secure. If you need encryption, use one of the several AES Python modules that are available separately.

- The `shutil` module gained a `move(src, dest)` function that recursively moves a file or directory to a new location.

- Support for more advanced POSIX signal handling was added to the `signal` but then removed again as it proved impossible to make it work reliably across platforms.
The `socket` module now supports timeouts. You can call the `settimeout(t)` method on a socket object to set a timeout of `t` seconds. Subsequent socket operations that take longer than `t` seconds to complete will abort and raise a `socket.timeout` exception.

The original timeout implementation was by Tim O’Malley. Michael Gilfix integrated it into the Python `socket` module and shepherded it through a lengthy review. After the code was checked in, Guido van Rossum rewrote parts of it. (This is a good example of a collaborative development process in action.)

On Windows, the `socket` module now ships with Secure Sockets Layer (SSL) support.

The value of the C `PYTHON_API_VERSION` macro is now exposed at the Python level as `sys.api_version`. The current exception can be cleared by calling the new `sys.exc_clear()` function.

The new `tarfile` module allows reading from and writing to tar-format archive files. (Contributed by Lars Gustäbel.)

The new `textwrap` module contains functions for wrapping strings containing paragraphs of text. The `wrap(text, width)` function takes a string and returns a list containing the text split into lines of no more than the chosen width. The `fill(text, width)` function returns a single string, reformatted to fit into lines no longer than the chosen width. (As you can guess, `fill()` is built on top of `wrap()`.) For example:

```python
>>> import textwrap
```
The module also contains a TextWrapper class that actually implements the text wrapping strategy. Both the TextWrapper class and the wrap() and fill() functions support a number of additional keyword arguments for fine-tuning the formatting; consult the module's documentation for details. (Contributed by Greg Ward.)

- The thread and threading modules now have companion modules, dummy_thread and dummy_threading, that provide a do-nothing implementation of the thread module's interface for platforms where threads are not supported. The intention is to simplify thread-aware modules (ones that don't rely on threads to run) by putting the following code at the top:

```python
try:
    import threading as _threading
except ImportError:
    import dummy_threading as _threading
```

In this example, _threading is used as the module name to
make it clear that the module being used is not necessarily the actual threading module. Code can call functions and use classes in _threading whether or not threads are supported, avoiding an if statement and making the code slightly clearer. This module will not magically make multithreaded code run without threads; code that waits for another thread to return or to do something will simply hang forever.

- The time module’s strftime() function has long been an annoyance because it uses the platform C library’s strftime() implementation, and different platforms sometimes have odd bugs. Brett Cannon contributed a portable implementation that’s written in pure Python and should behave identically on all platforms.

- The new timeit module helps measure how long snippets of Python code take to execute. The timeit.py file can be run directly from the command line, or the module’s Timer class can be imported and used directly. Here’s a short example that figures out whether it’s faster to convert an 8-bit string to Unicode by appending an empty Unicode string to it or by using the unicode() function:

```python
import timeit

timer1 = timeit.Timer('unicode("abc")')
timer2 = timeit.Timer('"abc" + u""')

# Run three trials
print timer1.repeat(repeat=3, number=100000)
print timer2.repeat(repeat=3, number=100000)

# On my laptop this outputs:
```
- The Tix module has received various bug fixes and updates for the current version of the Tix package.

- The Tkinter module now works with a thread-enabled version of Tcl. Tcl's threading model requires that widgets only be accessed from the thread in which they're created; accesses from another thread can cause Tcl to panic. For certain Tcl interfaces, Tkinter will now automatically avoid this when a widget is accessed from a different thread by marshalling a command, passing it to the correct thread, and waiting for the results. Other interfaces can't be handled automatically but Tkinter will now raise an exception on such an access so that you can at least find out about the problem. See https://mail.python.org/pipermail/python-dev/2002-December/031107.html for a more detailed explanation of this change. (Implemented by Martin von Löwis.)

- Calling Tcl methods through _tkinter no longer returns only strings. Instead, if Tcl returns other objects those objects are converted to their Python equivalent, if one exists, or wrapped with a _tkinter.Tcl_Obj object if no Python equivalent exists. This behavior can be controlled through the wantobjects() method of tkapp objects.

When using _tkinter through the Tkinter module (as most Tkinter applications will), this feature is always activated. It should not cause compatibility problems, since Tkinter would always convert string results to Python types where possible.

If any incompatibilities are found, the old behavior can be restored.
by setting the wantobjects variable in the Tkinter module to false before creating the first tkapp object.

```python
import Tkinter
Tkinter.wantobjects = 0
```

Any breakage caused by this change should be reported as a bug.

- The UserDict module has a new DictMixin class which defines all dictionary methods for classes that already have a minimum mapping interface. This greatly simplifies writing classes that need to be substitutable for dictionaries, such as the classes in the shelve module.

Adding the mix-in as a superclass provides the full dictionary interface whenever the class defines `__getitem__()`, `__setitem__()`, `__delitem__()`, and `keys()`. For example:

```python
>>> import UserDict
>>> class SeqDict(UserDict.DictMixin):
...     
...     def __init__(self):
...         self.keylist = []
...         self.valuelist = []
...     def __getitem__(self, key):
...         try:
...             i = self.keylist.index(key)
...         except ValueError:
...             raise KeyError
...         return self.valuelist[i]
...     def __setitem__(self, key, value):
...         try:
...             i = self.keylist.index(key)
...             self.valuelist[i] = value
...             
... ```
```python
... except ValueError:
...     self.keylist.append(key)
...     self.valuelist.append(value)
... def __delitem__(self, key):
...     try:
...         i = self.keylist.index(key)
...     except ValueError:
...         raise KeyError
...     self.keylist.pop(i)
...     self.valuelist.pop(i)
... def keys(self):
...     return list(self.keylist)
...
>>> s = SeqDict()
>>> dir(s)  # See that other dictionary methods
['__cmp__', '__contains__', '__delitem__', '__doc__', '__init__', '__iter__', '__len__', '__module__', '__setitem__', 'clear', 'get', 'has_key', 'items', 'iterkeys', 'itervalues', 'keylist', 'keys', 'pop', 'setdefault', 'update', 'valuelist', 'values']

(Contributed by Raymond Hettinger.)

- The DOM implementation in `xml.dom.minidom` can now generate XML output in a particular encoding by providing an optional encoding argument to the `toxml()` and `toprettyxml()` methods of DOM nodes.

- The `xmlrpclib` module now supports an XML-RPC extension for handling nil data values such as Python’s `None`. Nil values are always supported on unmarshalling an XML-RPC response. To generate requests containing None, you must supply a true value for the `allow_none` parameter when creating a `Marshaller` instance.
• The new DocXMLRPCServer module allows writing self-documenting XML-RPC servers. Run it in demo mode (as a program) to see it in action. Pointing the Web browser to the RPC server produces pydoc-style documentation; pointing xmlrpclib to the server allows invoking the actual methods. (Contributed by Brian Quinlan.)

• Support for internationalized domain names (RFCs 3454, 3490, 3491, and 3492) has been added. The “idna” encoding can be used to convert between a Unicode domain name and the ASCII-compatible encoding (ACE) of that name.

\[
>\{\}<>u"www.Alliancefrançaise.nu".encode("idna\n'www.xn--alliancefranaise-npb.nu'
\]

The socket module has also been extended to transparently convert Unicode hostnames to the ACE version before passing them to the C library. Modules that deal with hostnames such as httplib and ftplib) also support Unicode host names; httplib also sends HTTP Host headers using the ACE version of the domain name. urllib supports Unicode URLs with non-ASCII host names as long as the path part of the URL is ASCII only.

To implement this change, the stringprep module, the mkstringprep tool and the punycode encoding have been added.

**Date/Time Type**

Date and time types suitable for expressing timestamps were added
as the `datetime` module. The types don’t support different calendars or many fancy features, and just stick to the basics of representing time.

The three primary types are: date, representing a day, month, and year; `time`, consisting of hour, minute, and second; and `datetime`, which contains all the attributes of both date and `time`. There’s also a `timedelta` class representing differences between two points in time, and time zone logic is implemented by classes inheriting from the abstract `tzinfo` class.

You can create instances of date and `time` by either supplying keyword arguments to the appropriate constructor, e.g. `datetime.date(year=1972, month=10, day=15)`, or by using one of a number of class methods. For example, the `date.today()` class method returns the current local date.

Once created, instances of the date/time classes are all immutable. There are a number of methods for producing formatted strings from objects:

```python
>>> import datetime
>>> now = datetime.datetime.now()
>>> now.isoformat()
'2002-12-30T21:27:03.994956'
>>> now.ctime()  # Only available on date, datetime
'Mon Dec 30 21:27:03 2002'
>>> now.strftime('%Y %d %b')
'2002 30 Dec'
```

The `replace()` method allows modifying one or more fields of a date or `datetime` instance, returning a new instance:
Instances can be compared, hashed, and converted to strings (the result is the same as that of isoformat()). date and datetime instances can be subtracted from each other, and added to timedelta instances. The largest missing feature is that there’s no standard library support for parsing strings and getting back a date or datetime.

For more information, refer to the module’s reference documentation. (Contributed by Tim Peters.)

**The optparse Module**

The getopt module provides simple parsing of command-line arguments. The new optparse module (originally named Optik) provides more elaborate command-line parsing that follows the Unix conventions, automatically creates the output for --help, and can perform different actions for different options.

You start by creating an instance of OptionParser and telling it what your program’s options are.

```python
import sys
from optparse import OptionParser

op = OptionParser()
op.add_option('-i', '--input',
```
Parsing a command line is then done by calling the `parse_args()` method.

```python
options, args = op.parse_args(sys.argv[1:])
print options
print args
```

This returns an object containing all of the option values, and a list of strings containing the remaining arguments.

Invoking the script with the various arguments now works as you’d expect it to. Note that the length argument is automatically converted to an integer.

```bash
$ ./python opt.py -i data arg1
<Values at 0x400cad4c: {'input': 'data', 'length': None}>
['arg1']
$ ./python opt.py --input=data --length=4
<Values at 0x400cad2c: {'input': 'data', 'length': 4}>
[]
```

The help message is automatically generated for you:

```bash
$ ./python opt.py --help
usage: opt.py [options]
options:
```
-h, --help show this help message and exit
-INPUT, --input=INPUT  set input filename
-lLENGTH, --length=LENGTH  set maximum length of output

See the module’s documentation for more details.

Optik was written by Greg Ward, with suggestions from the readers of the Getopt SIG.
Pymalloc: A Specialized Object Allocator

Pymalloc, a specialized object allocator written by Vladimir Marangozov, was a feature added to Python 2.1. Pymalloc is intended to be faster than the system malloc() and to have less memory overhead for allocation patterns typical of Python programs. The allocator uses C's malloc() function to get large pools of memory and then fulfills smaller memory requests from these pools.

In 2.1 and 2.2, pymalloc was an experimental feature and wasn't enabled by default; you had to explicitly enable it when compiling Python by providing the --with-pymalloc option to the configure script. In 2.3, pymalloc has had further enhancements and is now enabled by default; you'll have to supply --without-pymalloc to disable it.

This change is transparent to code written in Python; however, pymalloc may expose bugs in C extensions. Authors of C extension modules should test their code with pymalloc enabled, because some incorrect code may cause core dumps at runtime.

There's one particularly common error that causes problems. There are a number of memory allocation functions in Python's C API that have previously just been aliases for the C library's malloc() and free(), meaning that if you accidentally called mismatched functions the error wouldn't be noticeable. When the object allocator is enabled, these functions aren't aliases of malloc() and free() any more, and calling the wrong function to free memory may get you a core dump. For example, if memory was allocated using PyObject_Malloc(), it has to be freed using PyObject_Free(), not free(). A few modules included with Python fell afoul of this and
had to be fixed; doubtless there are more third-party modules that will have the same problem.

As part of this change, the confusing multiple interfaces for allocating memory have been consolidated down into two API families. Memory allocated with one family must not be manipulated with functions from the other family. There is one family for allocating chunks of memory and another family of functions specifically for allocating Python objects.

- To allocate and free an undistinguished chunk of memory use the “raw memory” family: `PyMem_Malloc()`, `PyMem_Realloc()`, and `PyMem_Free()`.
- The “object memory” family is the interface to the pymalloc facility described above and is biased towards a large number of “small” allocations: `PyObject_Malloc()`, `PyObject_Realloc()`, and `PyObject_Free()`.
- To allocate and free Python objects, use the “object” family `PyObject_New()`, `PyObject_NewVar()`, and `PyObject_Del()`.

Thanks to lots of work by Tim Peters, pymalloc in 2.3 also provides debugging features to catch memory overwrites and doubled frees in both extension modules and in the interpreter itself. To enable this support, compile a debugging version of the Python interpreter by running `configure` with `--with-pydebug`.

To aid extension writers, a header file `Misc/pymemcompat.h` is distributed with the source to Python 2.3 that allows Python extensions to use the 2.3 interfaces to memory allocation while compiling against any version of Python since 1.5.2. You would copy the file from Python’s source distribution and bundle it with the source of your extension.
See also:

https://svn.python.org/view/python/trunk/Objects/obmalloc.c

For the full details of the pymalloc implementation, see the comments at the top of the file Objects/obmalloc.c in the Python source code. The above link points to the file within the python.org SVN browser.
Build and C API Changes

Changes to Python’s build process and to the C API include:

- The cycle detection implementation used by the garbage collection has proven to be stable, so it’s now been made mandatory. You can no longer compile Python without it, and the --with-cycle-gc switch to `configure` has been removed.
- Python can now optionally be built as a shared library (libpython2.3.so) by supplying `--enable-shared` when running Python’s `configure` script. (Contributed by Ondrej Palkovsky.)
- The DL_EXPORT and DL_IMPORT macros are now deprecated. Initialization functions for Python extension modules should now be declared using the new macro PyMODINIT_FUNC, while the Python core will generally use the PyAPI_FUNC and PyAPI_DATA macros.
- The interpreter can be compiled without any docstrings for the built-in functions and modules by supplying `--without-docstrings` to the `configure` script. This makes the Python executable about 10% smaller, but will also mean that you can’t get help for Python’s built-ins. (Contributed by Gustavo Niemeyer.)
- The PyArg_NoArgs() macro is now deprecated, and code that uses it should be changed. For Python 2.2 and later, the method definition table can specify the METH_NOARGS flag, signalling that there are no arguments, and the argument checking can then be removed. If compatibility with pre-2.2 versions of Python is important, the code could use `PyArg_ParseTuple(args, "")` instead, but this will be slower than using METH_NOARGS.
- `PyArg_ParseTuple()` accepts new format characters for various sizes of unsigned integers: B for unsigned char, H for unsigned short int, I for unsigned int, and K for
unsigned long long.

- A new function, `PyObject_DelItemString(mapping, char *key)` was added as shorthand for `PyObject_DelItem(mapping, PyString_New(key))`.

- File objects now manage their internal string buffer differently, increasing it exponentially when needed. This results in the benchmark tests in `Lib/test/test_bufio.py` speeding up considerably (from 57 seconds to 1.7 seconds, according to one measurement).

- It's now possible to define class and static methods for a C extension type by setting either the `METH_CLASS` or `METH_STATIC` flags in a method's `PyMethodDef` structure.

- Python now includes a copy of the Expat XML parser's source code, removing any dependence on a system version or local installation of Expat.

- If you dynamically allocate type objects in your extension, you should be aware of a change in the rules relating to the `__module__` and `__name__` attributes. In summary, you will want to ensure the type's dictionary contains a '__module__' key; making the module name the part of the type name leading up to the final period will no longer have the desired effect. For more detail, read the API reference documentation or the source.

### Port-Specific Changes

Support for a port to IBM’s OS/2 using the EMX runtime environment was merged into the main Python source tree. EMX is a POSIX emulation layer over the OS/2 system APIs. The Python port for EMX tries to support all the POSIX-like capability exposed by the EMX runtime, and mostly succeeds; `fork()` and `fcntl()` are restricted by the limitations of the underlying emulation layer. The standard OS/2 port, which uses IBM’s Visual Age compiler, also gained support for
case-sensitive import semantics as part of the integration of the EMX port into CVS. (Contributed by Andrew MacIntyre.)

On MacOS, most toolbox modules have been weaklinked to improve backward compatibility. This means that modules will no longer fail to load if a single routine is missing on the current OS version. Instead calling the missing routine will raise an exception. (Contributed by Jack Jansen.)

The RPM spec files, found in the Misc/RPM/ directory in the Python source distribution, were updated for 2.3. (Contributed by Sean Reifschneider.)

Other new platforms now supported by Python include AthoOS (http://www.atheos.cx/), GNU/Hurd, and OpenVMS.
Other Changes and Fixes

As usual, there were a bunch of other improvements and bugfixes scattered throughout the source tree. A search through the CVS change logs finds there were 523 patches applied and 514 bugs fixed between Python 2.2 and 2.3. Both figures are likely to be underestimates.

Some of the more notable changes are:

- If the `PYTHONINSPECT` environment variable is set, the Python interpreter will enter the interactive prompt after running a Python program, as if Python had been invoked with the `-i` option. The environment variable can be set before running the Python interpreter, or it can be set by the Python program as part of its execution.

- The `regrtest.py` script now provides a way to allow “all resources except foo.” A resource name passed to the `-u` option can now be prefixed with a hyphen ('-') to mean “remove this resource.” For example, the option ‘-uall,-bsddb’ could be used to enable the use of all resources except bsddb.

- The tools used to build the documentation now work under Cygwin as well as Unix.

- The `SET_LINENO` opcode has been removed. Back in the mists of time, this opcode was needed to produce line numbers in tracebacks and support trace functions (for, e.g., `pdb`). Since Python 1.5, the line numbers in tracebacks have been computed using a different mechanism that works with “python -O”. For Python 2.3 Michael Hudson implemented a similar scheme to
determine when to call the trace function, removing the need for SET_LINENO entirely.

It would be difficult to detect any resulting difference from Python code, apart from a slight speed up when Python is run without `-O`.

C extensions that access the `f_lineno` field of frame objects should instead call `PyCode_Addr2Line(f->f_code, f->f_lasti)`. This will have the added effect of making the code work as desired under “python -O” in earlier versions of Python.

A nifty new feature is that trace functions can now assign to the `f_lineno` attribute of frame objects, changing the line that will be executed next. A jump command has been added to the `pdb` debugger taking advantage of this new feature. (Implemented by Richie Hindle.)
Porting to Python 2.3

This section lists previously described changes that may require changes to your code:

- `yield` is now always a keyword; if it’s used as a variable name in your code, a different name must be chosen.

- For strings $X$ and $Y$, $X$ in $Y$ now works if $X$ is more than one character long.

- The `int()` type constructor will now return a long integer instead of raising an `OverflowError` when a string or floating-point number is too large to fit into an integer.

- If you have Unicode strings that contain 8-bit characters, you must declare the file’s encoding (UTF-8, Latin-1, or whatever) by adding a comment to the top of the file. See section PEP 263: Source Code Encodings for more information.

- Calling Tcl methods through `_tkinter` no longer returns only strings. Instead, if Tcl returns other objects those objects are converted to their Python equivalent, if one exists, or wrapped with a `_tkinter.Tcl_Obj` object if no Python equivalent exists.

- Large octal and hex literals such as `0xffffffff` now trigger a `FutureWarning`. Currently they’re stored as 32-bit numbers and result in a negative value, but in Python 2.4 they’ll become positive long integers.

There are a few ways to fix this warning. If you really need a positive number, just add an `L` to the end of the literal. If you’re
trying to get a 32-bit integer with low bits set and have previously used an expression such as ~(1 << 31), it’s probably clearest to start with all bits set and clear the desired upper bits. For example, to clear just the top bit (bit 31), you could write 0xffffffffL &~(1L<<31).

- You can no longer disable assertions by assigning to `__debug__`.

- The Distutils setup() function has gained various new keyword arguments such as `depends`. Old versions of the Distutils will abort if passed unknown keywords. A solution is to check for the presence of the new `get_distutil_options()` function in your setup.py and only uses the new keywords with a version of the Distutils that supports them:

```python
from distutils import core

kw = {'sources': 'foo.c', '...'}
if hasattr(core, 'get_distutil_options'):
    kw['depends'] = ['foo.h']
ext = Extension(**kw)
```

- Using None as a variable name will now result in a `SyntaxWarning` warning.

- Names of extension types defined by the modules included with Python now contain the module and a '.' in front of the type name.
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What’s New in Python 2.2

Author: A.M. Kuchling
Introduction

This article explains the new features in Python 2.2.2, released on October 14, 2002. Python 2.2.2 is a bugfix release of Python 2.2, originally released on December 21, 2001.

Python 2.2 can be thought of as the “cleanup release”. There are some features such as generators and iterators that are completely new, but most of the changes, significant and far-reaching though they may be, are aimed at cleaning up irregularities and dark corners of the language design.

This article doesn’t attempt to provide a complete specification of the new features, but instead provides a convenient overview. For full details, you should refer to the documentation for Python 2.2, such as the Python Library Reference and the Python Reference Manual. If you want to understand the complete implementation and design rationale for a change, refer to the PEP for a particular new feature.
PEPs 252 and 253: Type and Class Changes

The largest and most far-reaching changes in Python 2.2 are to Python’s model of objects and classes. The changes should be backward compatible, so it’s likely that your code will continue to run unchanged, but the changes provide some amazing new capabilities. Before beginning this, the longest and most complicated section of this article, I’ll provide an overview of the changes and offer some comments.

A long time ago I wrote a Web page listing flaws in Python’s design. One of the most significant flaws was that it’s impossible to subclass Python types implemented in C. In particular, it’s not possible to subclass built-in types, so you can’t just subclass, say, lists in order to add a single useful method to them. The UserList module provides a class that supports all of the methods of lists and that can be subclassed further, but there’s lots of C code that expects a regular Python list and won’t accept a UserList instance.

Python 2.2 fixes this, and in the process adds some exciting new capabilities. A brief summary:

- You can subclass built-in types such as lists and even integers, and your subclasses should work in every place that requires the original type.
- It’s now possible to define static and class methods, in addition to the instance methods available in previous versions of Python.
- It’s also possible to automatically call methods on accessing or setting an instance attribute by using a new mechanism called properties. Many uses of __getattr__() can be rewritten to use properties instead, making the resulting code simpler and
faster. As a small side benefit, attributes can now have docstrings, too.

- The list of legal attributes for an instance can be limited to a particular set using slots, making it possible to safeguard against typos and perhaps make more optimizations possible in future versions of Python.

Some users have voiced concern about all these changes. Sure, they say, the new features are neat and lend themselves to all sorts of tricks that weren’t possible in previous versions of Python, but they also make the language more complicated. Some people have said that they’ve always recommended Python for its simplicity, and feel that its simplicity is being lost.

Personally, I think there’s no need to worry. Many of the new features are quite esoteric, and you can write a lot of Python code without ever needed to be aware of them. Writing a simple class is no more difficult than it ever was, so you don’t need to bother learning or teaching them unless they’re actually needed. Some very complicated tasks that were previously only possible from C will now be possible in pure Python, and to my mind that’s all for the better.

I’m not going to attempt to cover every single corner case and small change that were required to make the new features work. Instead this section will paint only the broad strokes. See section Related Links, “Related Links”, for further sources of information about Python 2.2’s new object model.

Old and New Classes

First, you should know that Python 2.2 really has two kinds of classes: classic or old-style classes, and new-style classes. The old-style class model is exactly the same as the class model in earlier versions of
Python. All the new features described in this section apply only to new-style classes. This divergence isn’t intended to last forever; eventually old-style classes will be dropped, possibly in Python 3.0.

So how do you define a new-style class? You do it by subclassing an existing new-style class. Most of Python’s built-in types, such as integers, lists, dictionaries, and even files, are new-style classes now. A new-style class named `object`, the base class for all built-in types, has also been added so if no built-in type is suitable, you can just subclass `object`:

```python
class C(object):
    def __init__(self):
        ...
```

This means that `class` statements that don’t have any base classes are always classic classes in Python 2.2. (Actually you can also change this by setting a module-level variable named `__metaclass__` — see PEP 253 for the details — but it’s easier to just subclass `object`.)

The type objects for the built-in types are available as built-ins, named using a clever trick. Python has always had built-in functions named `int()`, `float()`, and `str()`. In 2.2, they aren’t functions any more, but type objects that behave as factories when called.

```python
>>> int
<type 'int'>
>>> int('123')
123
```

To make the set of types complete, new type objects such as `dict()`
and file() have been added. Here's a more interesting example, adding a lock() method to file objects:

```python
class LockableFile(file):
    def lock(self, operation, length=0, start=0, whence=0):
        import fcntl
        return fcntl.lockf(self.fileno(), operation, length, start, whence)
```

The now-obsolete posixfile module contained a class that emulated all of a file object's methods and also added a lock() method, but this class couldn't be passed to internal functions that expected a built-in file, something which is possible with our new LockableFile.

Descriptors

In previous versions of Python, there was no consistent way to discover what attributes and methods were supported by an object. There were some informal conventions, such as defining __members__ and __methods__ attributes that were lists of names, but often the author of an extension type or a class wouldn't bother to define them. You could fall back on inspecting the __dict__ of an object, but when class inheritance or an arbitrary __getattr__() hook were in use this could still be inaccurate.

The one big idea underlying the new class model is that an API for describing the attributes of an object using descriptors has been formalized. Descriptors specify the value of an attribute, stating whether it's a method or a field. With the descriptor API, static methods and class methods become possible, as well as more exotic
Attribute descriptors are objects that live inside class objects, and have a few attributes of their own:

- `__name__` is the attribute's name.
- `__doc__` is the attribute's docstring.
- `__get__(object)` is a method that retrieves the attribute value from `object`.
- `__set__(object, value)` sets the attribute on `object` to `value`.
- `__delete__(object, value)` deletes the `value` attribute of `object`.

For example, when you write `obj.x`, the steps that Python actually performs are:

```python
descriptor = obj.__class__.x
descriptor.__get__(obj)
```

For methods, `descriptor.__get__()` returns a temporary object that's callable, and wraps up the instance and the method to be called on it. This is also why static methods and class methods are now possible; they have descriptors that wrap up just the method, or the method and the class. As a brief explanation of these new kinds of methods, static methods aren't passed the instance, and therefore resemble regular functions. Class methods are passed the class of the object, but not the object itself. Static and class methods are defined like this:

```python
class C(object):
    def f(arg1, arg2):
        ...
    f = staticmethod(f)
```
The `staticmethod()` function takes the function `f()`, and returns it wrapped up in a descriptor so it can be stored in the class object. You might expect there to be special syntax for creating such methods (def static f, defstatic f(), or something like that) but no such syntax has been defined yet; that’s been left for future versions of Python.

More new features, such as slots and properties, are also implemented as new kinds of descriptors, and it’s not difficult to write a descriptor class that does something novel. For example, it would be possible to write a descriptor class that made it possible to write Eiffel-style preconditions and postconditions for a method. A class that used this feature might be defined like this:

```python
from eiffel import eiffelmethod

class C(object):
    def f(self, arg1, arg2):
        # The actual function
        ...
    def pre_f(self):
        # Check preconditions
        ...
    def post_f(self):
        # Check postconditions
        ...
    f = eiffelmethod(f, pre_f, post_f)
```

Note that a person using the new `eiffelmethod()` doesn’t have to
understand anything about descriptors. This is why I think the new features don't increase the basic complexity of the language. There will be a few wizards who need to know about it in order to write eiffelmethod() or the ZODB or whatever, but most users will just write code on top of the resulting libraries and ignore the implementation details.

Multiple Inheritance: The Diamond Rule

Multiple inheritance has also been made more useful through changing the rules under which names are resolved. Consider this set of classes (diagram taken from PEP 253 by Guido van Rossum):

```python
class A:
    def save(self): ...

class B
class C:
    def save(self): ...

class D
```

The lookup rule for classic classes is simple but not very smart; the base classes are searched depth-first, going from left to right. A reference to D.save() will search the classes D, B, and then A, where save() would be found and returned. C.save() would never be found at all. This is bad, because if C's save() method is saving some internal state specific to C, not calling it will result in that state
never getting saved.

New-style classes follow a different algorithm that's a bit more complicated to explain, but does the right thing in this situation. (Note that Python 2.3 changes this algorithm to one that produces the same results in most cases, but produces more useful results for really complicated inheritance graphs.)

1. List all the base classes, following the classic lookup rule and include a class multiple times if it’s visited repeatedly. In the above example, the list of visited classes is [D, B, A, C, A].
2. Scan the list for duplicated classes. If any are found, remove all but one occurrence, leaving the last one in the list. In the above example, the list becomes [D, B, C, A] after dropping duplicates.

Following this rule, referring to D.save() will return C.save(), which is the behaviour we're after. This lookup rule is the same as the one followed by Common Lisp. A new built-in function, super(), provides a way to get at a class's superclasses without having to reimplement Python's algorithm. The most commonly used form will be super(class, obj), which returns a bound superclass object (not the actual class object). This form will be used in methods to call a method in the superclass; for example, D's save() method would look like this:

```python
class D (B,C):
    def save (self):
        # Call superclass .save()
        super(D, self).save()
        # Save D's private information here
        ...
```

super() can also return unbound superclass objects when called as
super(class) or super(class1, class2), but this probably won't often be useful.

Attribute Access

A fair number of sophisticated Python classes define hooks for attribute access using \_\_getattr\_\__(\)\_; most commonly this is done for convenience, to make code more readable by automatically mapping an attribute access such as obj.parent into a method call such as obj.get\_parent. Python 2.2 adds some new ways of controlling attribute access.

First, \_\_getattr\_(attr\_name) is still supported by new-style classes, and nothing about it has changed. As before, it will be called when an attempt is made to access obj.foo and no attribute named foo is found in the instance's dictionary.

New-style classes also support a new method, \_\_getattribute\_(attr\_name). The difference between the two methods is that \_\_getattribute\_\()\) is always called whenever any attribute is accessed, while the old \_\_getattr\_\()\) is only called if foo isn't found in the instance's dictionary.

However, Python 2.2's support for properties will often be a simpler way to trap attribute references. Writing a \_\_getattr\_\() method is complicated because to avoid recursion you can't use regular attribute accesses inside them, and instead have to mess around with the contents of \_\_dict\_. \_\_getattribute\_\() methods also end up being called by Python when it checks for other methods such as \_\_repr\_\() or \_\_coerce\_\(), and so have to be written with this in mind. Finally, calling a function on every attribute access results in a
sizable performance loss.

`property` is a new built-in type that packages up three functions that get, set, or delete an attribute, and a docstring. For example, if you want to define a size attribute that's computed, but also settable, you could write:

```python
class C(object):
    def get_size (self):
        result = ... computation ...
        return result
    def set_size (self, size):
        ... compute something based on the size and set internal state appropriately ...

    # Define a property. The 'delete this attribute' method is defined as None, so the attribute can't be deleted.
    size = property(get_size, set_size, None,
                    "Storage size of this instance")
```

That is certainly clearer and easier to write than a pair of `__getattr__()`/`__setattr__() methods that check for the size attribute and handle it specially while retrieving all other attributes from the instance's `__dict__`. Accesses to size are also the only ones which have to perform the work of calling a function, so references to other attributes run at their usual speed.

Finally, it's possible to constrain the list of attributes that can be referenced on an object using the new `__slots__` class attribute. Python objects are usually very dynamic; at any time it's possible to define a new attribute on an instance by just doing `obj.new_attr=1`. 
A new-style class can define a class attribute named __slots__ to limit the legal attributes to a particular set of names. An example will make this clear:

```python
>>> class C(object):
...     __slots__ = ('template', 'name')
...
>>> obj = C()
>>> print obj.template
None
>>> obj.template = 'Test'
>>> print obj.template
Test
>>> obj.newattr = None
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
AttributeError: 'C' object has no attribute 'newattr'
```

Note how you get an AttributeError on the attempt to assign to an attribute not listed in __slots__.

**Related Links**

This section has just been a quick overview of the new features, giving enough of an explanation to start you programming, but many details have been simplified or ignored. Where should you go to get a more complete picture?

[https://www.python.org/2.2/descrintro.html](https://www.python.org/2.2/descrintro.html) is a lengthy tutorial introduction to the descriptor features, written by Guido van Rossum. If my description has whetted your appetite, go read this tutorial next, because it goes into much more detail about the new features while still remaining quite easy to read.
Next, there are two relevant PEPs, **PEP 252** and **PEP 253**. **PEP 252** is titled “Making Types Look More Like Classes”, and covers the descriptor API. **PEP 253** is titled “Subtyping Built-in Types”, and describes the changes to type objects that make it possible to subtype built-in objects. **PEP 253** is the more complicated PEP of the two, and at a few points the necessary explanations of types and meta-types may cause your head to explode. Both PEPs were written and implemented by Guido van Rossum, with substantial assistance from the rest of the Zope Corp. team.

Finally, there’s the ultimate authority: the source code. Most of the machinery for the type handling is in `Objects/typeobject.c`, but you should only resort to it after all other avenues have been exhausted, including posting a question to python-list or python-dev.
PEP 234: Iterators

Another significant addition to 2.2 is an iteration interface at both the C and Python levels. Objects can define how they can be looped over by callers.

In Python versions up to 2.1, the usual way to make for item in obj work is to define a `__getitem__()` method that looks something like this:

```python
def __getitem__(self, index):
    return <next item>
```

`__getitem__()` is more properly used to define an indexing operation on an object so that you can write `obj[5]` to retrieve the sixth element. It’s a bit misleading when you’re using this only to support `for` loops. Consider some file-like object that wants to be looped over; the `index` parameter is essentially meaningless, as the class probably assumes that a series of `__getitem__()` calls will be made with `index` incrementing by one each time. In other words, the presence of the `__getitem__()` method doesn’t mean that using `file[5]` to randomly access the sixth element will work, though it really should.

In Python 2.2, iteration can be implemented separately, and `__getitem__()` methods can be limited to classes that really do support random access. The basic idea of iterators is simple. A new built-in function, `iter(obj)` or `iter(C, sentinel)`, is used to get an iterator. `iter(obj)` returns an iterator for the object `obj`, while `iter(C, sentinel)` returns an iterator that will invoke the callable object `C` until it returns `sentinel` to signal that the iterator is done.
Python classes can define an `__iter__()` method, which should create and return a new iterator for the object; if the object is its own iterator, this method can just return `self`. In particular, iterators will usually be their own iterators. Extension types implemented in C can implement a `tp_iter` function in order to return an iterator, and extension types that want to behave as iterators can define a `tp_iternext` function.

So, after all this, what do iterators actually do? They have one required method, `next()`, which takes no arguments and returns the next value. When there are no more values to be returned, calling `next()` should raise the `StopIteration` exception.

```python
>>> L = [1,2,3]
>>> i = iter(L)
>>> print i
<iterator object at 0x8116870>
>>> i.next()
1
>>> i.next()
2
>>> i.next()
3
>>> i.next()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
StopIteration

In 2.2, Python's `for` statement no longer expects a sequence; it expects something for which `iter()` will return an iterator. For backward compatibility and convenience, an iterator is automatically constructed for sequences that don't implement `__iter__()` or a
The `tp_iter` slot, so for `i in [1,2,3]` will still work. Wherever the Python interpreter loops over a sequence, it's been changed to use the iterator protocol. This means you can do things like this:

```python
>>> L = [1,2,3]
>>> i = iter(L)
>>> a,b,c = i
>>> a, b, c
(1, 2, 3)
```

Iterator support has been added to some of Python's basic types. Calling `iter()` on a dictionary will return an iterator which loops over its keys:

```python
>>> m = {'Jan': 1, 'Feb': 2, 'Mar': 3, 'Apr': 4, 'May': 5, 'Jun': 6, 'Jul': 7, 'Aug': 8, 'Sep': 9, 'Oct': 10, 'Nov': 11, 'Dec': 12}
>>> for key in m: print key, m[key]
... Mar 3
Feb 2
Aug 8
Sep 9
May 5
Jun 6
Jul 7
Jan 1
Apr 4
Nov 11
Dec 12
Oct 10
```

That's just the default behaviour. If you want to iterate over keys, values, or key/value pairs, you can explicitly call the `iterkeys()`, `itervalues()`, or `iteritems()` methods to get an appropriate
iterator. In a minor related change, the `in` operator now works on dictionaries, so `key in dict` is now equivalent to `dict.has_key(key)`.

Files also provide an iterator, which calls the `readline()` method until there are no more lines in the file. This means you can now read each line of a file using code like this:

```python
for line in file:
    # do something for each line
...
```

Note that you can only go forward in an iterator; there's no way to get the previous element, reset the iterator, or make a copy of it. An iterator object could provide such additional capabilities, but the iterator protocol only requires a `next()` method.

**See also:**

**PEP 234 - Iterators**

Written by Ka-Ping Yee and GvR; implemented by the Python Labs crew, mostly by GvR and Tim Peters.
PEP 255: Simple Generators

Generators are another new feature, one that interacts with the introduction of iterators.

You're doubtless familiar with how function calls work in Python or C. When you call a function, it gets a private namespace where its local variables are created. When the function reaches a `return` statement, the local variables are destroyed and the resulting value is returned to the caller. A later call to the same function will get a fresh new set of local variables. But, what if the local variables weren't thrown away on exiting a function? What if you could later resume the function where it left off? This is what generators provide; they can be thought of as resumable functions.

Here’s the simplest example of a generator function:

```python
def generate_ints(N):
    for i in range(N):
        yield i
```

A new keyword, `yield`, was introduced for generators. Any function containing a `yield` statement is a generator function; this is detected by Python’s bytecode compiler which compiles the function specially as a result. Because a new keyword was introduced, generators must be explicitly enabled in a module by including a `from __future__ import generators` statement near the top of the module's source code. In Python 2.3 this statement will become unnecessary.

When you call a generator function, it doesn't return a single value; instead it returns a generator object that supports the iterator protocol. On executing the `yield` statement, the generator outputs the value of
i, similar to a return statement. The big difference between yield and a return statement is that on reaching a yield the generator's state of execution is suspended and local variables are preserved. On the next call to the generator's next() method, the function will resume executing immediately after the yield statement. (For complicated reasons, the yield statement isn't allowed inside the try block of a try...finally statement; read PEP 255 for a full explanation of the interaction between yield and exceptions.)

Here's a sample usage of the generate_ints() generator:

```python
>>> gen = generate_ints(3)
>>> gen
<generator object at 0x8117f90>
>>> gen.next()
0
>>> gen.next()
1
>>> gen.next()
2
>>> gen.next()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "<stdin>", line 2, in generate_ints
StopIteration
```

You could equally write for i in generate_ints(5), or a, b, c = generate_ints(3).

Inside a generator function, the return statement can only be used without a value, and signals the end of the procession of values; afterwards the generator cannot return any further values. return with a value, such as return 5, is a syntax error inside a generator.
function. The end of the generator’s results can also be indicated by raising `StopIteration` manually, or by just letting the flow of execution fall off the bottom of the function.

You could achieve the effect of generators manually by writing your own class and storing all the local variables of the generator as instance variables. For example, returning a list of integers could be done by setting `self.count` to 0, and having the `next()` method increment `self.count` and return it. However, for a moderately complicated generator, writing a corresponding class would be much messier. `Lib/test/test_generators.py` contains a number of more interesting examples. The simplest one implements an in-order traversal of a tree using generators recursively.

```python
# A recursive generator that generates Tree leaves in order.
def inorder(t):
    if t:
        for x in inorder(t.left):
            yield x
        yield t.label
        for x in inorder(t.right):
            yield x
```

Two other examples in `Lib/test/test_generators.py` produce solutions for the N-Queens problem (placing $N$ queens on an $NxN$ chess board so that no queen threatens another) and the Knight’s Tour (a route that takes a knight to every square of an $NxN$ chessboard without visiting any square twice).

The idea of generators comes from other programming languages, especially Icon (http://www.cs.arizona.edu/icon/), where the idea of generators is central. In Icon, every expression and function call behaves like a generator. One example from “An Overview of the Icon
Programming Language” at http://www.cs.arizona.edu/icon/docs/ipd266.htm gives an idea of what this looks like:

```
sentence := "Store it in the neighboring harbor"
if (i := find("or", sentence)) > 5 then write(i)
```

In Icon the find() function returns the indexes at which the substring “or” is found: 3, 23, 33. In the if statement, i is first assigned a value of 3, but 3 is less than 5, so the comparison fails, and Icon retries it with the second value of 23. 23 is greater than 5, so the comparison now succeeds, and the code prints the value 23 to the screen.

Python doesn’t go nearly as far as Icon in adopting generators as a central concept. Generators are considered a new part of the core Python language, but learning or using them isn’t compulsory; if they don’t solve any problems that you have, feel free to ignore them. One novel feature of Python’s interface as compared to Icon’s is that a generator’s state is represented as a concrete object (the iterator) that can be passed around to other functions or stored in a data structure.

**See also:**

**PEP 255 - Simple Generators**

Written by Neil Schemenauer, Tim Peters, Magnus Lie Hetland. Implemented mostly by Neil Schemenauer and Tim Peters, with other fixes from the Python Labs crew.
PEP 237: Unifying Long Integers and Integers

In recent versions, the distinction between regular integers, which are 32-bit values on most machines, and long integers, which can be of arbitrary size, was becoming an annoyance. For example, on platforms that support files larger than $2^{32}$ bytes, the `tell()` method of file objects has to return a long integer. However, there were various bits of Python that expected plain integers and would raise an error if a long integer was provided instead. For example, in Python 1.5, only regular integers could be used as a slice index, and `'abc'[1L:]` would raise a `TypeError` exception with the message ‘slice index must be int’.

Python 2.2 will shift values from short to long integers as required. The ‘L’ suffix is no longer needed to indicate a long integer literal, as now the compiler will choose the appropriate type. (Using the ‘L’ suffix will be discouraged in future 2.x versions of Python, triggering a warning in Python 2.4, and probably dropped in Python 3.0.) Many operations that used to raise an `OverflowError` will now return a long integer as their result. For example:

```python
>>> 1234567890123
1234567890123L
>>> 2 ** 64
18446744073709551616L
```

In most cases, integers and long integers will now be treated identically. You can still distinguish them with the `type()` built-in function, but that’s rarely needed.
See also:

**PEP 237 - Unifying Long Integers and Integers**

Written by Moshe Zadka and Guido van Rossum. Implemented mostly by Guido van Rossum.
PEP 238: Changing the Division Operator

The most controversial change in Python 2.2 heralds the start of an effort to fix an old design flaw that’s been in Python from the beginning. Currently Python’s division operator, \(/\), behaves like C’s division operator when presented with two integer arguments: it returns an integer result that’s truncated down when there would be a fractional part. For example, \(3/2\) is 1, not 1.5, and \((-1)/2\) is -1, not -0.5. This means that the results of division can vary unexpectedly depending on the type of the two operands and because Python is dynamically typed, it can be difficult to determine the possible types of the operands.

(The controversy is over whether this is really a design flaw, and whether it’s worth breaking existing code to fix this. It’s caused endless discussions on python-dev, and in July 2001 erupted into an storm of acidly sarcastic postings on comp.lang.python. I won’t argue for either side here and will stick to describing what’s implemented in 2.2. Read PEP 238 for a summary of arguments and counter-arguments.)

Because this change might break code, it’s being introduced very gradually. Python 2.2 begins the transition, but the switch won’t be complete until Python 3.0.

First, I’ll borrow some terminology from PEP 238. “True division” is the division that most non-programmers are familiar with: \(3/2\) is 1.5, \(1/4\) is 0.25, and so forth. “Floor division” is what Python’s \(/\) operator currently does when given integer operands; the result is the floor of the value returned by true division. “Classic division” is the current mixed behaviour of \(/\); it returns the result of floor division when the operands are integers, and returns the result of true division when one
of the operands is a floating-point number.

Here are the changes 2.2 introduces:

- A new operator, //, is the floor division operator. (Yes, we know it looks like C++'s comment symbol.) // always performs floor division no matter what the types of its operands are, so 1 // 2 is 0 and 1.0 // 2.0 is also 0.0.

  // is always available in Python 2.2; you don’t need to enable it using a __future__ statement.

- By including a from __future__ import division in a module, the / operator will be changed to return the result of true division, so 1/2 is 0.5. Without the __future__ statement, / still means classic division. The default meaning of / will not change until Python 3.0.

- Classes can define methods called __truediv__() and __floordiv__() to overload the two division operators. At the C level, there are also slots in the PyNumberMethods structure so extension types can define the two operators.

- Python 2.2 supports some command-line arguments for testing whether code will works with the changed division semantics. Running python with -Q warn will cause a warning to be issued whenever division is applied to two integers. You can use this to find code that’s affected by the change and fix it. By default, Python 2.2 will simply perform classic division without a warning; the warning will be turned on by default in Python 2.3.

See also:
PEP 238 - Changing the Division Operator

Written by Moshe Zadka and Guido van Rossum. Implemented by Guido van Rossum.
Unicode Changes

Python’s Unicode support has been enhanced a bit in 2.2. Unicode strings are usually stored as UCS-2, as 16-bit unsigned integers. Python 2.2 can also be compiled to use UCS-4, 32-bit unsigned integers, as its internal encoding by supplying `--enable-unicode=ucs4` to the configure script. (It’s also possible to specify `--disable-unicode` to completely disable Unicode support.)

When built to use UCS-4 (a “wide Python”), the interpreter can natively handle Unicode characters from U+000000 to U+110000, so the range of legal values for the `unichr()` function is expanded accordingly. Using an interpreter compiled to use UCS-2 (a “narrow Python”), values greater than 65535 will still cause `unichr()` to raise a `ValueError` exception. This is all described in PEP 261, “Support for ‘wide’ Unicode characters”; consult it for further details.

Another change is simpler to explain. Since their introduction, Unicode strings have supported an `encode()` method to convert the string to a selected encoding such as UTF-8 or Latin-1. A symmetric `decode([*encoding*])` method has been added to 8-bit strings (though not to Unicode strings) in 2.2. `decode()` assumes that the string is in the specified encoding and decodes it, returning whatever is returned by the codec.

Using this new feature, codecs have been added for tasks not directly related to Unicode. For example, codecs have been added for uu-encoding, MIME’s base64 encoding, and compression with the `zlib` module:

```python
>>> s = """Here is a lengthy piece of redundant, over""
```
... and repetitive text.

```python
>>> data = s.encode('zlib')
>>> data
'x\x9c\r\xc9\xc1\r\x80 \x10\x04\xc0?U1...
```
```python
>>> data.decode('zlib')
'Here is a lengthy piece of redundant, overly verbose, and repetitive text.
```
```python
>>> print s.encode('uu')
begin 666 <data>
M2&5R92!I<R!A(&QE;F=T:'D@<&EE8V4@;V8@<F5D=6YD86YT+"!
>=F5R8F]S92P*86YD(')E<&5T:71I=F4@=&5X="X*

end
```
```python
>>> "sheesh".encode('rot-13')
'furrfu'
```

To convert a class instance to Unicode, a `__unicode__()` method can be defined by a class, analogous to `__str__()`.

`encode()`, `decode()`, and `__unicode__()` were implemented by Marc-André Lemburg. The changes to support using UCS-4 internally were implemented by Fredrik Lundh and Martin von Löwis.

**See also:**

**PEP 261 - Support for ‘wide' Unicode characters**
Written by Paul Prescod.
PEP 227: Nested Scopes

In Python 2.1, statically nested scopes were added as an optional feature, to be enabled by a from __future__ import nested_scopes directive. In 2.2 nested scopes no longer need to be specially enabled, and are now always present. The rest of this section is a copy of the description of nested scopes from my “What's New in Python 2.1” document; if you read it when 2.1 came out, you can skip the rest of this section.

The largest change introduced in Python 2.1, and made complete in 2.2, is to Python’s scoping rules. In Python 2.0, at any given time there are at most three namespaces used to look up variable names: local, module-level, and the built-in namespace. This often surprised people because it didn't match their intuitive expectations. For example, a nested recursive function definition doesn’t work:

```python
def f():
    ... 
def g(value):
    ...
    return g(value-1) + 1
...```

The function g() will always raise a NameError exception, because the binding of the name g isn’t in either its local namespace or in the module-level namespace. This isn’t much of a problem in practice (how often do you recursively define interior functions like this?), but this also made using the lambda statement clumsier, and this was a problem in practice. In code which uses lambda you can often find local variables being copied by passing them as the default values of arguments.
```python
def find(self, name):
    "Return list of any entries equal to 'name'"
    L = filter(lambda x, name=name: x == name, self.list_attribute)
    return L
```

The readability of Python code written in a strongly functional style suffers greatly as a result.

The most significant change to Python 2.2 is that static scoping has been added to the language to fix this problem. As a first effect, the `name=name` default argument is now unnecessary in the above example. Put simply, when a given variable name is not assigned a value within a function (by an assignment, or the `def`, `class`, or `import` statements), references to the variable will be looked up in the local namespace of the enclosing scope. A more detailed explanation of the rules, and a dissection of the implementation, can be found in the PEP.

This change may cause some compatibility problems for code where the same variable name is used both at the module level and as a local variable within a function that contains further function definitions. This seems rather unlikely though, since such code would have been pretty confusing to read in the first place.

One side effect of the change is that the `from module import *` and `exec` statements have been made illegal inside a function scope under certain conditions. The Python reference manual has said all along that `from module import *` is only legal at the top level of a module, but the CPython interpreter has never enforced this before. As part of the implementation of nested scopes, the compiler which turns Python source into bytecodes has to generate different code to access variables in a containing scope. `from module import *`
and `exec` make it impossible for the compiler to figure this out, because they add names to the local namespace that are unknowable at compile time. Therefore, if a function contains function definitions or `lambda` expressions with free variables, the compiler will flag this by raising a `SyntaxError` exception.

To make the preceding explanation a bit clearer, here's an example:

```python
x = 1
def f():
    # The next line is a syntax error
    exec 'x=2'
def g():
    return x
```

Line 4 containing the `exec` statement is a syntax error, since `exec` would define a new local variable named `x` whose value should be accessed by `g()`. This shouldn't be much of a limitation, since `exec` is rarely used in most Python code (and when it is used, it's often a sign of a poor design anyway).

See also:

**PEP 227 - Statically Nested Scopes**
Written and implemented by Jeremy Hylton.
New and Improved Modules

- The `xmlrpclib` module was contributed to the standard library by Fredrik Lundh, providing support for writing XML-RPC clients. XML-RPC is a simple remote procedure call protocol built on top of HTTP and XML. For example, the following snippet retrieves a list of RSS channels from the O'Reilly Network, and then lists the recent headlines for one channel:

```python
import xmlrpclib

channels = s.meerkat.getChannels()
# channels is a list of dictionaries, like this:
# [{'id': 4, 'title': 'Freshmeat Daily News'},
# {'id': 190, 'title': '32Bits Online'},
# {'id': 4549, 'title': '3DGamers'}, ... ]

# Get the items for one channel
items = s.meerkat.getItems( {'channel': 4} )
# 'items' is another list of dictionaries, like:
# [{'link': 'http://freshmeat.net/releases/52719/',
# 'description': 'A utility which converts HTML to XSL FO.'},
# 'title': 'html2fo 0.3 (Default)'}, ... ]
```

The `SimpleXMLRPCServer` module makes it easy to create straightforward XML-RPC servers. See [http://www.xmlrpc.com/](http://www.xmlrpc.com/) for more information about XML-RPC.

- The new `hmac` module implements the HMAC algorithm described by [RFC 2104](https://tools.ietf.org/html/rfc2104). (Contributed by Gerhard Häring.)
Several functions that originally returned lengthy tuples now return
pseudo-sequences that still behave like tuples but also have
mnemonic attributes such as memberst_mtime or tm_year. The
enhanced functions include `stat()`, `fstat()`, `statvfs()`, and
`fstatvfs()` in the `os` module, and `localtime()`, `gmtime()`,
and `strptime()` in the `time` module.

For example, to obtain a file’s size using the old tuples, you’d end
up writing something like `file_size = os.stat(filename)
[stat.ST_SIZE]`, but now this can be written more clearly as
`file_size = os.stat(filename).st_size`.

The original patch for this feature was contributed by Nick
Mathewson.

The Python profiler has been extensively reworked and various
errors in its output have been corrected. (Contributed by Fred L.
Drake, Jr. and Tim Peters.)

The `socket` module can be compiled to support IPv6; specify the
`--enable-ipv6` option to Python’s configure script. (Contributed
by Jun-ichiro “itojun” Hagino.)

Two new format characters were added to the `struct` module for
64-bit integers on platforms that support the C `long long` type.
q is for a signed 64-bit integer, and Q is for an unsigned one. The
value is returned in Python’s long integer type. (Contributed by
Tim Peters.)

In the interpreter’s interactive mode, there’s a new built-in function
`help()` that uses the `pydoc` module introduced in Python 2.1 to
provide interactive help. `help(object)` displays any available
help text about object. `help()` with no argument puts you in an online help utility, where you can enter the names of functions, classes, or modules to read their help text. (Contributed by Guido van Rossum, using Ka-Ping Yee’s `pydoc` module.)

- Various bugfixes and performance improvements have been made to the SRE engine underlying the `re` module. For example, the `re.sub()` and `re.split()` functions have been rewritten in C. Another contributed patch speeds up certain Unicode character ranges by a factor of two, and a new `finditer()` method that returns an iterator over all the non-overlapping matches in a given string. (SRE is maintained by Fredrik Lundh. The BIGCHARSET patch was contributed by Martin von Löwis.)

- The `smtplib` module now supports RFC 2487, “Secure SMTP over TLS”, so it’s now possible to encrypt the SMTP traffic between a Python program and the mail transport agent being handed a message. `smtplib` also supports SMTP authentication. (Contributed by Gerhard Häring.)

- The `imaplib` module, maintained by Piers Lauder, has support for several new extensions: the NAMESPACE extension defined in RFC 2342, SORT, GETACL and SETACL. (Contributed by Anthony Baxter and Michel Pelletier.)

- The rfc822 module’s parsing of email addresses is now compliant with RFC 2822, an update to RFC 822. (The module’s name is not going to be changed to rfc2822.) A new package, `email`, has also been added for parsing and generating e-mail messages. (Contributed by Barry Warsaw, and arising out of his work on Mailman.)
• The **difflib** module now contains a new Differ class for producing human-readable lists of changes (a “delta”) between two sequences of lines of text. There are also two generator functions, `ndiff()` and `restore()`, which respectively return a delta from two sequences, or one of the original sequences from a delta. (Grunt work contributed by David Goodger, from ndiff.py code by Tim Peters who then did the generatorization.)

• New constants `ascii_letters`, `ascii_lowercase`, and `ascii_uppercase` were added to the **string** module. There were several modules in the standard library that used `string.letters` to mean the ranges A-Za-z, but that assumption is incorrect when locales are in use, because `string.letters` varies depending on the set of legal characters defined by the current locale. The buggy modules have all been fixed to use `ascii_letters` instead. (Reported by an unknown person; fixed by Fred L. Drake, Jr.)

• The **mimetypes** module now makes it easier to use alternative MIME-type databases by the addition of a MimeTypes class, which takes a list of filenames to be parsed. (Contributed by Fred L. Drake, Jr.)

• A Timer class was added to the **threading** module that allows scheduling an activity to happen at some future time. (Contributed by Itamar Shtull-Trauring.)
Interpreter Changes and Fixes

Some of the changes only affect people who deal with the Python interpreter at the C level because they're writing Python extension modules, embedding the interpreter, or just hacking on the interpreter itself. If you only write Python code, none of the changes described here will affect you very much.

- Profiling and tracing functions can now be implemented in C, which can operate at much higher speeds than Python-based functions and should reduce the overhead of profiling and tracing. This will be of interest to authors of development environments for Python. Two new C functions were added to Python’s API, `PyEval_SetProfile()` and `PyEval_SetTrace()`. The existing `sys.setprofile()` and `sys.settrace()` functions still exist, and have simply been changed to use the new C-level interface. (Contributed by Fred L. Drake, Jr.)

- Another low-level API, primarily of interest to implementors of Python debuggers and development tools, was added. `PyInterpreterState_Head()` and `PyInterpreterState_Next()` let a caller walk through all the existing interpreter objects; `PyInterpreterState_ThreadHead()` and `PyThreadState_Next()` allow looping over all the thread states for a given interpreter. (Contributed by David Beazley.)

- The C-level interface to the garbage collector has been changed to make it easier to write extension types that support garbage collection and to debug misuses of the functions. Various functions have slightly different semantics, so a bunch of functions
had to be renamed. Extensions that use the old API will still compile but will *not* participate in garbage collection, so updating them for 2.2 should be considered fairly high priority.

To upgrade an extension module to the new API, perform the following steps:

- Rename `Py_TPFLAGS_GC()` to `PyTPFLAGS_HAVE_GC()`.

- Use `PyObject_GC_New()` or `PyObject_GC_NewVar()` to allocate objects, and `PyObject_GC_Del()` to deallocate them.

- Rename `PyObject_GC_Init()` to `PyObject_GC_Track()` and `PyObject_GC_Fini()` to `PyObject_GC_UnTrack()`.

- Remove `PyGC_HEAD_SIZE()` from object size calculations.

- Remove calls to `PyObject_AS_GC()` and `PyObject_FROM_GC()`.

- A new et format sequence was added to `PyArg_ParseTuple()`; et takes both a parameter and an encoding name, and converts the parameter to the given encoding if the parameter turns out to be a Unicode string, or leaves it alone if it’s an 8-bit string, assuming it to already be in the desired encoding. This differs from the es format character, which assumes that 8-bit strings are in Python’s default ASCII encoding and converts them to the specified new encoding. (Contributed by M.-A. Lemburg, and used for the MBCS support on Windows described in the following section.)
• A different argument parsing function, \texttt{PyArg_UnpackTuple()}, has been added that's simpler and presumably faster. Instead of specifying a format string, the caller simply gives the minimum and maximum number of arguments expected, and a set of pointers to \texttt{PyObject*} variables that will be filled in with argument values.

• Two new flags \texttt{METH_NOARGS} and \texttt{METH_O} are available in method definition tables to simplify implementation of methods with no arguments or a single untyped argument. Calling such methods is more efficient than calling a corresponding method that uses \texttt{METH_VARARGS}. Also, the old \texttt{METH_OLDARGS} style of writing C methods is now officially deprecated.

• Two new wrapper functions, \texttt{PyOS_snprintf()} and \texttt{PyOS_vsnprintf()} were added to provide cross-platform implementations for the relatively new \texttt{snprintf()} and \texttt{vsnprintf()} C lib APIs. In contrast to the standard \texttt{sprintf()} and \texttt{vsprintf()} functions, the Python versions check the bounds of the buffer used to protect against buffer overruns. (Contributed by M.-A. Lemburg.)

• The \texttt{_PyTuple_Resize()} function has lost an unused parameter, so now it takes 2 parameters instead of 3. The third argument was never used, and can simply be discarded when porting code from earlier versions to Python 2.2.
Other Changes and Fixes

As usual there were a bunch of other improvements and bugfixes scattered throughout the source tree. A search through the CVS change logs finds there were 527 patches applied and 683 bugs fixed between Python 2.1 and 2.2; 2.2.1 applied 139 patches and fixed 143 bugs; 2.2.2 applied 106 patches and fixed 82 bugs. These figures are likely to be underestimates.

Some of the more notable changes are:

- The code for the MacOS port for Python, maintained by Jack Jansen, is now kept in the main Python CVS tree, and many changes have been made to support MacOS X.

The most significant change is the ability to build Python as a framework, enabled by supplying the `--enable-framework` option to the configure script when compiling Python. According to Jack Jansen, “This installs a self-contained Python installation plus the OS X framework “glue” into /Library/Frameworks/Python.framework (or another location of choice). For now there is little immediate added benefit to this (actually, there is the disadvantage that you have to change your PATH to be able to find Python), but it is the basis for creating a full-blown Python application, porting the MacPython IDE, possibly using Python as a standard OSA scripting language and much more.”

Most of the MacPython toolbox modules, which interface to MacOS APIs such as windowing, QuickTime, scripting, etc. have been ported to OS X, but they’ve been left commented out in setup.py. People who want to experiment with these modules
can uncomment them manually.

- Keyword arguments passed to built-in functions that don’t take them now cause a `TypeError` exception to be raised, with the message “*function* takes no keyword arguments”.

- Weak references, added in Python 2.1 as an extension module, are now part of the core because they’re used in the implementation of new-style classes. The `ReferenceError` exception has therefore moved from the `weakref` module to become a built-in exception.

- A new script, `Tools/scripts/cleanfuture.py` by Tim Peters, automatically removes obsolete `__future__` statements from Python source code.

- An additional `flags` argument has been added to the built-in function `compile()`, so the behaviour of `__future__` statements can now be correctly observed in simulated shells, such as those presented by IDLE and other development environments. This is described in PEP 264. (Contributed by Michael Hudson.)

- The new license introduced with Python 1.6 wasn’t GPL-compatible. This is fixed by some minor textual changes to the 2.2 license, so it’s now legal to embed Python inside a GPLed program again. Note that Python itself is not GPLed, but instead is under a license that’s essentially equivalent to the BSD license, same as it always was. The license changes were also applied to the Python 2.0.1 and 2.1.1 releases.

- When presented with a Unicode filename on Windows, Python will now convert it to an MBCS encoded string, as used by the
Microsoft file APIs. As MBCS is explicitly used by the file APIs, Python’s choice of ASCII as the default encoding turns out to be an annoyance. On Unix, the locale’s character set is used if `locale.nl_langinfo(CODESET)` is available. (Windows support was contributed by Mark Hammond with assistance from Marc-André Lemburg. Unix support was added by Martin von Löwis.)

- Large file support is now enabled on Windows. (Contributed by Tim Peters.)

- The `Tools/scripts/ftpmirror.py` script now parses a `.netrc` file, if you have one. (Contributed by Mike Romberg.)

- Some features of the object returned by the `xrange()` function are now deprecated, and trigger warnings when they’re accessed; they’ll disappear in Python 2.3. `xrange` objects tried to pretend they were full sequence types by supporting slicing, sequence multiplication, and the `in` operator, but these features were rarely used and therefore buggy. The `tolist()` method and the `start`, `stop`, and `step` attributes are also being deprecated. At the C level, the fourth argument to the `PyRange_New()` function, `repeat`, has also been deprecated.

- There were a bunch of patches to the dictionary implementation, mostly to fix potential core dumps if a dictionary contains objects that sneakily changed their hash value, or mutated the dictionary they were contained in. For a while python-dev fell into a gentle rhythm of Michael Hudson finding a case that dumped core, Tim Peters fixing the bug, Michael finding another case, and round and round it went.
On Windows, Python can now be compiled with Borland C thanks to a number of patches contributed by Stephen Hansen, though the result isn't fully functional yet. (But this is progress...)

Another Windows enhancement: Wise Solutions generously offered PythonLabs use of their InstallerMaster 8.1 system. Earlier PythonLabs Windows installers used Wise 5.0a, which was beginning to show its age. (Packaged up by Tim Peters.)

Files ending in .pyw can now be imported on Windows. .pyw is a Windows-only thing, used to indicate that a script needs to be run using PYTHONW.EXE instead of PYTHON.EXE in order to prevent a DOS console from popping up to display the output. This patch makes it possible to import such scripts, in case they're also usable as modules. (Implemented by David Bolen.)

On platforms where Python uses the C dlopen() function to load extension modules, it's now possible to set the flags used by dlopen() using the sys.getdlopenflags() and sys.setdlopenflags() functions. (Contributed by Bram Stolk.)

The pow() built-in function no longer supports 3 arguments when floating-point numbers are supplied. pow(x, y, z) returns (x**y) % z, but this is never useful for floating point numbers, and the final result varies unpredictably depending on the platform. A call such as pow(2.0, 8.0, 7.0) will now raise a TypeError exception.
Acknowledgements

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What’s New in Python 2.1

Author: A.M. Kuchling
Introduction

This article explains the new features in Python 2.1. While there aren’t as many changes in 2.1 as there were in Python 2.0, there are still some pleasant surprises in store. 2.1 is the first release to be steered through the use of Python Enhancement Proposals, or PEPs, so most of the sizable changes have accompanying PEPs that provide more complete documentation and a design rationale for the change. This article doesn’t attempt to document the new features completely, but simply provides an overview of the new features for Python programmers. Refer to the Python 2.1 documentation, or to the specific PEP, for more details about any new feature that particularly interests you.

One recent goal of the Python development team has been to accelerate the pace of new releases, with a new release coming every 6 to 9 months. 2.1 is the first release to come out at this faster pace, with the first alpha appearing in January, 3 months after the final version of 2.0 was released.

The final release of Python 2.1 was made on April 17, 2001.
PEP 227: Nested Scopes

The largest change in Python 2.1 is to Python’s scoping rules. In Python 2.0, at any given time there are at most three namespaces used to look up variable names: local, module-level, and the built-in namespace. This often surprised people because it didn’t match their intuitive expectations. For example, a nested recursive function definition doesn’t work:

```
def f():
    ...
    def g(value):
        ...
        return g(value-1) + 1
    ...
```

The function `g()` will always raise a `NameError` exception, because the binding of the name `g` isn’t in either its local namespace or in the module-level namespace. This isn’t much of a problem in practice (how often do you recursively define interior functions like this?), but this also made using the `lambda` statement clumsier, and this was a problem in practice. In code which uses `lambda` you can often find local variables being copied by passing them as the default values of arguments.

```
def find(self, name):
    "Return list of any entries equal to 'name'"
    L = filter(lambda x, name=name: x == name, self.list_attribute)
    return L
```

The readability of Python code written in a strongly functional style
suffers greatly as a result.

The most significant change to Python 2.1 is that static scoping has been added to the language to fix this problem. As a first effect, the name=name default argument is now unnecessary in the above example. Put simply, when a given variable name is not assigned a value within a function (by an assignment, or the def, class, or import statements), references to the variable will be looked up in the local namespace of the enclosing scope. A more detailed explanation of the rules, and a dissection of the implementation, can be found in the PEP.

This change may cause some compatibility problems for code where the same variable name is used both at the module level and as a local variable within a function that contains further function definitions. This seems rather unlikely though, since such code would have been pretty confusing to read in the first place.

One side effect of the change is that the from module import * and exec statements have been made illegal inside a function scope under certain conditions. The Python reference manual has said all along that from module import * is only legal at the top level of a module, but the CPython interpreter has never enforced this before. As part of the implementation of nested scopes, the compiler which turns Python source into bytecodes has to generate different code to access variables in a containing scope. from module import * and exec make it impossible for the compiler to figure this out, because they add names to the local namespace that are unknowable at compile time. Therefore, if a function contains function definitions or lambda expressions with free variables, the compiler will flag this by raising a SyntaxError exception.
To make the preceding explanation a bit clearer, here’s an example:

```python
x = 1
def f():
    # The next line is a syntax error
    exec 'x=2'
def g():
    return x
```

Line 4 containing the `exec` statement is a syntax error, since `exec` would define a new local variable named `x` whose value should be accessed by `g()`.

This shouldn’t be much of a limitation, since `exec` is rarely used in most Python code (and when it is used, it’s often a sign of a poor design anyway).

Compatibility concerns have led to nested scopes being introduced gradually; in Python 2.1, they aren’t enabled by default, but can be turned on within a module by using a future statement as described in PEP 236. (See the following section for further discussion of PEP 236.) In Python 2.2, nested scopes will become the default and there will be no way to turn them off, but users will have had all of 2.1’s lifetime to fix any breakage resulting from their introduction.

See also:

**PEP 227 - Statically Nested Scopes**

Written and implemented by Jeremy Hylton.
PEP 236: __future__ Directives

The reaction to nested scopes was widespread concern about the dangers of breaking code with the 2.1 release, and it was strong enough to make the Pythoneers take a more conservative approach. This approach consists of introducing a convention for enabling optional functionality in release N that will become compulsory in release N+1.

The syntax uses a from...import statement using the reserved module name __future__. Nested scopes can be enabled by the following statement:

```python
from __future__ import nested_scopes
```

While it looks like a normal import statement, it's not; there are strict rules on where such a future statement can be put. They can only be at the top of a module, and must precede any Python code or regular import statements. This is because such statements can affect how the Python bytecode compiler parses code and generates bytecode, so they must precede any statement that will result in bytecodes being produced.

See also:

**PEP 236 - Back to the __future__**

Written by Tim Peters, and primarily implemented by Jeremy Hylton.
PEP 207: Rich Comparisons

In earlier versions, Python's support for implementing comparisons on user-defined classes and extension types was quite simple. Classes could implement a `__cmp__()` method that was given two instances of a class, and could only return 0 if they were equal or +1 or -1 if they weren’t; the method couldn’t raise an exception or return anything other than a Boolean value. Users of Numeric Python often found this model too weak and restrictive, because in the number-crunching programs that numeric Python is used for, it would be more useful to be able to perform elementwise comparisons of two matrices, returning a matrix containing the results of a given comparison for each element. If the two matrices are of different sizes, then the compare has to be able to raise an exception to signal the error.

In Python 2.1, rich comparisons were added in order to support this need. Python classes can now individually overload each of the <, <=, >, >=, ==, and != operations. The new magic method names are:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Method name</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;</td>
<td><strong>lt</strong>()</td>
</tr>
<tr>
<td>&lt;=</td>
<td><strong>le</strong>()</td>
</tr>
<tr>
<td>&gt;</td>
<td><strong>gt</strong>()</td>
</tr>
<tr>
<td>&gt;=</td>
<td><strong>ge</strong>()</td>
</tr>
<tr>
<td>==</td>
<td><strong>eq</strong>()</td>
</tr>
<tr>
<td>!=</td>
<td><strong>ne</strong>()</td>
</tr>
</tbody>
</table>

(The magic methods are named after the corresponding Fortran operators .LT., .LE., &c. Numeric programmers are almost certainly...
quite familiar with these names and will find them easy to remember.)

Each of these magic methods is of the form `method(self, other)`, where `self` will be the object on the left-hand side of the operator, while `other` will be the object on the right-hand side. For example, the expression `A < B` will cause `A.__lt__(B)` to be called.

Each of these magic methods can return anything at all: a Boolean, a matrix, a list, or any other Python object. Alternatively they can raise an exception if the comparison is impossible, inconsistent, or otherwise meaningless.

The built-in `cmp(A, B)` function can use the rich comparison machinery, and now accepts an optional argument specifying which comparison operation to use; this is given as one of the strings "<", "<=", ">", ">=", "==", or "!=". If called without the optional third argument, `cmp()` will only return -1, 0, or +1 as in previous versions of Python; otherwise it will call the appropriate method and can return any Python object.

There are also corresponding changes of interest to C programmers; there’s a new slot `tp_richcmp` in type objects and an API for performing a given rich comparison. I won’t cover the C API here, but will refer you to PEP 207, or to 2.1’s C API documentation, for the full list of related functions.

**See also:**

**PEP 207 - Rich Comparisons**

Written by Guido van Rossum, heavily based on earlier work by David Ascher, and implemented by Guido van Rossum.
PEP 230: Warning Framework

Over its 10 years of existence, Python has accumulated a certain number of obsolete modules and features along the way. It’s difficult to know when a feature is safe to remove, since there’s no way of knowing how much code uses it — perhaps no programs depend on the feature, or perhaps many do. To enable removing old features in a more structured way, a warning framework was added. When the Python developers want to get rid of a feature, it will first trigger a warning in the next version of Python. The following Python version can then drop the feature, and users will have had a full release cycle to remove uses of the old feature.

Python 2.1 adds the warning framework to be used in this scheme. It adds a warnings module that provide functions to issue warnings, and to filter out warnings that you don’t want to be displayed. Third-party modules can also use this framework to deprecate old features that they no longer wish to support.

For example, in Python 2.1 the regex module is deprecated, so importing it causes a warning to be printed:

```python
>>> import regex
__main__:1: DeprecationWarning: the regex module is deprecated; please use the re module
```

Warnings can be issued by calling the `warnings.warn()` function:

```python
warnings.warn("feature X no longer supported")
```

The first parameter is the warning message; an additional optional
parameters can be used to specify a particular warning category.

Filters can be added to disable certain warnings; a regular expression pattern can be applied to the message or to the module name in order to suppress a warning. For example, you may have a program that uses the regex module and not want to spare the time to convert it to use the \texttt{re} module right now. The warning can be suppressed by calling

```python
import warnings
warnings.filterwarnings(action = 'ignore',
    message='.*regex module is deprecated',
    category=DeprecationWarning,
    module = '__main__')
```

This adds a filter that will apply only to warnings of the class \texttt{DeprecationWarning} triggered in the \texttt{__main__} module, and applies a regular expression to only match the message about the regex module being deprecated, and will cause such warnings to be ignored. Warnings can also be printed only once, printed every time the offending code is executed, or turned into exceptions that will cause the program to stop (unless the exceptions are caught in the usual way, of course).

Functions were also added to Python's C API for issuing warnings; refer to PEP 230 or to Python's API documentation for the details.

\textbf{See also:}

\textbf{PEP 5 - Guidelines for Language Evolution}

Written by Paul Prescod, to specify procedures to be followed when removing old features from Python. The policy described in this PEP hasn’t been officially adopted, but the eventual policy
probably won’t be too different from Prescod’s proposal.

**PEP 230 - Warning Framework**
Written and implemented by Guido van Rossum.
PEP 229: New Build System

When compiling Python, the user had to go in and edit the Modules/Setup file in order to enable various additional modules; the default set is relatively small and limited to modules that compile on most Unix platforms. This means that on Unix platforms with many more features, most notably Linux, Python installations often don’t contain all useful modules they could.

Python 2.0 added the Distutils, a set of modules for distributing and installing extensions. In Python 2.1, the Distutils are used to compile much of the standard library of extension modules, autodetecting which ones are supported on the current machine. It’s hoped that this will make Python installations easier and more featureful.

Instead of having to edit the Modules/Setup file in order to enable modules, a setup.py script in the top directory of the Python source distribution is run at build time, and attempts to discover which modules can be enabled by examining the modules and header files on the system. If a module is configured in Modules/Setup, the setup.py script won’t attempt to compile that module and will defer to the Modules/Setup file’s contents. This provides a way to specify any strange command-line flags or libraries that are required for a specific platform.

In another far-reaching change to the build mechanism, Neil Schemenauer restructured things so Python now uses a single makefile that isn’t recursive, instead of makefiles in the top directory and in each of the Python/, Parser/, Objects/, and Modules/ subdirectories. This makes building Python faster and also makes hacking the Makefiles clearer and simpler.
See also:

**PEP 229** - Using Distutils to Build Python

Written and implemented by A.M. Kuchling.
Weak references, available through the `weakref` module, are a minor but useful new data type in the Python programmer’s toolbox.

Storing a reference to an object (say, in a dictionary or a list) has the side effect of keeping that object alive forever. There are a few specific cases where this behaviour is undesirable, object caches being the most common one, and another being circular references in data structures such as trees.

For example, consider a memoizing function that caches the results of another function \( f(x) \) by storing the function’s argument and its result in a dictionary:

```python
_cache = {}

def memoize(x):
    if _cache.has_key(x):
        return _cache[x]

    retval = f(x)
    # Cache the returned object
    _cache[x] = retval

    return retval
```

This version works for simple things such as integers, but it has a side effect; the `_cache` dictionary holds a reference to the return values, so they'll never be deallocated until the Python process exits and cleans up. This isn't very noticeable for integers, but if \( f() \) returns an object, or a data structure that takes up a lot of memory, this can be a problem.
Weak references provide a way to implement a cache that won’t keep objects alive beyond their time. If an object is only accessible through weak references, the object will be deallocated and the weak references will now indicate that the object it referred to no longer exists. A weak reference to an object `obj` is created by calling `wr = weakref.ref(obj)`. The object being referred to is returned by calling the weak reference as if it were a function: `wr()`. It will return the referenced object, or None if the object no longer exists.

This makes it possible to write a `memoize()` function whose cache doesn’t keep objects alive, by storing weak references in the cache.

```python
_cache = {}
def memoize(x):
    if _cache.has_key(x):
        obj = _cache[x]()
        # If weak reference object still exists,
        # return it
        if obj is not None: return obj

    retval = f(x)

    # Cache a weak reference
    _cache[x] = weakref.ref(retval)

    return retval
```

The `weakref` module also allows creating proxy objects which behave like weak references — an object referenced only by proxy objects is deallocated – but instead of requiring an explicit call to retrieve the object, the proxy transparently forwards all operations to the object as long as the object still exists. If the object is deallocated, attempting to use a proxy will cause a `weakref.ReferenceError` exception to be raised.
proxy = weakref.proxy(obj)
proxy.attr    # Equivalent to obj.attr
proxy.meth()  # Equivalent to obj.meth()
Del obj
proxy.attr    # raises weakref.ReferenceError

See also:

**PEP 205 - Weak References**

Written and implemented by Fred L. Drake, Jr.
PEP 232: Function Attributes

In Python 2.1, functions can now have arbitrary information attached to them. People were often using docstrings to hold information about functions and methods, because the __doc__ attribute was the only way of attaching any information to a function. For example, in the Zope Web application server, functions are marked as safe for public access by having a docstring, and in John Aycock’s SPARK parsing framework, docstrings hold parts of the BNF grammar to be parsed. This overloading is unfortunate, since docstrings are really intended to hold a function’s documentation; for example, it means you can’t properly document functions intended for private use in Zope.

Arbitrary attributes can now be set and retrieved on functions using the regular Python syntax:

```python
def f(): pass
f.publish = 1
f.secure = 1
f.grammar = "A ::= B (C D)*"
```

The dictionary containing attributes can be accessed as the function’s __dict__. Unlike the __dict__ attribute of class instances, in functions you can actually assign a new dictionary to __dict__, though the new value is restricted to a regular Python dictionary; you can’t be tricky and set it to a UserDict instance, or any other random object that behaves like a mapping.

See also:

PEP 232 - Function Attributes
Written and implemented by Barry Warsaw.
PEP 235: Importing Modules on Case-Insensitive Platforms

Some operating systems have filesystems that are case-insensitive, MacOS and Windows being the primary examples; on these systems, it's impossible to distinguish the filenames FILE.PY and file.py, even though they do store the file's name in its original case (they're case-preserving, too).

In Python 2.1, the `import` statement will work to simulate case-sensitivity on case-insensitive platforms. Python will now search for the first case-sensitive match by default, raising an `ImportError` if no such file is found, so `import file` will not import a module named FILE.PY. Case-insensitive matching can be requested by setting the `PYTHONCASEOK` environment variable before starting the Python interpreter.
PEP 217: Interactive Display Hook

When using the Python interpreter interactively, the output of commands is displayed using the built-in `repr()` function. In Python 2.1, the variable `sys.displayhook()` can be set to a callable object which will be called instead of `repr()`. For example, you can set it to a special pretty-printing function:

```python
>>> # Create a recursive data structure
... L = [1,2,3]
>>> L.append(L)
>>> L # Show Python's default output
[1, 2, 3, [...]]
>>> # Use pprint.pprint() as the display function
... import sys, pprint
>>> sys.displayhook = pprint.pprint
>>> L
[1, 2, 3, <Recursion on list with id=135143996>]
>>>  
```

See also:

**PEP 217 - Display Hook for Interactive Use**

Written and implemented by Moshe Zadka.
PEP 208: New Coercion Model

How numeric coercion is done at the C level was significantly modified. This will only affect the authors of C extensions to Python, allowing them more flexibility in writing extension types that support numeric operations.

Extension types can now set the type flag Py_TPFLAGS_CHECKTYPES in their PyTypeObject structure to indicate that they support the new coercion model. In such extension types, the numeric slot functions can no longer assume that they’ll be passed two arguments of the same type; instead they may be passed two arguments of differing types, and can then perform their own internal coercion. If the slot function is passed a type it can’t handle, it can indicate the failure by returning a reference to the Py_NotImplemented singleton value. The numeric functions of the other type will then be tried, and perhaps they can handle the operation; if the other type also returns Py_NotImplemented, then a TypeError will be raised. Numeric methods written in Python can also return Py_NotImplemented, causing the interpreter to act as if the method did not exist (perhaps raising a TypeError, perhaps trying another object’s numeric methods).

See also:

PEP 208 - Reworking the Coercion Model
Written and implemented by Neil Schemenauer, heavily based upon earlier work by Marc-André Lemburg. Read this to understand the fine points of how numeric operations will now be processed at the C level.
PEP 241: Metadata in Python Packages

A common complaint from Python users is that there’s no single catalog of all the Python modules in existence. T. Middleton’s Vaults of Parnassus at http://www.vex.net/parnassus/ are the largest catalog of Python modules, but registering software at the Vaults is optional, and many people don’t bother.

As a first small step toward fixing the problem, Python software packaged using the Distutils `sdist` command will include a file named `PKG-INFO` containing information about the package such as its name, version, and author (metadata, in cataloguing terminology). PEP 241 contains the full list of fields that can be present in the `PKG-INFO` file. As people began to package their software using Python 2.1, more and more packages will include metadata, making it possible to build automated cataloguing systems and experiment with them. With the result experience, perhaps it'll be possible to design a really good catalog and then build support for it into Python 2.2. For example, the Distutils `sdist` and `bdist_*` commands could support an `upload` option that would automatically upload your package to a catalog server.

You can start creating packages containing `PKG-INFO` even if you’re not using Python 2.1, since a new release of the Distutils will be made for users of earlier Python versions. Version 1.0.2 of the Distutils includes the changes described in PEP 241, as well as various bugfixes and enhancements. It will be available from the Distutils SIG at https://www.python.org/sigs/distutils-sig/.

**See also:**

**PEP 241 - Metadata for Python Software Packages**
Written and implemented by A.M. Kuchling.

**PEP 243 - Module Repository Upload Mechanism**

Written by Sean Reifschneider, this draft PEP describes a proposed mechanism for uploading Python packages to a central server.
New and Improved Modules

- Ka-Ping Yee contributed two new modules: inspect.py, a module for getting information about live Python code, and pydoc.py, a module for interactively converting docstrings to HTML or text. As a bonus, Tools/scripts/pydoc, which is now automatically installed, uses pydoc.py to display documentation given a Python module, package, or class name. For example, pydoc xml.dom displays the following:

```ini
NAME
xml.dom - W3C Document Object Model implementation

FILE
/usr/local/lib/python2.1/xml/dom/__init__.pyc

DESCRIPTION
The Python mapping of the Document Object Model
Python Library Reference in the section on the

This package contains the following modules:
...
```

pydoc also includes a Tk-based interactive help browser. pydoc quickly becomes addictive; try it out!

- Two different modules for unit testing were added to the standard library. The doctest module, contributed by Tim Peters, provides a testing framework based on running embedded examples in docstrings and comparing the results against the expected output.
PyUnit, contributed by Steve Purcell, is a unit testing framework inspired by JUnit, which was in turn an adaptation of Kent Beck's Smalltalk testing framework. See http://pyunit.sourceforge.net/ for more information about PyUnit.

- The **difflib** module contains a class, SequenceMatcher, which compares two sequences and computes the changes required to transform one sequence into the other. For example, this module can be used to write a tool similar to the Unix **diff** program, and in fact the sample program Tools/scripts/ndiff.py demonstrates how to write such a script.

- **curses.panel**, a wrapper for the panel library, part of ncurses and of SYSV curses, was contributed by Thomas Gellekum. The panel library provides windows with the additional feature of depth. Windows can be moved higher or lower in the depth ordering, and the panel library figures out where panels overlap and which sections are visible.

- The PyXML package has gone through a few releases since Python 2.0, and Python 2.1 includes an updated version of the **xml** package. Some of the noteworthy changes include support for Expat 1.2 and later versions, the ability for Expat parsers to handle files in any encoding supported by Python, and various bugfixes for SAX, DOM, and the minidom module.

- Ping also contributed another hook for handling uncaught exceptions. **sys.excepthook()** can be set to a callable object. When an exception isn't caught by any **try...except** blocks, the exception will be passed to **sys.excepthook()**, which can then do whatever it likes. At the Ninth Python Conference, Ping
demonstrated an application for this hook: printing an extended traceback that not only lists the stack frames, but also lists the function arguments and the local variables for each frame.

- Various functions in the `time` module, such as `asctime()` and `localtime()`, require a floating point argument containing the time in seconds since the epoch. The most common use of these functions is to work with the current time, so the floating point argument has been made optional; when a value isn’t provided, the current time will be used. For example, log file entries usually need a string containing the current time; in Python 2.1, `time.asctime()` can be used, instead of the lengthier `time.asctime(time.localtime(time.time()))` that was previously required.

  This change was proposed and implemented by Thomas Wouters.

- The `ftplib` module now defaults to retrieving files in passive mode, because passive mode is more likely to work from behind a firewall. This request came from the Debian bug tracking system, since other Debian packages use `ftplib` to retrieve files and then don’t work from behind a firewall. It’s deemed unlikely that this will cause problems for anyone, because Netscape defaults to passive mode and few people complain, but if passive mode is unsuitable for your application or network setup, call `set_pasv(0)` on FTP objects to disable passive mode.

- Support for raw socket access has been added to the `socket` module, contributed by Grant Edwards.

- The `pstats` module now contains a simple interactive statistics
A new implementation-dependent function, `sys._getframe([depth])`, has been added to return a given frame object from the current call stack. `sys._getframe()` returns the frame at the top of the call stack; if the optional integer argument `depth` is supplied, the function returns the frame that is `depth` calls below the top of the stack. For example, `sys._getframe(1)` returns the caller’s frame object.

This function is only present in CPython, not in Jython or the .NET implementation. Use it for debugging, and resist the temptation to put it into production code.
Other Changes and Fixes

There were relatively few smaller changes made in Python 2.1 due to the shorter release cycle. A search through the CVS change logs turns up 117 patches applied, and 136 bugs fixed; both figures are likely to be underestimates. Some of the more notable changes are:

- A specialized object allocator is now optionally available, that should be faster than the system `malloc()` and have less memory overhead. The allocator uses C’s `malloc()` function to get large pools of memory, and then fulfills smaller memory requests from these pools. It can be enabled by providing the `--with-pymalloc` option to the `configure` script; see Objects/obmalloc.c for the implementation details.

Authors of C extension modules should test their code with the object allocator enabled, because some incorrect code may break, causing core dumps at runtime. There are a bunch of memory allocation functions in Python’s C API that have previously been just aliases for the C library’s `malloc()` and `free()`, meaning that if you accidentally called mismatched functions, the error wouldn’t be noticeable. When the object allocator is enabled, these functions aren’t aliases of `malloc()` and `free()` any more, and calling the wrong function to free memory will get you a core dump. For example, if memory was allocated using `PyMem_New()`, it has to be freed using `PyMem_Del()`, not `free()`. A few modules included with Python fell afoul of this and had to be fixed; doubtless there are more third-party modules that will have the same problem.

The object allocator was contributed by Vladimir Marangozov.
The speed of line-oriented file I/O has been improved because people often complain about its lack of speed, and because it's often been used as a naïve benchmark. The `readline()` method of file objects has therefore been rewritten to be much faster. The exact amount of the speedup will vary from platform to platform depending on how slow the C library's `getc()` was, but is around 66%, and potentially much faster on some particular operating systems. Tim Peters did much of the benchmarking and coding for this change, motivated by a discussion in `comp.lang.python`.

A new module and method for file objects was also added, contributed by Jeff Epler. The new method, `xreadlines()`, is similar to the existing `xrange()` built-in. `xreadlines()` returns an opaque sequence object that only supports being iterated over, reading a line on every iteration but not reading the entire file into memory as the existing `readlines()` method does. You'd use it like this:

```python
for line in sys.stdin.xreadlines():
    # ... do something for each line ...

...  
```


A new method, `popitem()`, was added to dictionaries to enable destructively iterating through the contents of a dictionary; this can be faster for large dictionaries because there's no need to construct a list containing all the keys or values. `D.popitem()` removes a random (key, value) pair from the dictionary D and
returns it as a 2-tuple. This was implemented mostly by Tim Peters and Guido van Rossum, after a suggestion and preliminary patch by Moshe Zadka.

- Modules can now control which names are imported when from module import * is used, by defining an __all__ attribute containing a list of names that will be imported. One common complaint is that if the module imports other modules such as sys or string, from module import * will add them to the importing module's namespace. To fix this, simply list the public names in __all__:

```python
# List public names
__all__ = ['Database', 'open']
```

A stricter version of this patch was first suggested and implemented by Ben Wolfson, but after some python-dev discussion, a weaker final version was checked in.

- Applying repr() to strings previously used octal escapes for non-printable characters; for example, a newline was '\012'. This was a vestigial trace of Python's C ancestry, but today octal is of very little practical use. Ka-Ping Yee suggested using hex escapes instead of octal ones, and using the \n, \t, \r escapes for the appropriate characters, and implemented this new formatting.

- Syntax errors detected at compile-time can now raise exceptions containing the filename and line number of the error, a pleasant side effect of the compiler reorganization done by Jeremy Hylton.

- C extensions which import other modules have been changed to use PyImport_ImportModule(), which means that they will
use any import hooks that have been installed. This is also encouraged for third-party extensions that need to import some other module from C code.

- The size of the Unicode character database was shrunk by another 340K thanks to Fredrik Lundh.

- Some new ports were contributed: MacOS X (by Steven Majewski), Cygwin (by Jason Tishler); RISCOS (by Dietmar Schwertberger); Unixware 7 (by Billy G. Allie).

And there's the usual list of minor bugfixes, minor memory leaks, docstring edits, and other tweaks, too lengthy to be worth itemizing; see the CVS logs for the full details if you want them.
Acknowledgements

The author would like to thank the following people for offering suggestions on various drafts of this article: Graeme Cross, David Goodger, Jay Graves, Michael Hudson, Marc-André Lemburg, Fredrik Lundh, Neil Schemenauer, Thomas Wouters.
What’s New in Python 2.0

Author: A.M. Kuchling and Moshe Zadka
Introduction

A new release of Python, version 2.0, was released on October 16, 2000. This article covers the exciting new features in 2.0, highlights some other useful changes, and points out a few incompatible changes that may require rewriting code.

Python’s development never completely stops between releases, and a steady flow of bug fixes and improvements are always being submitted. A host of minor fixes, a few optimizations, additional docstrings, and better error messages went into 2.0; to list them all would be impossible, but they’re certainly significant. Consult the publicly-available CVS logs if you want to see the full list. This progress is due to the five developers working for PythonLabs are now getting paid to spend their days fixing bugs, and also due to the improved communication resulting from moving to SourceForge.
What About Python 1.6?

Python 1.6 can be thought of as the Contractual Obligations Python release. After the core development team left CNRI in May 2000, CNRI requested that a 1.6 release be created, containing all the work on Python that had been performed at CNRI. Python 1.6 therefore represents the state of the CVS tree as of May 2000, with the most significant new feature being Unicode support. Development continued after May, of course, so the 1.6 tree received a few fixes to ensure that it’s forward-compatible with Python 2.0. 1.6 is therefore part of Python’s evolution, and not a side branch.

So, should you take much interest in Python 1.6? Probably not. The 1.6final and 2.0beta1 releases were made on the same day (September 5, 2000), the plan being to finalize Python 2.0 within a month or so. If you have applications to maintain, there seems little point in breaking things by moving to 1.6, fixing them, and then having another round of breakage within a month by moving to 2.0; you’re better off just going straight to 2.0. Most of the really interesting features described in this document are only in 2.0, because a lot of work was done between May and September.
New Development Process

The most important change in Python 2.0 may not be to the code at all, but to how Python is developed: in May 2000 the Python developers began using the tools made available by SourceForge for storing source code, tracking bug reports, and managing the queue of patch submissions. To report bugs or submit patches for Python 2.0, use the bug tracking and patch manager tools available from Python's project page, located at http://sourceforge.net/projects/python/.

The most important of the services now hosted at SourceForge is the Python CVS tree, the version-controlled repository containing the source code for Python. Previously, there were roughly 7 or so people who had write access to the CVS tree, and all patches had to be inspected and checked in by one of the people on this short list. Obviously, this wasn’t very scalable. By moving the CVS tree to SourceForge, it became possible to grant write access to more people; as of September 2000 there were 27 people able to check in changes, a fourfold increase. This makes possible large-scale changes that wouldn’t be attempted if they’d have to be filtered through the small group of core developers. For example, one day Peter Schneider-Kamp took it into his head to drop K&R C compatibility and convert the C source for Python to ANSI C. After getting approval on the python-dev mailing list, he launched into a flurry of checkins that lasted about a week, other developers joined in to help, and the job was done. If there were only 5 people with write access, probably that task would have been viewed as “nice, but not worth the time and effort needed” and it would never have gotten done.

The shift to using SourceForge's services has resulted in a remarkable increase in the speed of development. Patches now get submitted,
commented on, revised by people other than the original submitter, and bounced back and forth between people until the patch is deemed worth checking in. Bugs are tracked in one central location and can be assigned to a specific person for fixing, and we can count the number of open bugs to measure progress. This didn’t come without a cost: developers now have more e-mail to deal with, more mailing lists to follow, and special tools had to be written for the new environment. For example, SourceForge sends default patch and bug notification e-mail messages that are completely unhelpful, so Ka-Ping Yee wrote an HTML screen-scraper that sends more useful messages.

The ease of adding code caused a few initial growing pains, such as code was checked in before it was ready or without getting clear agreement from the developer group. The approval process that has emerged is somewhat similar to that used by the Apache group. Developers can vote +1, +0, -0, or -1 on a patch; +1 and -1 denote acceptance or rejection, while +0 and -0 mean the developer is mostly indifferent to the change, though with a slight positive or negative slant. The most significant change from the Apache model is that the voting is essentially advisory, letting Guido van Rossum, who has Benevolent Dictator For Life status, know what the general opinion is. He can still ignore the result of a vote, and approve or reject a change even if the community disagrees with him.

Producing an actual patch is the last step in adding a new feature, and is usually easy compared to the earlier task of coming up with a good design. Discussions of new features can often explode into lengthy mailing list threads, making the discussion hard to follow, and no one can read every posting to python-dev. Therefore, a relatively formal process has been set up to write Python Enhancement Proposals (PEPs), modelled on the Internet RFC process. PEPs are draft documents that describe a proposed new feature, and are continually
revised until the community reaches a consensus, either accepting or rejecting the proposal. Quoting from the introduction to PEP 1, “PEP Purpose and Guidelines”:

PEP stands for Python Enhancement Proposal. A PEP is a design document providing information to the Python community, or describing a new feature for Python. The PEP should provide a concise technical specification of the feature and a rationale for the feature.

We intend PEPs to be the primary mechanisms for proposing new features, for collecting community input on an issue, and for documenting the design decisions that have gone into Python. The PEP author is responsible for building consensus within the community and documenting dissenting opinions.

Read the rest of PEP 1 for the details of the PEP editorial process, style, and format. PEPs are kept in the Python CVS tree on SourceForge, though they’re not part of the Python 2.0 distribution, and are also available in HTML form from https://www.python.org/peps/. As of September 2000, there are 25 PEPs, ranging from PEP 201, “Lockstep Iteration”, to PEP 225, “Elementwise/Objectwise Operators”. 
Unicode

The largest new feature in Python 2.0 is a new fundamental data type: Unicode strings. Unicode uses 16-bit numbers to represent characters instead of the 8-bit number used by ASCII, meaning that 65,536 distinct characters can be supported.

The final interface for Unicode support was arrived at through countless often-stormy discussions on the python-dev mailing list, and mostly implemented by Marc-André Lemburg, based on a Unicode string type implementation by Fredrik Lundh. A detailed explanation of the interface was written up as PEP 100, “Python Unicode Integration”. This article will simply cover the most significant points about the Unicode interfaces.

In Python source code, Unicode strings are written as u"string". Arbitrary Unicode characters can be written using a new escape sequence, \uHHHH, where HHHH is a 4-digit hexadecimal number from 0000 to FFFF. The existing \xHHHH escape sequence can also be used, and octal escapes can be used for characters up to U+01FF, which is represented by \777.

Unicode strings, just like regular strings, are an immutable sequence type. They can be indexed and sliced, but not modified in place. Unicode strings have an encode( [encoding] ) method that returns an 8-bit string in the desired encoding. Encodings are named by strings, such as 'ascii', 'utf-8', 'iso-8859-1', or whatever. A codec API is defined for implementing and registering new encodings that are then available throughout a Python program. If an encoding isn’t specified, the default encoding is usually 7-bit ASCII, though it can be changed for your Python installation by calling the
sys.setdefaultencoding(encoding) function in a customised version of site.py.

Combining 8-bit and Unicode strings always coerces to Unicode, using the default ASCII encoding; the result of 'a' + u'bc' is u'abc'.

New built-in functions have been added, and existing built-ins modified to support Unicode:

- unichr(ch) returns a Unicode string 1 character long, containing the character ch.
- ord(u), where u is a 1-character regular or Unicode string, returns the number of the character as an integer.
- unicode(string [, encoding] [, errors] ) creates a Unicode string from an 8-bit string. encoding is a string naming the encoding to use. The errors parameter specifies the treatment of characters that are invalid for the current encoding; passing 'strict' as the value causes an exception to be raised on any encoding error, while 'ignore' causes errors to be silently ignored and 'replace' uses U+FFFD, the official replacement character, in case of any problems.
- The exec statement, and various built-ins such as eval(), setattr(), and setattr() will also accept Unicode strings as well as regular strings. (It's possible that the process of fixing this missed some built-ins; if you find a built-in function that accepts strings but doesn't accept Unicode strings at all, please report it as a bug.)

A new module, unicodedata, provides an interface to Unicode character properties. For example, unicodedata.category(u'A') returns the 2-character string ‘Lu’, the ‘L’ denoting it’s a letter, and ‘u’ meaning it’s uppercase. unicodedata.bidirectional(u'\u0660') returns ‘AN’,
meaning that U+0660 is an Arabic number.

The `codecs` module contains functions to look up existing encodings and register new ones. Unless you want to implement a new encoding, you'll most often use the `codecs.lookup(encoding)` function, which returns a 4-element tuple: `(encode_func, decode_func, stream_reader, stream_writer).

- `encode_func` is a function that takes a Unicode string, and returns a 2-tuple `(string, length)`. `string` is an 8-bit string containing a portion (perhaps all) of the Unicode string converted into the given encoding, and `length` tells you how much of the Unicode string was converted.
- `decode_func` is the opposite of `encode_func`, taking an 8-bit string and returning a 2-tuple `(ustring, length)`, consisting of the resulting Unicode string `ustring` and the integer `length` telling how much of the 8-bit string was consumed.
- `stream_reader` is a class that supports decoding input from a stream. `stream_reader(file_obj)` returns an object that supports the `read()`, `readline()`, and `readlines()` methods. These methods will all translate from the given encoding and return Unicode strings.
- `stream_writer`, similarly, is a class that supports encoding output to a stream. `stream_writer(file_obj)` returns an object that supports the `write()` and `writelines()` methods. These methods expect Unicode strings, translating them to the given encoding on output.

For example, the following code writes a Unicode string into a file, encoding it as UTF-8:

```python
import codecs
unistr = u'\u0660\u2000ab ...
```
(UTF8_encode, UTF8_decode,
  UTF8_streamreader, UTF8_streamwriter) = codecs.lookup

output = UTF8_streamwriter( open( '/tmp/output', 'wb'
output.write( unistr )
output.close()

The following code would then read UTF-8 input from the file:

input = UTF8_streamreader( open( '/tmp/output', 'rb'
print repr(input.read())
input.close()

Unicode-aware regular expressions are available through the re module, which has a new underlying implementation called SRE written by Fredrik Lundh of Secret Labs AB.

A -U command line option was added which causes the Python compiler to interpret all string literals as Unicode string literals. This is intended to be used in testing and future-proofing your Python code, since some future version of Python may drop support for 8-bit strings and provide only Unicode strings.
List Comprehensions

Lists are a workhorse data type in Python, and many programs manipulate a list at some point. Two common operations on lists are to loop over them, and either pick out the elements that meet a certain criterion, or apply some function to each element. For example, given a list of strings, you might want to pull out all the strings containing a given substring, or strip off trailing whitespace from each line.

The existing `map()` and `filter()` functions can be used for this purpose, but they require a function as one of their arguments. This is fine if there's an existing built-in function that can be passed directly, but if there isn't, you have to create a little function to do the required work, and Python’s scoping rules make the result ugly if the little function needs additional information. Take the first example in the previous paragraph, finding all the strings in the list containing a given substring. You could write the following to do it:

```
# Given the list L, make a list of all strings
# containing the substring S.
sublist = filter( lambda s, substring=S:
    string.find(s, substring) != -1
L)
```

Because of Python’s scoping rules, a default argument is used so that the anonymous function created by the `lambda` statement knows what substring is being searched for. List comprehensions make this cleaner:

```
sublist = [ s for s in L if string.find(s, S) != -1
```
List comprehensions have the form:

```
[ expression for expr in sequence1
  for expr2 in sequence2 ...
  for exprN in sequenceN
  if condition ]
```

The `for...in` clauses contain the sequences to be iterated over. The sequences do not have to be the same length, because they are *not* iterated over in parallel, but from left to right; this is explained more clearly in the following paragraphs. The elements of the generated list will be the successive values of `expression`. The final `if` clause is optional; if present, `expression` is only evaluated and added to the result if `condition` is true.

To make the semantics very clear, a list comprehension is equivalent to the following Python code:

```
for expr1 in sequence1:
  for expr2 in sequence2:
    ...
  for exprN in sequenceN:
    if (condition):
      # Append the value of
      # the expression to the
      # resulting list.
```

This means that when there are multiple `for...in` clauses, the resulting list will be equal to the product of the lengths of all the sequences. If you have two lists of length 3, the output list is 9 elements long:

```
seq1 = 'abc'
seq2 = (1,2,3)
```
To avoid introducing an ambiguity into Python’s grammar, if *expression* is creating a tuple, it must be surrounded with parentheses. The first list comprehension below is a syntax error, while the second one is correct:

```python
# Syntax error
[ x, y for x in seq1 for y in seq2]
# Correct
[ (x, y) for x in seq1 for y in seq2]
```

The idea of list comprehensions originally comes from the functional programming language Haskell ([http://www.haskell.org](http://www.haskell.org)). Greg Ewing argued most effectively for adding them to Python and wrote the initial list comprehension patch, which was then discussed for a seemingly endless time on the python-dev mailing list and kept up-to-date by Skip Montanaro.
Augmented Assignment

Augmented assignment operators, another long-requested feature, have been added to Python 2.0. Augmented assignment operators include +=, -=, *=, and so forth. For example, the statement `a += 2` increments the value of the variable `a` by 2, equivalent to the slightly lengthier `a = a + 2`.

The full list of supported assignment operators is +=, -=, *=, /=, %=, **=, &=, |=, ^=, >>=, and <<=. Python classes can override the augmented assignment operators by defining methods named `__iadd__()`, `__isub__()`, etc. For example, the following `Number` class stores a number and supports using += to create a new instance with an incremented value.

```python
class Number:
    def __init__(self, value):
        self.value = value
    def __iadd__(self, increment):
        return Number(self.value + increment)

n = Number(5)
n += 3
print n.value
```

The `__iadd__()` special method is called with the value of the increment, and should return a new instance with an appropriately modified value; this return value is bound as the new value of the variable on the left-hand side.

Augmented assignment operators were first introduced in the C programming language, and most C-derived languages, such as `awk`,
C++, Java, Perl, and PHP also support them. The augmented assignment patch was implemented by Thomas Wouters.
String Methods

Until now string-manipulation functionality was in the `string` module, which was usually a front-end for the `strop` module written in C. The addition of Unicode posed a difficulty for the `strop` module, because the functions would all need to be rewritten in order to accept either 8-bit or Unicode strings. For functions such as `string.replace()`, which takes 3 string arguments, that means eight possible permutations, and correspondingly complicated code.

Instead, Python 2.0 pushes the problem onto the string type, making string manipulation functionality available through methods on both 8-bit strings and Unicode strings.

```python
>>> 'andrew'.capitalize()
'Andrew'
>>> 'hostname'.replace('os', 'linux')
'hlinuxtname'
>>> 'moshe'.find('sh')
2
```

One thing that hasn't changed, a noteworthy April Fools' joke notwithstanding, is that Python strings are immutable. Thus, the string methods return new strings, and do not modify the string on which they operate.

The old `string` module is still around for backwards compatibility, but it mostly acts as a front-end to the new string methods.

Two methods which have no parallel in pre-2.0 versions, although they did exist in JPython for quite some time, are `startswith()` and `endswith()`. `s.startswith(t)` is equivalent to `s[:len(t)] ==
```
t, while s.endswith(t) is equivalent to s[-len(t):] == t.

One other method which deserves special mention is join(). The join() method of a string receives one parameter, a sequence of strings, and is equivalent to the string.join() function from the old string module, with the arguments reversed. In other words, s.join(seq) is equivalent to the old string.join(seq, s).
Garbage Collection of Cycles

The C implementation of Python uses reference counting to implement garbage collection. Every Python object maintains a count of the number of references pointing to itself, and adjusts the count as references are created or destroyed. Once the reference count reaches zero, the object is no longer accessible, since you need to have a reference to an object to access it, and if the count is zero, no references exist any longer.

Reference counting has some pleasant properties: it's easy to understand and implement, and the resulting implementation is portable, fairly fast, and reacts well with other libraries that implement their own memory handling schemes. The major problem with reference counting is that it sometimes doesn't realise that objects are no longer accessible, resulting in a memory leak. This happens when there are cycles of references.

Consider the simplest possible cycle, a class instance which has a reference to itself:

```python
instance = SomeClass()
instance.myself = instance
```

After the above two lines of code have been executed, the reference count of `instance` is 2; one reference is from the variable named 'instance', and the other is from the `myself` attribute of the instance.

If the next line of code is `del instance`, what happens? The reference count of `instance` is decreased by 1, so it has a reference count of 1; the reference in the `myself` attribute still exists. Yet the
instance is no longer accessible through Python code, and it could be deleted. Several objects can participate in a cycle if they have references to each other, causing all of the objects to be leaked.

Python 2.0 fixes this problem by periodically executing a cycle detection algorithm which looks for inaccessible cycles and deletes the objects involved. A new gc module provides functions to perform a garbage collection, obtain debugging statistics, and tuning the collector’s parameters.

Running the cycle detection algorithm takes some time, and therefore will result in some additional overhead. It is hoped that after we’ve gotten experience with the cycle collection from using 2.0, Python 2.1 will be able to minimize the overhead with careful tuning. It’s not yet obvious how much performance is lost, because benchmarking this is tricky and depends crucially on how often the program creates and destroys objects. The detection of cycles can be disabled when Python is compiled, if you can’t afford even a tiny speed penalty or suspect that the cycle collection is buggy, by specifying the --without-cycle-gc switch when running the configure script.

Several people tackled this problem and contributed to a solution. An early implementation of the cycle detection approach was written by Toby Kelsey. The current algorithm was suggested by Eric Tiedemann during a visit to CNRI, and Guido van Rossum and Neil Schemenauer wrote two different implementations, which were later integrated by Neil. Lots of other people offered suggestions along the way; the March 2000 archives of the python-dev mailing list contain most of the relevant discussion, especially in the threads titled “Reference cycle collection for Python” and “Finalization again”.
Other Core Changes

Various minor changes have been made to Python’s syntax and built-in functions. None of the changes are very far-reaching, but they’re handy conveniences.

Minor Language Changes

A new syntax makes it more convenient to call a given function with a tuple of arguments and/or a dictionary of keyword arguments. In Python 1.5 and earlier, you’d use the `apply()` built-in function: `apply(f, args, kw)` calls the function `f()` with the argument tuple `args` and the keyword arguments in the dictionary `kw`. `apply()` is the same in 2.0, but thanks to a patch from Greg Ewing, `f(*args, **kw)` as a shorter and clearer way to achieve the same effect. This syntax is symmetrical with the syntax for defining functions:

```python
def f(*args, **kw):
    # args is a tuple of positional args,
    # kw is a dictionary of keyword args
    ...
```

The print statement can now have its output directed to a file-like object by following the `print` with `>>` file, similar to the redirection operator in Unix shells. Previously you’d either have to use the `write()` method of the file-like object, which lacks the convenience and simplicity of `print`, or you could assign a new value to `sys.stdout` and then restore the old value. For sending output to standard error, it’s much easier to write this:

```python
print >> sys.stderr, "Warning: action field not supp..."
Modules can now be renamed on importing them, using the syntax `import module as name` or `from module import name as othername`. The patch was submitted by Thomas Wouters.

A new format style is available when using the `%` operator; `‘%r’` will insert the `repr()` of its argument. This was also added from symmetry considerations, this time for symmetry with the existing `%s` format style, which inserts the `str()` of its argument. For example, `'%r %s' % ('abc', 'abc')` returns a string containing 'abc'

Previously there was no way to implement a class that overrode Python's built-in `in` operator and implemented a custom version. `obj in seq` returns true if `obj` is present in the sequence `seq`; Python computes this by simply trying every index of the sequence until either `obj` is found or an `IndexError` is encountered. Moshe Zadka contributed a patch which adds a `__contains__()` magic method for providing a custom implementation for `in`. Additionally, new built-in objects written in C can define what `in` means for them via a new slot in the sequence protocol.

Earlier versions of Python used a recursive algorithm for deleting objects. Deeply nested data structures could cause the interpreter to fill up the C stack and crash; Christian Tismer rewrote the deletion logic to fix this problem. On a related note, comparing recursive objects recursed infinitely and crashed; Jeremy Hylton rewrote the code to no longer crash, producing a useful result instead. For example, after this code:

```python
a = []
b = []
```
The comparison `a==b` returns true, because the two recursive data structures are isomorphic. See the thread “trashcan and PR#7” in the April 2000 archives of the python-dev mailing list for the discussion leading up to this implementation, and some useful relevant links. Note that comparisons can now also raise exceptions. In earlier versions of Python, a comparison operation such as `cmp(a, b)` would always produce an answer, even if a user-defined `__cmp__()` method encountered an error, since the resulting exception would simply be silently swallowed.

Work has been done on porting Python to 64-bit Windows on the Itanium processor, mostly by Trent Mick of ActiveState. (Confusingly, `sys.platform` is still 'win32' on Win64 because it seems that for ease of porting, MS Visual C++ treats code as 32 bit on Itanium.) PythonWin also supports Windows CE; see the Python CE page at http://pythonce.sourceforge.net/ for more information.

Another new platform is Darwin/MacOS X; initial support for it is in Python 2.0. Dynamic loading works, if you specify “configure –with-dyld –with-suffix=.x”. Consult the README in the Python source distribution for more instructions.

An attempt has been made to alleviate one of Python’s warts, the often-confusing NameError exception when code refers to a local variable before the variable has been assigned a value. For example, the following code raises an exception on the print statement in both 1.5.2 and 2.0; in 1.5.2 a NameError exception is raised, while 2.0 raises a new UnboundLocalError exception. UnboundLocalError is a subclass of NameError, so any existing
code that expects NameError to be raised should still work.

```python
def f():
    print "i=", i
    i = i + 1
f()
```

Two new exceptions, TabError and IndentationError, have been introduced. They're both subclasses of SyntaxError, and are raised when Python code is found to be improperly indented.

**Changes to Built-in Functions**

A new built-in, zip(seq1, seq2, ...), has been added. zip() returns a list of tuples where each tuple contains the i-th element from each of the argument sequences. The difference between zip() and map(None, seq1, seq2) is that map() pads the sequences with None if the sequences aren't all of the same length, while zip() truncates the returned list to the length of the shortest argument sequence.

The int() and long() functions now accept an optional “base” parameter when the first argument is a string. int('123', 10) returns 123, while int('123', 16) returns 291. int(123, 16) raises a TypeError exception with the message “can’t convert non-string with explicit base”.

A new variable holding more detailed version information has been added to the sys module. sys.version_info is a tuple (major, minor, micro, level, serial) For example, in a hypothetical 2.0.1beta1, sys.version_info would be (2, 0, 1, 'beta', 1). level is a string such as "alpha", "beta", or "final" for a final
Dictionaries have an odd new method, setdefault(key, default), which behaves similarly to the existing get() method. However, if the key is missing, setdefault() both returns the value of default as get() would do, and also inserts it into the dictionary as the value for key. Thus, the following lines of code:

```python
if dict.has_key( key ): return dict[key]
else:
    dict[key] = []
    return dict[key]
```

can be reduced to a single return `dict.setdefault(key, [])` statement.

The interpreter sets a maximum recursion depth in order to catch runaway recursion before filling the C stack and causing a core dump or GPF. Previously this limit was fixed when you compiled Python, but in 2.0 the maximum recursion depth can be read and modified using `sys.getrecursionlimit()` and `sys.setrecursionlimit()`. The default value is 1000, and a rough maximum value for a given platform can be found by running a new script, Misc/find_recursionlimit.py.
Porting to 2.0

New Python releases try hard to be compatible with previous releases, and the record has been pretty good. However, some changes are considered useful enough, usually because they fix initial design decisions that turned out to be actively mistaken, that breaking backward compatibility can’t always be avoided. This section lists the changes in Python 2.0 that may cause old Python code to break.

The change which will probably break the most code is tightening up the arguments accepted by some methods. Some methods would take multiple arguments and treat them as a tuple, particularly various list methods such as append() and insert(). In earlier versions of Python, if L is a list, L.append( 1,2 ) appends the tuple (1,2) to the list. In Python 2.0 this causes a TypeError exception to be raised, with the message: ‘append requires exactly 1 argument; 2 given’. The fix is to simply add an extra set of parentheses to pass both values as a tuple: L.append( (1,2) ).

The earlier versions of these methods were more forgiving because they used an old function in Python’s C interface to parse their arguments; 2.0 modernizes them to use PyArg_ParseTuple(), the current argument parsing function, which provides more helpful error messages and treats multi-argument calls as errors. If you absolutely must use 2.0 but can’t fix your code, you can edit Objects/listobject.c and define the preprocessor symbol NO_STRICT_LIST_APPEND to preserve the old behaviour; this isn’t recommended.

Some of the functions in the socket module are still forgiving in this way. For example, socket.connect( ( 'hostname', 25 ) )() is
the correct form, passing a tuple representing an IP address, but `socket.connect( 'hostname', 25 )()` also works. `socket.connect_ex()` and `socket.bind()` are similarly easy-going. 2.0alpha1 tightened these functions up, but because the documentation actually used the erroneous multiple argument form, many people wrote code which would break with the stricter argument checking. GvR backed out the changes in the face of public reaction, so for the `socket` module, the documentation was fixed and the multiple argument form is simply marked as deprecated; it will be tightened up again in a future Python version.

The \x escape in string literals now takes exactly 2 hex digits. Previously it would consume all the hex digits following the ‘x’ and take the lowest 8 bits of the result, so \x123456 was equivalent to \x56.

The `AttributeError` and `NameError` exceptions have a more friendly error message, whose text will be something like 'Spam' instance has no attribute 'eggs' or name 'eggs' is not defined. Previously the error message was just the missing attribute name eggs, and code written to take advantage of this fact will break in 2.0.

Some work has been done to make integers and long integers a bit more interchangeable. In 1.5.2, large-file support was added for Solaris, to allow reading files larger than 2 GiB; this made the `tell()` method of file objects return a long integer instead of a regular integer. Some code would subtract two file offsets and attempt to use the result to multiply a sequence or slice a string, but this raised a `TypeError`. In 2.0, long integers can be used to multiply or slice a sequence, and it’ll behave as you’d intuitively expect it to; 3L * 'abc' produces ‘abcabcabc’, and (0, 1, 2, 3)[2L:4L] produces (2,3). Long integers can also be used in various contexts where previously only integers
were accepted, such as in the \texttt{seek()} method of file objects, and in the formats supported by the \texttt{%} operator (\texttt{%d}, \texttt{%i}, \texttt{%x}, etc.). For example, \texttt{"%d" \% 2L**64} will produce the string \texttt{18446744073709551616}.

The subtlest long integer change of all is that the \texttt{str()} of a long integer no longer has a trailing ‘L’ character, though \texttt{repr()} still includes it. The ‘L’ annoyed many people who wanted to print long integers that looked just like regular integers, since they had to go out of their way to chop off the character. This is no longer a problem in 2.0, but code which does \texttt{str(longval)[:-1]} and assumes the ‘L’ is there, will now lose the final digit.

Taking the \texttt{repr()} of a float now uses a different formatting precision than \texttt{str()}. \texttt{repr()} uses \texttt{%.17g} format string for C’s \texttt{sprintf()}, while \texttt{str()} uses \texttt{%.12g} as before. The effect is that \texttt{repr()} may occasionally show more decimal places than \texttt{str()}, for certain numbers. For example, the number 8.1 can’t be represented exactly in binary, so \texttt{repr(8.1)} is ‘8.0999999999999996’, while \texttt{str(8.1)} is ‘8.1’.

The \texttt{-X} command-line option, which turned all standard exceptions into strings instead of classes, has been removed; the standard exceptions will now always be classes. The exceptions module containing the standard exceptions was translated from Python to a built-in C module, written by Barry Warsaw and Fredrik Lundh.
Extending/Embedding Changes

Some of the changes are under the covers, and will only be apparent to people writing C extension modules or embedding a Python interpreter in a larger application. If you aren’t dealing with Python’s C API, you can safely skip this section.

The version number of the Python C API was incremented, so C extensions compiled for 1.5.2 must be recompiled in order to work with 2.0. On Windows, it’s not possible for Python 2.0 to import a third party extension built for Python 1.5.x due to how Windows DLLs work, so Python will raise an exception and the import will fail.

Users of Jim Fulton’s ExtensionClass module will be pleased to find out that hooks have been added so that ExtensionClasses are now supported by `isinstance()` and `issubclass()`. This means you no longer have to remember to write code such as `if type(obj) == myExtensionClass`, but can use the more natural `if isinstance(obj, myExtensionClass).

The Python/importdl.c file, which was a mass of `#ifdefs to support dynamic loading on many different platforms, was cleaned up and reorganised by Greg Stein. importdl.c is now quite small, and platform-specific code has been moved into a bunch of Python/dynload_*.c files. Another cleanup: there were also a number of my*.h files in the Include/ directory that held various portability hacks; they’ve been merged into a single file, Include/pyport.h.

Vladimir Marangozov’s long-awaited malloc restructuring was completed, to make it easy to have the Python interpreter use a
custom allocator instead of C’s standard malloc(). For documentation, read the comments in Include/pymem.h and Include/objimpl.h. For the lengthy discussions during which the interface was hammered out, see the Web archives of the ‘patches’ and ‘python-dev’ lists at python.org.

Recent versions of the GUSI development environment for MacOS support POSIX threads. Therefore, Python’s POSIX threading support now works on the Macintosh. Threading support using the user-space GNU pth library was also contributed.

Threading support on Windows was enhanced, too. Windows supports thread locks that use kernel objects only in case of contention; in the common case when there’s no contention, they use simpler functions which are an order of magnitude faster. A threaded version of Python 1.5.2 on NT is twice as slow as an unthreaded version; with the 2.0 changes, the difference is only 10%. These improvements were contributed by Yakov Markovitch.

Python 2.0’s source now uses only ANSI C prototypes, so compiling Python now requires an ANSI C compiler, and can no longer be done using a compiler that only supports K&R C.

Previously the Python virtual machine used 16-bit numbers in its bytecode, limiting the size of source files. In particular, this affected the maximum size of literal lists and dictionaries in Python source; occasionally people who are generating Python code would run into this limit. A patch by Charles G. Waldman raises the limit from $2^{16}$ to $2^{32}$.

Three new convenience functions intended for adding constants to a module’s dictionary at module initialization time were added: PyModule_AddObject(), PyModule_AddIntConstant(), and
PyModule_AddStringConstant(). Each of these functions takes a module object, a null-terminated C string containing the name to be added, and a third argument for the value to be assigned to the name. This third argument is, respectively, a Python object, a C long, or a C string.

A wrapper API was added for Unix-style signal handlers. PyOS_getsig() gets a signal handler and PyOS_setsig() will set a new handler.
Distutils: Making Modules Easy to Install

Before Python 2.0, installing modules was a tedious affair – there was no way to figure out automatically where Python is installed, or what compiler options to use for extension modules. Software authors had to go through an arduous ritual of editing Makefiles and configuration files, which only really work on Unix and leave Windows and MacOS unsupported. Python users faced wildly differing installation instructions which varied between different extension packages, which made administering a Python installation something of a chore.

The SIG for distribution utilities, shepherded by Greg Ward, has created the Distutils, a system to make package installation much easier. They form the distutils package, a new part of Python's standard library. In the best case, installing a Python module from source will require the same steps: first you simply mean unpack the tarball or zip archive, and the run “python setup.py install”. The platform will be automatically detected, the compiler will be recognized, C extension modules will be compiled, and the distribution installed into the proper directory. Optional command-line arguments provide more control over the installation process, the distutils package offers many places to override defaults – separating the build from the install, building or installing in non-default directories, and more.

In order to use the Distutils, you need to write a setup.py script. For the simple case, when the software contains only .py files, a minimal setup.py can be just a few lines long:

```python
from distutils.core import setup
setup (name = "foo", version = "1.0",
       py_modules = ["module1", "module2"])
```
The setup.py file isn't much more complicated if the software consists of a few packages:

```python
from distutils.core import setup
setup (name = "foo", version = "1.0",
       packages = ["package", "package.subpackage"]):
```

A C extension can be the most complicated case; here's an example taken from the PyXML package:

```python
from distutils.core import setup, Extension

expat_extension = Extension('xml.parsers.pyexpat',
   define_macros = [\'(XML_NS', None\)],
   include_dirs = [ 'extensions/expat/xmltok',
                   'extensions/expat/xmlparse' ],
   sources = [ 'extensions/pyexpat.c',
               'extensions/expat/xmltok/xmltok.c',
               'extensions/expat/xmltok/xmlrole.c' ],

setup (name = "PyXML", version = "0.5.4",
       ext_modules =[
                       expat_extension ]
)
```

The Distutils can also take care of creating source and binary distributions. The “sdist” command, run by “python setup.py sdist”, builds a source distribution such as foo-1.0.tar.gz. Adding new commands isn’t difficult, “bdist_rpm” and “bdist_wininst” commands have already been contributed to create an RPM distribution and a Windows installer for the software, respectively. Commands to create other distribution formats such as Debian packages and Solaris .pkg files are in various stages of development.
All this is documented in a new manual, *Distributing Python Modules*, that joins the basic set of Python documentation.
XML Modules

Python 1.5.2 included a simple XML parser in the form of the xmlib module, contributed by Sjoerd Mullender. Since 1.5.2's release, two different interfaces for processing XML have become common: SAX2 (version 2 of the Simple API for XML) provides an event-driven interface with some similarities to xmlib, and the DOM (Document Object Model) provides a tree-based interface, transforming an XML document into a tree of nodes that can be traversed and modified. Python 2.0 includes a SAX2 interface and a stripped-down DOM interface as part of the xml package. Here we will give a brief overview of these new interfaces; consult the Python documentation or the source code for complete details. The Python XML SIG is also working on improved documentation.

SAX2 Support

SAX defines an event-driven interface for parsing XML. To use SAX, you must write a SAX handler class. Handler classes inherit from various classes provided by SAX, and override various methods that will then be called by the XML parser. For example, the startElement() and endElement() methods are called for every starting and end tag encountered by the parser, the characters() method is called for every chunk of character data, and so forth.

The advantage of the event-driven approach is that the whole document doesn't have to be resident in memory at any one time, which matters if you are processing really huge documents. However, writing the SAX handler class can get very complicated if you're trying to modify the document structure in some elaborate way.
For example, this little example program defines a handler that prints a message for every starting and ending tag, and then parses the file hamlet.xml using it:

```python
from xml import sax

class SimpleHandler(sax.ContentHandler):
    def startElement(self, name, attrs):
        print 'Start of element:', name, attrs.keys()

    def endElement(self, name):
        print 'End of element:', name

# Create a parser object
parser = sax.make_parser()

# Tell it what handler to use
handler = SimpleHandler()
parsing.setContentHandler( handler )

# Parse a file!
parsing.parse( 'hamlet.xml' )
```

For more information, consult the Python documentation, or the XML HOWTO at [http://pyxml.sourceforge.net/topics/howto/xml-howto.html](http://pyxml.sourceforge.net/topics/howto/xml-howto.html).

**DOM Support**

The Document Object Model is a tree-based representation for an XML document. A top-level Document instance is the root of the tree, and has a single child which is the top-level Element instance. This Element has children nodes representing character data and any sub-elements, which may have further children of their own, and so
forth. Using the DOM you can traverse the resulting tree any way you like, access element and attribute values, insert and delete nodes, and convert the tree back into XML.

The DOM is useful for modifying XML documents, because you can create a DOM tree, modify it by adding new nodes or rearranging subtrees, and then produce a new XML document as output. You can also construct a DOM tree manually and convert it to XML, which can be a more flexible way of producing XML output than simply writing `<tag1>...</tag1>` to a file.

The DOM implementation included with Python lives in the `xml.dom.minidom` module. It's a lightweight implementation of the Level 1 DOM with support for XML namespaces. The parse() and parseString() convenience functions are provided for generating a DOM tree:

```python
from xml.dom import minidom
doc = minidom.parse('hamlet.xml')
```

doc is a Document instance. Document, like all the other DOM classes such as Element and Text, is a subclass of the Node base class. All the nodes in a DOM tree therefore support certain common methods, such as toxml() which returns a string containing the XML representation of the node and its children. Each class also has special methods of its own; for example, Element and Document instances have a method to find all child elements with a given tag name. Continuing from the previous 2-line example:

```python
perslist = doc.getElementsByTagName( 'PERSONA' )
print perslist[0].toxml()
print perslist[1].toxml()
```
For the *Hamlet* XML file, the above few lines output:

```xml
<Persona>CLAUDIOUS, king of Denmark. </Persona>
<Persona>HAMLET, son to the late, and nephew to the
```

The root element of the document is available as `doc.documentElement`, and its children can be easily modified by deleting, adding, or removing nodes:

```python
root = doc.documentElement

# Remove the first child
root.removeChild( root.childNodes[0] )

# Move the new first child to the end
root.appendChild( root.childNodes[0] )

# Insert the new first child (originally, the third child) before the 20th child.
root.insertBefore( root.childNodes[0], root.childNodes[19] )
```

Again, I will refer you to the Python documentation for a complete listing of the different Node classes and their various methods.

**Relationship to PyXML**

The XML Special Interest Group has been working on XML-related Python code for a while. Its code distribution, called PyXML, is available from the SIG's Web pages at [https://www.python.org/community/sigs/current/xml-sig](https://www.python.org/community/sigs/current/xml-sig). The PyXML distribution also used the package name `xml`. If you’ve written programs that used PyXML, you’re probably wondering about its
compatibility with the 2.0 xml package.

The answer is that Python 2.0's xml package isn't compatible with PyXML, but can be made compatible by installing a recent version PyXML. Many applications can get by with the XML support that is included with Python 2.0, but more complicated applications will require that the full PyXML package will be installed. When installed, PyXML versions 0.6.0 or greater will replace the xml package shipped with Python, and will be a strict superset of the standard package, adding a bunch of additional features. Some of the additional features in PyXML include:

- 4DOM, a full DOM implementation from FourThought, Inc.
- The xmlproc validating parser, written by Lars Marius Garshol.
- The sgmlop parser accelerator module, written by Fredrik Lundh.
Module changes

Lots of improvements and bugfixes were made to Python's extensive standard library; some of the affected modules include `readline`, `ConfigParser`, `cgi`, `calendar`, `posix`, `readline`, `xmllib`, `aifc`, `chunk`, `wave`, `random`, `shelve`, and `ntplib`. Consult the CVS logs for the exact patch-by-patch details.

Brian Gallew contributed OpenSSL support for the `socket` module. OpenSSL is an implementation of the Secure Socket Layer, which encrypts the data being sent over a socket. When compiling Python, you can edit `Modules/Setup` to include SSL support, which adds an additional function to the `socket` module: `socket.ssl(socket, keyfile, certfile)`, which takes a socket object and returns an SSL socket. The `httplib` and `urllib` modules were also changed to support https:// URLs, though no one has implemented FTP or SMTP over SSL.

The `httplib` module has been rewritten by Greg Stein to support HTTP/1.1. Backward compatibility with the 1.5 version of `httplib` is provided, though using HTTP/1.1 features such as pipelining will require rewriting code to use a different set of interfaces.

The `Tkinter` module now supports Tcl/Tk version 8.1, 8.2, or 8.3, and support for the older 7.x versions has been dropped. The `Tkinter` module now supports displaying Unicode strings in Tk widgets. Also, Fredrik Lundh contributed an optimization which makes operations like `create_line` and `create_polygon` much faster, especially when using lots of coordinates.

The `curses` module has been greatly extended, starting from Oliver
Andrich’s enhanced version, to provide many additional functions from ncurses and SYSV curses, such as colour, alternative character set support, pads, and mouse support. This means the module is no longer compatible with operating systems that only have BSD curses, but there don’t seem to be any currently maintained OSes that fall into this category.

As mentioned in the earlier discussion of 2.0’s Unicode support, the underlying implementation of the regular expressions provided by the re module has been changed. SRE, a new regular expression engine written by Fredrik Lundh and partially funded by Hewlett Packard, supports matching against both 8-bit strings and Unicode strings.
New modules

A number of new modules were added. We'll simply list them with brief descriptions; consult the 2.0 documentation for the details of a particular module.

- **atexit**: For registering functions to be called before the Python interpreter exits. Code that currently sets `sys.exitfunc` directly should be changed to use the `atexit` module instead, importing `atexit` and calling `atexit.register()` with the function to be called on exit. (Contributed by Skip Montanaro.)
- **codecs, encodings, unicodedata**: Added as part of the new Unicode support.
- **filecmp**: Supersedes the old `cmp`, `cmpcache` and `dircmp` modules, which have now become deprecated. (Contributed by Gordon MacMillan and Moshe Zadka.)
- **gettext**: This module provides internationalization (I18N) and localization (L10N) support for Python programs by providing an interface to the GNU gettext message catalog library. (Integrated by Barry Warsaw, from separate contributions by Martin von Löwis, Peter Funk, and James Henstridge.)
- **linuxaudiodev**: Support for the `/dev/audio` device on Linux, a twin to the existing `sunaudiodev` module. (Contributed by Peter Bosch, with fixes by Jeremy Hylton.)
- **mmap**: An interface to memory-mapped files on both Windows and Unix. A file's contents can be mapped directly into memory, at which point it behaves like a mutable string, so its contents can be read and modified. They can even be passed to functions that expect ordinary strings, such as the `re` module. (Contributed by Sam Rushing, with some extensions by A.M. Kuchling.)
- **pyexpat**: An interface to the Expat XML parser. (Contributed by Paul Prescod.)
robotparser: Parse a robots.txt file, which is used for writing Web spiders that politely avoid certain areas of a Web site. The parser accepts the contents of a robots.txt file, builds a set of rules from it, and can then answer questions about the fetchability of a given URL. (Contributed by Skip Montanaro.)

tabnanny: A module/script to check Python source code for ambiguous indentation. (Contributed by Tim Peters.)

UserString: A base class useful for deriving objects that behave like strings.

webbrowser: A module that provides a platform independent way to launch a web browser on a specific URL. For each platform, various browsers are tried in a specific order. The user can alter which browser is launched by setting the BROWSER environment variable. (Originally inspired by Eric S. Raymond's patch to urllib which added similar functionality, but the final module comes from code originally implemented by Fred Drake as Tools/idle/BrowserControl.py, and adapted for the standard library by Fred.)

_winreg: An interface to the Windows registry. _winreg is an adaptation of functions that have been part of PythonWin since 1995, but has now been added to the core distribution, and enhanced to support Unicode. _winreg was written by Bill Tutt and Mark Hammond.

zipfile: A module for reading and writing ZIP-format archives. These are archives produced by PKZIP on DOS/Windows or zip on Unix, not to be confused with gzip-format files (which are supported by the gzip module) (Contributed by James C. Ahlstrom.)

imputil: A module that provides a simpler way for writing customised import hooks, in comparison to the existing ihooks module. (Implemented by Greg Stein, with much discussion on python-dev along the way.)
IDLE Improvements

IDLE is the official Python cross-platform IDE, written using Tkinter. Python 2.0 includes IDLE 0.6, which adds a number of new features and improvements. A partial list:

- UI improvements and optimizations, especially in the area of syntax highlighting and auto-indentation.
- The class browser now shows more information, such as the top level functions in a module.
- Tab width is now a user settable option. When opening an existing Python file, IDLE automatically detects the indentation conventions, and adapts.
- There is now support for calling browsers on various platforms, used to open the Python documentation in a browser.
- IDLE now has a command line, which is largely similar to the vanilla Python interpreter.
- Call tips were added in many places.
- IDLE can now be installed as a package.
- In the editor window, there is now a line/column bar at the bottom.
- Three new keystroke commands: Check module (Alt-F5), Import module (F5) and Run script (Ctrl-F5).
Deleted and Deprecated Modules

A few modules have been dropped because they’re obsolete, or because there are now better ways to do the same thing. The stdwin module is gone; it was for a platform-independent windowing toolkit that’s no longer developed.

A number of modules have been moved to the lib-old subdirectory: cmp, cmpcache, dircmp, dump, find, grep, packmail, poly, util, whatsound, zmod. If you have code which relies on a module that’s been moved to lib-old, you can simply add that directory to sys.path to get them back, but you’re encouraged to update any code that uses these modules.
Acknowledgements

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Changelog
Python 3.5.1 final?

Release date: 2015-12-06

Core and Builtins

- **Issue #25709**: Fixed problem with in-place string concatenation and utf-8 cache.

Windows

- **Issue #25715**: Python 3.5.1 installer shows wrong upgrade path and incorrect logic for launcher detection.
Python 3.5.1 release candidate 1?

Release date: 2015-11-22

Core and Builtins

- **Issue #25630**: Fix a possible segfault during argument parsing in functions that accept filesystem paths.

- **Issue #23564**: Fixed a partially broken sanity check in the `_posixsubprocess` internals regarding how fds_to_pass were passed to the child. The bug had no actual impact as subprocess.py already avoided it.

- **Issue #25388**: Fixed tokenizer crash when processing undecodable source code with a null byte.

- **Issue #25462**: The hash of the key now is calculated only once in most operations in C implementation of OrderedDict.

- **Issue #22995**: Default implementation of `__reduce__` and `__reduce_ex__` now rejects builtin types with not defined `__new__`.

- **Issue #25555**: Fix parser and AST: fill lineno and col_offset of “arg” node when compiling AST from Python objects.

- **Issue #24802**: Avoid buffer overreads when `int()`, `float()`, `compile()`, `exec()` and `eval()` are passed bytes-like objects. These objects are not necessarily terminated by a null byte, but the functions assumed they were.

- **Issue #24726**: Fixed a crash and leaking NULL in `repr()` of OrderedDict that was mutated by direct calls of dict methods.

- **Issue #25449**: Iterating OrderedDict with keys with unstable hash now raises `KeyError` in C implementations as well as in Python implementation.

- **Issue #25395**: Fixed crash when highly nested OrderedDict structures were garbage collected.

- **Issue #25274**: `sys.setrecursionlimit()` now raises a `RecursionError`
if the new recursion limit is too low depending at the current recursion depth. Modify also the “lower-water mark” formula to make it monotonic. This mark is used to decide when the overflowed flag of the thread state is reset.

- **Issue #24402**: Fix input() to prompt to the redirected stdout when sys.stdout.fileno() fails.
- **Issue #24806**: Prevent builtin types that are not allowed to be subclassed from being subclassed through multiple inheritance.
- **Issue #24848**: Fixed a number of bugs in UTF-7 decoding of misformed data.
- **Issue #25280**: Import trace messages emitted in verbose (-v) mode are no longer formatted twice.
- **Issue #25003**: On Solaris 11.3 or newer, os.urandom() now uses the getrandom() function instead of the getentropy() function. The getentropy() function is blocking to generate very good quality entropy, os.urandom() doesn’t need such high-quality entropy.
- **Issue #25182**: The stdprinter (used as sys.stderr before the io module is imported at startup) now uses the backslashreplace error handler.
- **Issue #25131**: Make the line number and column offset of set/dict literals and comprehensions correspond to the opening brace.
- **Issue #25150**: Hide the private _Py_atomic_xxx symbols from the public Python.h header to fix a compilation error with OpenMP. PyThreadState_GET() becomes an alias to PyThreadState_Get() to avoid ABI incompatibilities.

**Library**

- **Issue #25626**: Change three zlib functions to accept sizes that fit in Py_ssize_t, but internally cap those sizes to UINT_MAX. This resolves a regression in 3.5 where GzipFile.read() failed to read chunks larger than 2 or 4 GiB. The change affects the zlib.Decompress.decompress() max_length parameter, the zlib.decompress() bufsize parameter, and the
zlib.Decompress.flush() length parameter.

- **Issue #25583**: Avoid incorrect errors raised by os.makedirs(exist_ok=True) when the OS gives priority to errors such as EACCES over EEXIST.
- **Issue #25593**: Change semantics of EventLoop.stop() in asyncio.
- **Issue #6973**: When we know a subprocess.Popen process has died, do not allow the send_signal(), terminate(), or kill() methods to do anything as they could potentially signal a different process.
- **Issue #25590**: In the Readline completer, only call getattr() once per attribute.
- **Issue #25498**: Fix a crash when garbage-collecting ctypes objects created by wrapping a memoryview. This was a regression made in 3.5a1. Based on patch by Eryksun.
- **Issue #25584**: Added “escape” to the __all__ list in the glob module.
- **Issue #25584**: Fixed recursive glob() with patterns starting with ‘**’.
- **Issue #25446**: Fix regression in smtplib’s AUTH LOGIN support.
- **Issue #18010**: Fix the pydoc web server’s module search function to handle exceptions from importing packages.
- **Issue #25554**: Got rid of circular references in regular expression parsing.
- **Issue #25510**: fileinput.FileInput.readline() now returns b"" instead of "" at the end if the FileInput was opened with binary mode. Patch by Ryosuke Ito.
- **Issue #25503**: Fixed inspect.getdoc() for inherited docstrings of properties. Original patch by John Mark Vandenberg.
- **Issue #25515**: Always use os.urandom as a source of randomness in uuid.uuid4.
- **Issue #21827**: Fixed textwrap.dedent() for the case when largest common whitespace is a substring of smallest leading whitespace. Based on patch by Robert Li.
- **Issue #25447**: The lru_cache() wrapper objects now can be copied and pickled (by returning the original object unchanged).
• **Issue #25390**: typing: Don’t crash on Union[str, Pattern].
• **Issue #25441**: asyncio: Raise error from drain() when socket is closed.
• **Issue #25410**: Cleaned up and fixed minor bugs in C implementation of OrderedDict.
• **Issue #25411**: Improved Unicode support in SMTPHandler through better use of the email package. Thanks to user simon04 for the patch.
• **Issue #25407**: Remove mentions of the formatter module being removed in Python 3.6.
• **Issue #25406**: Fixed a bug in C implementation of OrderedDict.move_to_end() that caused segmentation fault or hang in iterating after moving several items to the start of ordered dict.
• **Issue #25364**: zipfile now works in threads disabled builds.
• **Issue #25328**: smtpd’s SMTPChannel now correctly raises a ValueError if both decode_data and enable_SMTPUTF8 are set to true.
• **Issue #25316**: distutils raises OSError instead of DistutilsPlatformError when MSVC is not installed.
• **Issue #25380**: Fixed protocol for the STACK_GLOBAL opcode in pickletools.opcodes.
• **Issue #23972**: Updates asyncio datagram create method allowing reuseport and reuseaddr socket options to be set prior to binding the socket. Mirroring the existing asyncio create_server method the reuseaddr option for datagram sockets defaults to True if the O/S is ‘posix’ (except if the platform is Cygwin). Patch by Chris Laws.
• **Issue #25304**: Add asyncio.run_coroutine_threadsafe(). This lets you submit a coroutine to a loop from another thread, returning a concurrent.futures.Future. By Vincent Michel.
• **Issue #25232**: Fix CGIRequestHandler to split the query from the URL at the first question mark (?) rather than the last. Patch from Xiang Zhang.
- **Issue #24657**: Prevent CGIRequestHandler from collapsing slashes in the query part of the URL as if it were a path. Patch from Xiang Zhang.
- **Issue #24483**: C implementation of functools.lru_cache() now calculates key’s hash only once.
- **Issue #22958**: Constructor and update method of weakref.WeakValueDictionary now accept the self and the dict keyword arguments.
- **Issue #22609**: Constructor of collections.UserDict now accepts the self keyword argument.
- **Issue #25111**: Fixed comparison of traceback.FrameSummary.
- **Issue #25262**: Added support for BINBYTES8 opcode in Python implementation of unpickler. Highest 32 bits of 64-bit size for BINUNICODE8 and BINBYTES8 opcodes no longer silently ignored on 32-bit platforms in C implementation.
- **Issue #25034**: Fix string.Formatter problem with auto-numbering and nested format_specs. Patch by Anthon van der Neut.
- **Issue #25233**: Rewrite the guts of asyncio.Queue and asyncio.Semaphore to be more understandable and correct.
- **Issue #25203**: Failed readline.set_completer_delims() no longer left the module in inconsistent state.
- **Issue #23600**: Default implementation of tzinfo.fromutc() was returning wrong results in some cases.
- **Issue #23329**: Allow the ssl module to be built with older versions of LibreSSL.
- Prevent overflow in _Unpickler_Read.
- **Issue #25047**: The XML encoding declaration written by Element Tree now respects the letter case given by the user. This restores the ability to write encoding names in uppercase like “UTF-8”, which worked in Python 2.
- **Issue #25135**: Make deque_clear() safer by emptying the deque before clearing. This helps avoid possible reentrancy issues.
- **Issue #19143**: platform module now reads Windows version from kernel32.dll to avoid compatibility shims.
- **Issue #25092**: Fix datetime.strptime() failure when errno was already set to EINVAL.
- **Issue #23517**: Fix rounding in fromtimestamp() and utcfromtimestamp() methods of datetime.datetime: microseconds are now rounded to nearest with ties going to nearest even integer (ROUND_HALF_EVEN), instead of being rounding towards minus infinity (ROUND_FLOOR). It's important that these methods use the same rounding mode than datetime.timedelta to keep the property: (datetime(1970,1,1) + timedelta(seconds=t)) == datetime.utcfromtimestamp(t). It also the rounding mode used by round(float) for example.
- **Issue #25155**: Fix datetime.datetime.now() and datetime.datetime.utcnow() on Windows to support date after year 2038. It was a regression introduced in Python 3.5.0.
- **Issue #25108**: Omitted internal frames in traceback functions print_stack(), format_stack(), and extract_stack() called without arguments.
- **Issue #25118**: Fix a regression of Python 3.5.0 in os.waitpid() on Windows.
- **Issue #24684**: socket.socket.getaddrinfo() now calls PyUnicode_AsEncodedString() instead of calling the encode() method of the host, to handle correctly custom string with an encode() method which doesn’t return a byte string. The encoder of the IDNA codec is now called directly instead of calling the encode() method of the string.
- **Issue #25060**: Correctly compute stack usage of the BUILD_MAP opcode.
- **Issue #24857**: Comparing call_args to a long sequence now correctly returns a boolean result instead of raising an exception. Patch by A Kaptur.
- **Issue #23144**: Make sure that HTMLParser.feed() returns all the data, even when convert_charrefs is True.
- **Issue #24982**: shutil.make_archive() with the “zip” format now adds entries for directories (including empty directories) in ZIP file.
• **Issue #25019**: Fixed a crash caused by setting non-string key of expat parser. Based on patch by John Leitch.
• **Issue #16180**: Exit pdb if file has syntax error, instead of trapping user in an infinite loop. Patch by Xavier de Gaye.
• **Issue #24891**: Fix a race condition at Python startup if the file descriptor of stdin (0), stdout (1) or stderr (2) is closed while Python is creating sys.stdin, sys.stdout and sys.stderr objects. These attributes are now set to None if the creation of the object failed, instead of raising an OSError exception. Initial patch written by Marco Paolini.
• **Issue #24992**: Fix error handling and a race condition (related to garbage collection) in collections.OrderedDict constructor.
• **Issue #24881**: Fixed setting binary mode in Python implementation of FileIO on Windows and Cygwin. Patch from Akira Li.
• **Issue #25578**: Fix (another) memory leak in SSLSocket.getpeercert().
• **Issue #25530**: Disable the vulnerable SSLv3 protocol by default when creating ssl.SSLContext.
• **Issue #25569**: Fix memory leak in SSLSocket.getpeercert().
• **Issue #25471**: Sockets returned from accept() shouldn't appear to be nonblocking.
• **Issue #25319**: When threading.Event is reinitialized, the underlying condition should use a regular lock rather than a recursive lock.
• **Issue #21112**: Fix regression in unittest.expectedFailure on subclasses. Patch from Berker Peksag.
• **Issue #24764**: cgi.FieldStorage.read_multi() now ignores the Content-Length header in part headers. Patch written by Peter Landry and reviewed by Pierre Quentel.
• **Issue #24913**: Fix overrun error in deque.index(). Found by John Leitch and Bryce Darling.
• **Issue #24774**: Fix docstring in http.server.test. Patch from Chiu-Hsiang Hsu.
• **Issue #21159**: Improve message in configparser.InterpolationMissingOptionError. Patch from Łukasz Langa.
• **Issue #20362**: Honour testCase.longMessage correctly in assertRegex. Patch from Ilia Kurenkov.
• **Issue #23572**: Fixed functools.singledispatch on classes with falsy metaclasses. Patch by Ethan Furman.
• asyncio: ensure_future() now accepts awaitable objects.

**IDLE**

• Issue 15348: Stop the debugger engine (normally in a user process) before closing the debugger window (running in the IDLE process). This prevents the RuntimeErrors that were being caught and ignored.
• **Issue #24455**: Prevent IDLE from hanging when a) closing the shell while the debugger is active (15347); b) closing the debugger with the [X] button (15348); and c) activating the debugger when already active (24455). The patch by Mark Roseman does this by making two changes. 1. Suspend and resume the gui.interaction method with the tcl vwait mechanism intended for this purpose (instead of root.mainloop & .quit). 2. In gui.run, allow any existing interaction to terminate first.
• Change ‘The program’ to ‘Your program’ in an IDLE ‘kill program?’ message to make it clearer that the program referred to is the currently running user program, not IDLE itself.
• **Issue #24750**: Improve the appearance of the IDLE editor window status bar. Patch by Mark Roseman.
• **Issue #25313**: Change the handling of new built-in text color themes to better address the compatibility problem introduced by the addition of IDLE Dark. Consistently use the revised idleConf.CurrentTheme everywhere in idlelib.
• **Issue #24782**: Extension configuration is now a tab in the IDLE Preferences dialog rather than a separate dialog. The former tabs
are now a sorted list. Patch by Mark Roseman.

- **Issue #22726**: Re-activate the config dialog help button with some content about the other buttons and the new IDLE Dark theme.
- **Issue #24820**: IDLE now has an ‘IDLE Dark’ built-in text color theme. It is more or less IDLE Classic inverted, with a cobalt blue background. Strings, comments, keywords, ... are still green, red, orange, ... . To use it with IDLEs released before November 2015, hit the ‘Save as New Custom Theme’ button and enter a new name, such as ‘Custom Dark’. The custom theme will work with any IDLE release, and can be modified.
- **Issue #25224**: README.txt is now an idlelib index for IDLE developers and curious users. The previous user content is now in the IDLE doc chapter. ‘IDLE’ now means ‘Integrated Development and Learning Environment’.
- **Issue #24820**: Users can now set breakpoint colors in Settings -> Custom Highlighting. Original patch by Mark Roseman.
- **Issue #24972**: Inactive selection background now matches active selection background, as configured by users, on all systems. Found items are now always highlighted on Windows. Initial patch by Mark Roseman.
- **Issue #24570**: Idle: make calltip and completion boxes appear on Macs affected by a tk regression. Initial patch by Mark Roseman.
- **Issue #24988**: Idle ScrolledList context menus (used in debugger) now work on Mac Aqua. Patch by Mark Roseman.
- **Issue #24801**: Make right-click for context menu work on Mac Aqua. Patch by Mark Roseman.
- **Issue #25173**: Associate tkinter messageboxes with a specific widget. For Mac OSX, make them a ‘sheet’. Patch by Mark Roseman.
- **Issue #25198**: Enhance the initial html viewer now used for Idle Help. * Properly indent fixed-pitch text (patch by Mark Roseman). * Give code snippet a very Sphinx-like light blueish-gray background. * Re-use initial width and height set by users for shell and editor. * When the Table of Contents (TOC) menu is used, put
the section header at the top of the screen.

- **Issue #25225**: Condense and rewrite Idle doc section on text colors.
- **Issue #21995**: Explain some differences between IDLE and console Python.
- **Issue #22820**: Explain need for `print` when running file from Idle editor.
- **Issue #25224**: Doc: augment Idle feature list and no-subprocess section.
- **Issue #25219**: Update doc for Idle command line options. Some were missing and notes were not correct.
- **Issue #24861**: Most of idlelib is private and subject to change. Use `idlelib.idle.*` to start Idle. See `idlelib.__init__.__doc__`.
- **Issue #25199**: Idle: add synchronization comments for future maintainers.
- **Issue #16893**: Replace help.txt with help.html for Idle doc display. The new `idlelib/help.html` is rstripped Doc/build/html/library/idle.html. It looks better than help.txt and will better document Idle as released. The tkinter html viewer that works for this file was written by Mark Roseman. The now unused `EditorWindow.HelpDialog` class and `helt.txt` file are deprecated.
- **Issue #24199**: Deprecate unused `idlelib.idlever` with possible removal in 3.6.
- **Issue #24790**: Remove extraneous code (which also create 2 & 3 conflicts).

**Documentation**

- **Issue #12067**: Rewrite Comparisons section in the Expressions chapter of the language reference. Some of the details of comparing mixed types were incorrect or ambiguous. `NotImplemented` is only relevant at a lower level than the Expressions chapter. Added details of comparing range() objects, and default behaviour and consistency suggestions for user-
defined classes. Patch from Andy Maier.

- **Issue #24952**: Clarify the default size argument of stack_size() in the “threading” and “_thread” modules. Patch from Mattip.
- **Issue #23725**: Overhaul tempfile docs. Note deprecated status of mktemp. Patch from Zbigniew Jędrzejewski-Szmek.
- **Issue #24808**: Update the types of some PyTypeObject fields. Patch by Joseph Weston.
- **Issue #22812**: Fix unittest discovery examples. Patch from Pam McA’Nulty.

**Tests**

- **Issue #25449**: Added tests for OrderedDict subclasses.
- **Issue #25099**: Make test_compileall not fail when an entry on sys.path cannot be written to (commonly seen in administrative installs on Windows).
- **Issue #23919**: Prevents assert dialogs appearing in the test suite.
- PCbuild\rt.bat now accepts an unlimited number of arguments to pass along to regrtest.py. Previously there was a limit of 9.

**Build**

- **Issue #24915**: Add LLVM support for PGO builds and use the test suite to generate the profile data. Initial patch by Alecsandru Patrascu of Intel.
- **Issue #24910**: Windows MSIs now have unique display names.
- **Issue #24986**: It is now possible to build Python on Windows without errors when external libraries are not available.

**Windows**

- **Issue #25450**: Updates shortcuts to start Python in installation
• **Issue #25164**: Changes default all-users install directory to match per-user directory.
• **Issue #25143**: Improves installer error messages for unsupported platforms.
• **Issue #25163**: Display correct directory in installer when using non-default settings.
• **Issue #25361**: Disables use of SSE2 instructions in Windows 32-bit build
• **Issue #25089**: Adds logging to installer for case where launcher is not selected on upgrade.
• **Issue #25165**: Windows uninstallation should not remove launcher if other versions remain
• **Issue #25112**: py.exe launcher is missing icons
• **Issue #25102**: Windows installer does not precompile for -O or -OO.
• **Issue #25081**: Makes Back button in installer go back to upgrade page when upgrading.
• **Issue #25091**: Increases font size of the installer.
• **Issue #25126**: Clarifies that the non-web installer will download some components.
• **Issue #25213**: Restores requestedExecutionLevel to manifest to disable UAC virtualization.
• **Issue #25022**: Removed very outdated PC/example_nt/ directory.

**Tools/Demos**

• **Issue #25440**: Fix output of python-config –extension-suffix.
Python 3.5.0 final?

Release date: 2015-09-13

Build

- Issue #25071: Windows installer should not require TargetDir parameter when installing quietly.
Python 3.5.0 release candidate 4?

Release date: 2015-09-09

Library

- Issue #25029: Fixes MemoryError in test_strptime.

Build

- Issue #25027: Reverts partial-static build options and adds vcruntime140.dll to Windows installation.
Python 3.5.0 release candidate 3?

Release date: 2015-09-07

Core and Builtins

- **Issue #24305**: Prevent import subsystem stack frames from being counted by the warnings.warn(stacklevel=) parameter.
- **Issue #24912**: Prevent __class__ assignment to immutable built-in objects.
- **Issue #24975**: Fix AST compilation for PEP 448 syntax.

Library

- **Issue #24917**: time.strftime() buffer over-read.
- **Issue #24748**: To resolve a compatibility problem found with py2exe and pywin32, imp.load_dynamic() once again ignores previously loaded modules to support Python modules replacing themselves with extension modules. Patch by Petr Viktorin.
- **Issue #24635**: Fixed a bug in typing.py where isinstance([], typing.Iterable) would return True once, then False on subsequent calls.
- **Issue #24989**: Fixed buffer overread in BytesIO.readline() if a position is set beyond size. Based on patch by John Leitch.
- **Issue #24913**: Fix overrun error in deque.index(). Found by John Leitch and Bryce Darling.
Python 3.5.0 release candidate 2?

Release date: 2015-08-25

Core and Builtins

- **Issue #24769**: Interpreter now starts properly when dynamic loading is disabled. Patch by Petr Viktorin.
- **Issue #21167**: NAN operations are now handled correctly when python is compiled with ICC even if -fp-model strict is not specified.
- **Issue #24492**: A “package” lacking a __name__ attribute when trying to perform a from .. import ... statement will trigger an ImportError instead of an AttributeError.

Library

- **Issue #24847**: Removes vcruntime140.dll dependency from Tcl/Tk.
- **Issue #24839**: platform._syscmd_ver raises DeprecationWarning
- **Issue #24867**: Fix Task.get_stack() for ‘async def’ coroutines
Python 3.5.0 release candidate 1?

Release date: 2015-08-09

Core and Builtins

- **Issue #24667**: Resize odict in all cases that the underlying dict resizes.

Library

- **Issue #24824**: Signatures of codecs.encode() and codecs.decode() now are compatible with pydoc.
- **Issue #24634**: Importing uuid should not try to load libc on Windows
- **Issue #24798**: _msvccompiler.py doesn’t properly support manifests
- **Issue #4395**: Better testing and documentation of binary operators. Patch by Martin Panter.
- **Issue #23973**: Update typing.py from GitHub repo.
- **Issue #23004**: mock_open() now reads binary data correctly when the type of read_data is bytes. Initial patch by Aaron Hill.
- **Issue #23888**: Handle fractional time in cookie expiry. Patch by ssh.
- **Issue #23652**: Make it possible to compile the select module against the libc headers from the Linux Standard Base, which do not include some EPOLL macros. Patch by Matt Frank.
- **Issue #22932**: Fix timezones in email.utils.formatdate. Patch from Dmitry Shachnev.
- **Issue #23779**: imaplib raises TypeError if authenticator tries to abort. Patch from Craig Holmquist.
- **Issue #23319**: Fix ctypes.BigEndianStructure, swap correctly
bytes. Patch written by Matthieu Gautier.

- **Issue #23254**: Document how to close the TCPServer listening socket. Patch from Martin Panter.
- **Issue #19450**: Update Windows and OS X installer builds to use SQLite 3.8.11.
- **Issue #17527**: Add PATCH to wsgiref.validator. Patch from Luca Sbardella.
- **Issue #24791**: Fix grammar regression for call syntax: ‘g(*a or b’.

**IDLE**

- **Issue #23672**: Allow Idle to edit and run files with astral chars in name. Patch by Mohd Sanad Zaki Rizvi.
- **Issue #24745**: Idle editor default font. Switch from Courier to platform-sensitive TkFixedFont. This should not affect current customized font selections. If there is a problem, edit $HOME/.idlerc/config-main.cfg and remove ‘fontxxx’ entries from [Editor Window]. Patch by Mark Roseman.
- **Issue #21192**: Idle editor. When a file is run, put its name in the restart bar. Do not print false prompts. Original patch by Adnan Umer.
- **Issue #13884**: Idle menus. Remove tearoff lines. Patch by Roger Serwy.

**Documentation**

- **Issue #24129**: Clarify the reference documentation for name resolution. This includes removing the assumption that readers will be familiar with the name resolution scheme Python used prior to the introduction of lexical scoping for function namespaces. Patch by Ivan Levkivskyi.
- **Issue #20769**: Improve reload() docs. Patch by Dorian Pula.
- **Issue #23589**: Remove duplicate sentence from the FAQ. Patch
by Yongzhi Pan.

- **Issue #24729**: Correct IO tutorial to match implementation regarding encoding parameter to open function.

## Tests

- **Issue #24751**: When running regrtest with the `-w` command line option, a test run is no longer marked as a failure if all tests succeed when re-run.
Python 3.5.0 beta 4?

Release date: 2015-07-26

Core and Builtins

- **Issue #23573**: Restored optimization of bytes.rfind() and bytearray.rfind() for single-byte argument on Linux.
- **Issue #24569**: Make PEP 448 dictionary evaluation more consistent.
- **Issue #24583**: Fix crash when set is mutated while being updated.
- **Issue #24407**: Fix crash when dict is mutated while being updated.
- **Issue #24619**: New approach for tokenizing async/await. As a consequence, is is now possible to have one-line ‘async def foo(): await ..’ functions.
- **Issue #24687**: Plug refleak on SyntaxError in function parameters annotations.
- **Issue #15944**: memoryview: Allow arbitrary formats when casting to bytes. Patch by Martin Panter.

Library

- **Issue #23441**: rcompleter now prints a tab character instead of displaying possible completions for an empty word. Initial patch by Martin Sekera.
- **Issue #24683**: Fixed crashes in _json functions called with arguments of inappropriate type.
- **Issue #21697**: shutil.copytree() now correctly handles symbolic links that point to directories. Patch by Eduardo Seabra and Thomas Kluyver.
- **Issue #14373**: Fixed segmentation fault when gc.collect() is called
during constructing lru_cache (C implementation).

- **Issue #24695**: Fix a regression in traceback.print_exception(). If exc_traceback is None we shouldn’t print a traceback header like described in the documentation.
- **Issue #24620**: Random.setstate() now validates the value of state last element.
- **Issue #22485**: Fixed an issue that caused inspect.getsource to return incorrect results on nested functions.
- **Issue #22153**: Improve unittest docs. Patch from Martin Panter and evilzero.
- **Issue #24580**: Symbolic group references to open group in re patterns now are explicitly forbidden as well as numeric group references.
- **Issue #24206**: Fixed __eq__ and __ne__ methods of inspect classes.
- **Issue #24631**: Fixed regression in the timeit module with multiline setup.
- **Issue #18622**: unittest.mock.mock_open().reset_mock would recurse infinitely. Patch from Nicola Palumbo and Laurent De Buyst.
- **Issue #23661**: unittest.mock side_effects can now be exceptions again. This was a regression vs Python 3.4. Patch from Ignacio Rossi
- **Issue #24608**: chunk.Chunk.read() now always returns bytes, not str.
- **Issue #18684**: Fixed reading out of the buffer in the re module.
- **Issue #24259**: tarfile now raises a ReadError if an archive is truncated inside a data segment.
- **Issue #15014**: SMTP.auth() and SMTP.login() now support RFC 4954’s optional initial-response argument to the SMTP AUTH command.
- **Issue #24669**: Fix inspect.getsource() for ‘async def’ functions. Patch by Kai Groner.
- **Issue #24688**: ast.get_docstring() for ‘async def’ functions.
Build

- **Issue #24603**: Update Windows builds and OS X 10.5 installer to use OpenSSL 1.0.2d.
Python 3.5.0 beta 3?

Release date: 2015-07-05

Core and Builtins

- **Issue #24467**: Fixed possible buffer over-read in bytearray. The bytearray object now always allocates place for trailing null byte and it's buffer now is always null-terminated.
- Upgrade to Unicode 8.0.0.
- **Issue #24345**: Add Py_tp_finalize slot for the stable ABI.
- **Issue #24400**: Introduce a distinct type for PEP 492 coroutines; add types.CoroutineType, inspect.getcoroutinestate, inspect.getcoroutinelocals; coroutines no longer use CO_GENERATOR flag; sys.set_coroutine_wrapper works only for ‘async def’ coroutines; inspect.iscoroutine no longer uses collections.abcCoroutine, it’s intended to test for pure ‘async def’ coroutines only; add new opcode: GET_YIELD_FROM_ITER; fix generators wrapper used in types.coroutine to be instance of collections.abc.Generator; collections.abc.Awaitable and collections.abcCoroutine can no longer be used to detect generator-based coroutines—use inspect.isawaitable instead.
- **Issue #24450**: Add gi_yieldfrom to generators and cr_await to coroutines. Contributed by Benno Leslie and Yury Selivanov.
- **Issue #19235**: Add new RecursionError exception. Patch by Georg Brandl.

Library

- **Issue #21750**: mock_open.read_data can now be read from each instance, as it could in Python 3.3.
- **Issue #24552**: Fix use after free in an error case of the _pickle
module.

- **Issue #24514**: tarfile now tolerates number fields consisting of only whitespace.
- **Issue #19176**: Fixed doctype() related bugs in C implementation of ElementTree. A deprecation warning no longer issued by XMLParser subclass with default doctype() method. Direct call of doctype() now issues a warning. Parser’s doctype() now is not called if target’s doctype() is called. Based on patch by Martin Panter.
- **Issue #20387**: Restore semantic round-trip correctness in tokenize/untokenize for tab-indent blocks.
- **Issue #24456**: Fixed possible buffer over-read in adpcm2lin() and lin2adpcm() functions of the audioop module.
- **Issue #24336**: The contextmanager decorator now works with functions with keyword arguments called “func” and “self”. Patch by Martin Panter.
- **Issue #24522**: Fix possible integer overflow in json accelerator module.
- **Issue #24489**: ensure a previously set C errno doesn’t disturb cmath.polar().
- **Issue #24408**: Fixed AttributeError in measure() and metrics() methods of tkinter.Font.
- **Issue #14373**: C implementation of functools.lru_cache() now can be used with methods.
- **Issue #24347**: Set KeyError if PyDict_GetItemWithError returns NULL.
- **Issue #24348**: Drop superfluous incref/decref.
- **Issue #24359**: Check for changed OrderedDict size during iteration.
- **Issue #24368**: Support keyword arguments in OrderedDict methods.
- **Issue #24362**: Simplify the C OrderedDict fast nodes resize logic.
- **Issue #24377**: Fix a ref leak in OrderedDict.__repr__.
- **Issue #24369**: Defend against key-changes during iteration.
Tests

- Issue #24373: _testmultiphase and xxlimited now use tp_traverse and tp_finalize to avoid reference leaks encountered when combining tp_dealloc with PyType_FromSpec (see issue #16690 for details)

Documentation

- Issue #24458: Update documentation to cover multi-phase initialization for extension modules (PEP 489). Patch by Petr Viktorin.
- Issue #24351: Clarify what is meant by “identifier” in the context of string.Template instances.

Build

- Issue #24432: Update Windows builds and OS X 10.5 installer to use OpenSSL 1.0.2c.
Python 3.5.0 beta 2?

Release date: 2015-05-31

Core and Builtins

- **Issue #24284**: The startswith and endswith methods of the str class no longer return True when finding the empty string and the indexes are completely out of range.
- **Issue #24115**: Update uses of PyObject_IsTrue(), PyObject_Not(), PyObject_IsInstanceOf(), PyObject_RichCompareBool() and _PyDict_Contains() to check for and handle errors correctly.
- **Issue #24328**: Fix importing one character extension modules.
- **Issue #11205**: In dictionary displays, evaluate the key before the value.
- **Issue #24285**: Fixed regression that prevented importing extension modules from inside packages. Patch by Petr Viktorin.

Library

- **Issue #23247**: Fix a crash in the StreamWriter.reset() of CJK codecs.
- **Issue #24270**: Add math.isclose() and cmath.isclose() functions as per PEP 485. Contributed by Chris Barker and Tal Einat.
- **Issue #5633**: Fixed timeit when the statement is a string and the setup is not.
- **Issue #24326**: Fixed audioop.ratecv() with non-default weightB argument. Original patch by David Moore.
- **Issue #16991**: Add a C implementation of OrderedDict.
- **Issue #23934**: Fix inspect.signature to fail correctly for builtin types lacking signature information. Initial patch by James Powell.
Python 3.5.0 beta 1?

Release date: 2015-05-24

Core and Builtins

- **Issue #24276**: Fixed optimization of property descriptor getter.
- **Issue #24268**: PEP 489: Multi-phase extension module initialization. Patch by Petr Viktorin.
- **Issue #23955**: Add pyvenv.cfg option to suppress registry/environment lookup for generating sys.path on Windows.
- **Issue #24257**: Fixed system error in the comparison of faked types.SimpleNamespace.
- **Issue #22939**: Fixed integer overflow in iterator object. Patch by Clement Rouault.
- **Issue #23985**: Fix a possible buffer overrun when deleting a slice from the front of a bytearray and then appending some other bytes data.
- **Issue #24102**: Fixed exception type checking in standard error handlers.
- **Issue #15027**: The UTF-32 encoder is now 3x to 7x faster.
- **Issue #23290**: Optimize set_merge() for cases where the target is empty. (Contributed by Serhiy Storchaka.)
- **Issue #2292**: PEP 448: Additional Unpacking Generalizations.
- **Issue #24096**: Make warnings.warn_explicit more robust against mutation of the warnings.filters list.
- **Issue #23996**: Avoid a crash when a delegated generator raises an unnormalized StopIteration exception. Patch by Stefan Behnel.
- **Issue #23910**: Optimize property() getter calls. Patch by Joe Jevnik.
- **Issue #23911**: Move path-based importhlib bootstrap code to a separate frozen module.
- **Issue #24192**: Fix namespace package imports.
- **Issue #24022**: Fix tokenizer crash when processing undecodable source code.
- **Issue #9951**: Added a hex() method to bytes, bytearray, and memoryview.
- **Issue #22906**: PEP 479: Change StopIteration handling inside generators.
- **Issue #24017**: PEP 492: Coroutines with async and await syntax.

**Library**

- **Issue #14373**: Added C implementation of functools.lru_cache(). Based on patches by Matt Joiner and Alexey Kachayev.
- **Issue #24230**: The tempfile module now accepts bytes for prefix, suffix and dir parameters and returns bytes in such situations (matching the os module APIs).
- **Issue #22189**: collections.UserString now supports __getnewargs__(), __rmod__() , casefold(), format_map(), isprintable(), and maketrans(). Patch by Joe Jevnik.
- **Issue #24244**: Prevents termination when an invalid format string is encountered on Windows in strftime.
- **Issue #23973**: PEP 484: Add the typing module.
- **Issue #23086**: The collections.abc.Sequence() abstract base class added start and stop parameters to the index() mixin. Patch by Devin Jeanpierre.
- **Issue #20035**: Replaced the tkinter._fix module used for setting up the Tcl/Tk environment on Windows with a private function in the _tkinter module that makes no permanent changes to the environment.
- **Issue #24257**: Fixed segmentation fault in sqlite3.Row constructor with faked cursor type.
- **Issue #15836**: assertRaises(), assertRaisesRegex(), assertWarns() and assertWarnsRegex() assertions now check the type of the first argument to prevent possible user error. Based on patch by Daniel Wagner-Hall.
• **Issue #9858**: Add missing method stubs to `_io.RawIOBase`. Patch by Laura Rupprecht.

• **Issue #22955**: `attrgetter`, `itemgetter` and `methodcaller` objects in the `operator` module now support pickling. Added readable and evaluable repr for these objects. Based on patch by Josh Rosenberg.

• **Issue #22107**: `tempfile.gettempdir()` and `tempfile.mkdtemp()` now try again when a directory with the chosen name already exists on Windows as well as on Unix. `tempfile.mkstemp()` now fails early if parent directory is not valid (not exists or is a file) on Windows.

• **Issue #23780**: Improved error message in `os.path.join()` with single argument.

• **Issue #6598**: Increased time precision and random number range in `email.utils.make_msgid()` to strengthen the uniqueness of the message ID.

• **Issue #24091**: Fixed various crashes in corner cases in C implementation of `ElementTree`.

• **Issue #21931**: `msilib.FCICreate()` now raises `TypeError` in the case of a bad argument instead of a `ValueError` with a bogus FCI error number. Patch by Jeffrey Armstrong.

• **Issue #13866**: `quote_via` argument added to `urlib.parse.urlencode`.

• **Issue #20098**: New `mangle_from` policy option for `email`, default `True` for `compat32`, but `False` for all other policies.

• **Issue #24211**: The `email` library now supports RFC 6532: it can generate headers using `utf-8` instead of encoded words.

• **Issue #16314**: Added support for the LZMA compression in `distutils`.

• **Issue #21804**: `poplib` now supports RFC 6856 (`UTF8`).

• **Issue #18682**: Optimized `pprint` functions for `builtin` scalar types.

• **Issue #22027**: `smtplib` now supports RFC 6531 (`SMTPUTF8`).

• **Issue #23488**: Random generator objects now consume 2x less memory on 64-bit.

• **Issue #1322**: `platform.dist()` and `platform.linux_distribution()`
functions are now deprecated. Initial patch by Vajrasky Kok.

- **Issue #22486**: Added the math.gcd() function. The fractions.gcd() function now is deprecated. Based on patch by Mark Dickinson.
- **Issue #24064**: Property() docstrings are now writeable. (Patch by Berker Peksag.)
- **Issue #22681**: Added support for the koi8_t encoding.
- **Issue #22682**: Added support for the kz1048 encoding.
- **Issue #23796**: peek and read1 methods of BufferedReader now raise ValueError if they called on a closed object. Patch by John Hergenroeder.
- **Issue #21795**: smtpd now supports the 8BITMIME extension whenever the new decode_data constructor argument is set to False.
- **Issue #24155**: optimize heapq.heapify() for better cache performance when heapifying large lists.
- **Issue #21800**: imaplib now supports RFC 5161 (enable), RFC 6855 (utf8/internationalized email) and automatically encodes non-ASCII usernames and passwords to UTF8.
- **Issue #20274**: When calling a _sqlite.Connection, it now complains if passed any keyword arguments. Previously it silently ignored them.
- **Issue #20274**: Remove ignored and erroneous “kwargs” parameters from three METH_VARARGS methods on _sqlite.Connection.
- **Issue #24134**: assertRaises(), assertRaisesRegex(), assertWarns() and assertWarnsRegex() checks now emits a deprecation warning when callable is None or keyword arguments except msg is passed in the context manager mode.
- **Issue #24018**: Add a collections.abc.Generator abstract base class. Contributed by Stefan Behnel.
- **Issue #23880**: Tkinter’s getint() and getdouble() now support Tcl_Obj. Tkinter’s getdouble() now supports any numbers (in particular int).
- **Issue #22619**: Added negative limit support in the traceback
module. Based on patch by Dmitry Kazakov.

- **Issue #24094**: Fix possible crash in json.encode with poorly behaved dict subclasses.
- **Issue #9246**: On POSIX, os.getcwdb() now supports paths longer than 1025 bytes. Patch written by William Orr.
- **Issue #17445**: add difflib.diff_bytes() to support comparison of byte strings (fixes a regression from Python 2).
- **Issue #23917**: Fall back to sequential compilation when ProcessPoolExecutor doesn’t exist. Patch by Claudiu Popa.
- **Issue #23008**: Fixed resolving attributes with boolean value is False in pydoc.

Fix asyncio issue 235: LifoQueue and PriorityQueue's put didn’t increment unfinished tasks (this bug was introduced when JoinableQueue was merged with Queue).

- **Issue #23908**: os functions now reject paths with embedded null character on Windows instead of silently truncate them.
- **Issue #23728**: binascii.crc_hqx() could return an integer outside of the range 0-0xffff for empty data.
- **Issue #23887**: urllib.error.HTTPError now has a proper repr() representation. Patch by Berker Peksag.
- **asyncio**: New event loop APIs: set_task_factory() and get_task_factory().
- **asyncio**: async() function is deprecated in favour of ensure_future().
- **Issue #24178**: asyncio.Lock, Condition, Semaphore, and BoundedSemaphore support new ‘async with’ syntax. Contributed by Yury Selivanov.
- **Issue #24184**: Add AsyncIterator and AsyncIterable ABCs to collections.abc. Contributed by Yury Selivanov.
- **Issue #22547**: Implement informative __repr__ for inspect.BoundArguments. Contributed by Yury Selivanov.
- **Issue #24190**: Implement

- **Issue #20691**: Add ‘follow_wrapped’ argument to inspect.Signature.fromCallable() and inspect.signature(). Contributed by Yury Selivanov.
- **Issue #24248**: Deprecate inspect.Signature.from_function() and inspect.Signature.from_builtin().
- **Issue #23898**: Fix inspect.classify_class_attrs() to support attributes with overloaded __eq__ and __bool__. Patch by Mike Bayer.
- **Issue #24298**: Fix inspect.signature() to correctly unwrap wrappers around bound methods.

**IDLE**

- **Issue #23184**: remove unused names and imports in idlelib. Initial patch by Al Sweigart.

**Tests**

- **Issue #21520**: test_zipfile no longer fails if the word ‘bad’ appears anywhere in the name of the current directory.
- **Issue #9517**: Move script_helper into the support package. Patch by Christie Wilson.

**Documentation**

- **Issue #22155**: Add File Handlers subsection with createfilehandler to tkinter doc. Remove obsolete example from FAQ. Patch by Martin Panter.
- **Issue #24029**: Document the name binding behavior for submodule imports.
- **Issue #24077**: Fix typo in man page for -I command option: -s, not
Tools/Demos

- **Issue #24000**: Improved Argument Clinic's mapping of converters to legacy “format units”. Updated the documentation to match.
- **Issue #24001**: Argument Clinic converters now use `accept={type}` instead of `types={'type'}` to specify the types the converter accepts.
- **Issue #23330**: h2py now supports arbitrary filenames in `#include`.
- **Issue #24031**: make patchcheck now supports git checkouts, too.
Python 3.5.0 alpha 4?

Release date: 2015-04-19

Core and Builtins

- **Issue #22980**: Under Linux, GNU/KFreeBSD and the Hurd, C extensions now include the architecture triplet in the extension name, to make it easy to test builds for different ABIs in the same working tree. Under OS X, the extension name now includes PEP 3149-style information.
- **Issue #22631**: Added Linux-specific socket constant CAN_RAW_FD_FRAMES. Patch courtesy of Joe Jevnik.
- **Issue #23731**: Implement PEP 488: removal of .pyo files.
- **Issue #23726**: Don’t enable GC for user subclasses of non-GC types that don’t add any new fields. Patch by Eugene Toder.
- **Issue #23309**: Avoid a deadlock at shutdown if a daemon thread is aborted while it is holding a lock to a buffered I/O object, and the main thread tries to use the same I/O object (typically stdout or stderr). A fatal error is emitted instead.
- **Issue #22977**: Fixed formatting Windows error messages on Wine. Patch by Martin Panter.
- **Issue #23466**: %c, %o, %x, and %X in bytes formatting now raise TypeError on non-integer input.
- **Issue #24044**: Fix possible null pointer dereference in list.sort in out of memory conditions.
- **Issue #21354**: PyCFunction_New function is exposed by python DLL again.

Library

- **Issue #23840**: tokenize.open() now closes the temporary binary
file on error to fix a resource warning.

- **Issue #16914**: new debuglevel 2 in smtplib adds timestamps to debug output.
- **Issue #7159**: urllib.request now supports sending auth credentials automatically after the first 401. This enhancement is a superset of the enhancement from issue #19494 and supersedes that change.
- **Issue #23703**: Fix a regression in urljoin() introduced in 901e4e52b20a. Patch by Demian Brecht.
- **Issue #4254**: Adds _curses.update_lines_cols(). Patch by Arnon Yaari
- **Issue #19933**: Provide default argument for ndigits in round. Patch by Vajrasky Kok.
- **Issue #23342**: Add a subprocess.run() function than returns a CalledProcess instance for a more consistent API than the existing call* functions.
- **Issue #21217**: inspect.getsourcelines() now tries to compute the start and end lines from the code object, fixing an issue when a lambda function is used as decorator argument. Patch by Thomas Ballinger and Allison Kaptur.
- **Issue #24521**: Fix possible integer overflows in the pickle module.
- **Issue #22931**: Allow '[' and ']' in cookie values.
- The keywords attribute of functools.partial is now always a dictionary.
- **Issue #23811**: Add missing newline to the PyCompileError error message. Patch by Alex Shkop.
- **Issue #21116**: Avoid blowing memory when allocating a multiprocessing shared array that's larger than 50% of the available RAM. Patch by Médéric Boquien.
- **Issue #22982**: Improve BOM handling when seeking to multiple positions of a writable text file.
- **Issue #23464**: Removed deprecated asyncio JoinableQueue.
- **Issue #23529**: Limit the size of decompressed data when reading from GzipFile, BZ2File or LZMAFile. This defeats denial of service attacks using compressed bombs (i.e. compressed payloads which decompress to a huge size). Patch by Martin Panter and Nikolaus Rath.
- **Issue #21859**: Added Python implementation of io.FileIO.
- **Issue #23865**: close() methods in multiple modules now are idempotent and more robust at shutdown. If they need to release multiple resources, all are released even if errors occur.
- **Issue #23400**: Raise same exception on both Python 2 and 3 if sem_open is not available. Patch by Davin Potts.
- **Issue #10838**: The subprocess now module includes SubprocessError and TimeoutError in its list of exported names for the users wild enough to use from subprocess import *.
- **Issue #23411**: Added DefragResult, ParseResult, SplitResult, DefragResultBytes, ParseResultBytes, and SplitResultBytes to urllib.parse.__all__. Patch by Martin Panter.
- **Issue #23881**: urllib.request.ftpwrapper constructor now closes the socket if the FTP connection failed to fix a ResourceWarning.
- **Issue #23853**: socket.socket.sendall() does no more reset the socket timeout each time data is sent successfully. The socket timeout is now the maximum total duration to send all data.
- **Issue #22721**: An order of multiline pprint output of set or dict containing orderable and non-orderable elements no longer depends on iteration order of set or dict.
- **Issue #15133**: _tkinter.tkapp.getboolean() now supports Tcl_Obj and always returns bool. tkinter.BooleanVar now validates input values (accepted bool, int, str, and Tcl_Obj). tkinter.BooleanVar.get() now always returns bool.
- **Issue #10590**: xml.sax.parseString() now supports string argument.
- **Issue #23338**: Fixed formatting ctypes error messages on Cygwin. Patch by Makoto Kato.
• **Issue #15582**: inspect.getdoc() now follows inheritance chains.
• **Issue #2175**: SAX parsers now support a character stream of InputSource object.
• **Issue #16840**: Tkinter now supports 64-bit integers added in Tcl 8.4 and arbitrary precision integers added in Tcl 8.5.
• **Issue #23834**: Fix socket.sendto(), use the C Py_ssize_t type to store the result of sendto() instead of the C int type.
• **Issue #23618**: `socket.socket.connect()` now waits until the connection completes instead of raising `InterruptedError` if the connection is interrupted by signals, signal handlers don't raise an exception and the socket is blocking or has a timeout. `socket.socket.connect()` still raise `InterruptedError` for non-blocking sockets.
• **Issue #21526**: Tkinter now supports new boolean type in Tcl 8.5.
• **Issue #23836**: Fix the faulthandler module to handle reentrant calls to its signal handlers.
• **Issue #23838**: linecache now clears the cache and returns an empty result on MemoryError.
• **Issue #10395**: Added `os.path.commonpath()`. Implemented in posixpath and ntpath. Based on patch by Rafik Draoui.
• **Issue #23611**: Serializing more "lookupable" objects (such as unbound methods or nested classes) now are supported with pickle protocols < 4.
• **Issue #13583**: sqlite3.Row now supports slice indexing.
• **Issue #18473**: Fixed 2to3 and 3to2 compatible pickle mappings. Fixed ambiguous reverse mappings. Added many new mappings. Import mapping is no longer applied to modules already mapped with full name mapping.
• **Issue #23485**: `select.select()` is now retried automatically with the recomputed timeout when interrupted by a signal, except if the signal handler raises an exception. This change is part of the PEP 475.
• **Issue #23752**: When built from an existing file descriptor, `io.FileIO()` now only calls `fstat()` once. Before `fstat()` was called
twice, which was not necessary.

- **Issue #23704**: collections.deque() objects now support `__add__`, `__mul__`, and `__imul__()`.
- **Issue #23171**: csv.Writer.writerow() now supports arbitrary iterables.
- **Issue #23745**: The new email header parser now handles duplicate MIME parameter names without error, similar to how `get_param` behaves.
- **Issue #22117**: Fix `os.utime()`, it now rounds the timestamp towards minus infinity (-inf) instead of rounding towards zero.
- **Issue #23310**: Fix MagicMock’s initializer to work with `__methods__`, just like `configure_mock()`. Patch by Kasia Jachim.

**Build**

- **Issue #23817**: FreeBSD now uses “1.0” the the SOVERSION as other operating systems, instead of just “1”.
- **Issue #23501**: Argument Clinic now generates code into separate files by default.

**Tests**

- **Issue #23799**: Added `test.support.start_threads()` for running and cleaning up multiple threads.
- **Issue #22390**: `test.regrtest` now emits a warning if temporary files or directories are left after running a test.

**Tools/Demos**

- **Issue #18128**: pygettext now uses standard +NNNN format in the POT-Creation-Date header.
- **Issue #23935**: Argument Clinic’s understanding of format units accepting bytes, bytearrays, and buffers is now consistent with
both the documentation and the implementation.

- **Issue #23944**: Argument Clinic now wraps long impl prototypes at column 78.
- **Issue #20586**: Argument Clinic now ensures that functions without docstrings have signatures.
- **Issue #23492**: Argument Clinic now generates argument parsing code with `PyArg_Parse` instead of `PyArg_ParseTuple` if possible.
- **Issue #23500**: Argument Clinic is now smarter about generating the “#ifndef” (empty) definition of the methoddef macro: it’s only generated once, even if Argument Clinic processes the same symbol multiple times, and it’s emitted at the end of all processing rather than immediately after the first use.

**C API**

- **Issue #23998**: `PyImport_ReInitLock()` now checks for lock allocation error
Python 3.5.0 alpha 3?

Release date: 2015-03-28

Core and Builtins

- **Issue #23573**: Increased performance of string search operations (str.find, str.index, str.count, the in operator, str.split, str.partition) with arguments of different kinds (UCS1, UCS2, UCS4).
- **Issue #23753**: Python doesn’t support anymore platforms without stat() or fstat(), these functions are always required.
- **Issue #23681**: The -b option now affects comparisons of bytes with int.
- **Issue #23632**: Memoryviews now allow tuple indexing (including for multi-dimensional memoryviews).
- **Issue #23192**: Fixed generator lambdas. Patch by Bruno Cauet.
- **Issue #23629**: Fix the default __sizeof__ implementation for variable-sized objects.

Library

- **Issue #14260**: The groupindex attribute of regular expression pattern object now is non-modifiable mapping.
- **Issue #23792**: Ignore KeyboardInterrupt when the pydoc pager is active. This mimics the behavior of the standard unix pagers, and prevents pipepager from shutting down while the pager itself is still running.
- **Issue #23775**: pprint() of OrderedDict now outputs the same representation as repr().
- **Issue #23765**: Removed IsBadStringPtr calls in ctypes
- **Issue #22364**: Improved some re error messages using regex for hints.
- **Issue #23742**: `ntpath.expandvars()` no longer loses unbalanced single quotes.
- **Issue #21717**: The `zipfile.ZipFile.open` function now supports `x` (exclusive creation) mode.
- **Issue #21802**: The reader in `BufferedRWPair` now is closed even when closing writer failed in `BufferedRWPair.close()`.
- **Issue #23622**: Unknown escapes in regular expressions that consist of `\` and ASCII letter now raise a deprecation warning and will be forbidden in Python 3.6.
- **Issue #23671**: `string.Template` now allows to specify the “self” parameter as keyword argument. `string.Formatter` now allows to specify the “self” and the “format_string” parameters as keyword arguments.
- **Issue #23502**: The `pprint` module now supports mapping proxies.
- **Issue #17530**: `pprint` now wraps long bytes objects and bytearrays.
- **Issue #22687**: Fixed some corner cases in breaking words in `textwrap`. Got rid of quadratic complexity in breaking long words.
- **Issue #4727**: The copy module now uses pickle protocol 4 (PEP 3154) and supports copying of instances of classes whose `__new__` method takes keyword-only arguments.
- **Issue #23491**: Added a `zipapp` module to support creating executable zip file archives of Python code. Registered `.pyz` and `.pyzw` extensions on Windows for these archives (PEP 441).
- **Issue #23657**: Avoid explicit checks for `str` in `zipapp`, adding support for `pathlib.Path` objects as arguments.
- **Issue #23688**: Added support of arbitrary bytes-like objects and avoided unnecessary copying of `memoryview` in `gzip.GzipFile.write()`. Original patch by Wolfgang Maier.
- **Issue #23252**: Added support for writing ZIP files to unseekable streams.
- **Issue #23647**: Increase `impalib`'s `MAXLINE` to accommodate modern mailbox sizes.
- **Issue #23539**: If `body` is None,
http.client.HTTPConnection.request now sets Content-Length to 0 for PUT, POST, and PATCH headers to avoid 411 errors from some web servers.

- **Issue #22351**: The nntplib.NNTP constructor no longer leaves the connection and socket open until the garbage collector cleans them up. Patch by Martin Panter.

- **Issue #23704**: collections.deque() objects now support methods for index(), insert(), and copy(). This allows deques to be registered as a MutableSequence and it improves their substitutability for lists.

- **Issue #23715**: signal.sigwaitinfo() and signal.sigtimedwait() are now retried when interrupted by a signal not in the sigset parameter, if the signal handler does not raise an exception. signal.sigtimedwait() recomputes the timeout with a monotonic clock when it is retried.

- **Issue #23001**: Few functions in modules mmap, ossaudiodev, socket, ssl, and codecs, that accepted only read-only bytes-like object now accept writable bytes-like object too.

- **Issue #23646**: If time.sleep() is interrupted by a signal, the sleep is now retried with the recomputed delay, except if the signal handler raises an exception (PEP 475).

- **Issue #23136**: _strptime now uniformly handles all days in week 0, including Dec 30 of previous year. Based on patch by Jim Carroll.

- **Issue #23700**: Iterator of NamedTemporaryFile now keeps a reference to NamedTemporaryFile instance. Patch by Bohuslav Kabrda.

- **Issue #22903**: The fake test case created by unittest.loader when it fails importing a test module is now picklable.

- **Issue #22181**: On Linux, os.urandom() now uses the new getrandom() syscall if available, syscall introduced in the Linux kernel 3.17. It is more reliable and more secure, because it avoids the need of a file descriptor and waits until the kernel has enough entropy.
- **Issue #2211**: Updated the implementation of the http.cookies.Morsel class. Setting attributes key, value and coded_value directly now is deprecated. update() and setdefault() now transform and check keys. Comparing for equality now takes into account attributes key, value and coded_value. copy() now returns a Morsel, not a dict. repr() now contains all attributes. Optimized checking keys and quoting values. Added new tests. Original patch by Demian Brecht.
- **Issue #18983**: Allow selection of output units in timeit. Patch by Julian Gindi.
- **Issue #23631**: Fix traceback.format_list when a traceback has been mutated.
- **Issue #23568**: Add rdivmod support to MagicMock() objects. Patch by Håkan Lövdahl.
- **Issue #2052**: Add charset parameter to HtmlDiff.make_file().
- **Issue #23668**: Support os.truncate and os.ftruncate on Windows.
- **Issue #23138**: Fixed parsing cookies with absent keys or values in cookiejar. Patch by Demian Brecht.
- **Issue #23051**: multiprocessing.Pool methods imap() and imap_unordered() now handle exceptions raised by an iterator. Patch by Alon Diamant and Davin Potts.
- **Issue #23581**: Add matmul support to MagicMock. Patch by Håkan Lövdahl.
- **Issue #23566**: enable(), register(), dump_traceback() and dump_traceback_later() functions of faulthandler now accept file descriptors. Patch by Wei Wu.
- **Issue #22928**: Disabled HTTP header injections in http.client. Original patch by Demian Brecht.
- **Issue #23615**: Modules bz2, tarfile and tokenize now can be reloaded with imp.reload(). Patch by Thomas Kluyver.
- **Issue #23605**: os.walk() now calls os.scandir() instead of os.listdir(). The usage of os.scandir() reduces the number of calls to os.stat(). Initial patch written by Ben Hoyt.
Build

- **Issue #23585**: make patchcheck will ensure the interpreter is built.

Tests

- **Issue #23583**: Added tests for standard IO streams in IDLE.
- **Issue #22289**: Prevent test_urllib2net failures due to ftp connection timeout.

Tools/Demos

- **Issue #22826**: The result of open() in Tools/ freeze/bkfile.py is now better compatible with regular files (in particular it now supports the context management protocol).
Python 3.5 alpha 2?

Release date: 2015-03-09

Core and Builtins

- **Issue #23571**: PyObject_Call() and PyCFunction_Call() now raise a SystemError if a function returns a result and raises an exception. The SystemError is chained to the previous exception.

Library

- **Issue #22524**: New os.scandir() function, part of the PEP 471: “os.scandir() function – a better and faster directory iterator”. Patch written by Ben Hoyt.
- **Issue #23103**: Reduced the memory consumption of IPv4Address and IPv6Address.
- **Issue #21793**: BaseHTTPRequestHandler again logs response code as numeric, not as stringified enum. Patch by Demian Brecht.
- **Issue #23476**: In the ssl module, enable OpenSSL’s X509_V_FLAG_TRUSTED_FIRST flag on certificate stores when it is available.
- **Issue #23576**: Avoid stalling in SSL reads when EOF has been reached in the SSL layer but the underlying connection hasn’t been closed.
- **Issue #23504**: Added an __all__ to the types module.
- **Issue #23563**: Optimized utility functions in urllib.parse.
- **Issue #7830**: Flatten nested functools.partial.
- **Issue #20204**: Added the __module__ attribute to _tkinter classes.
- **Issue #19980**: Improved help() for non-recognized strings. help('')
now shows the help on str. help('help') now shows the help on help(). Original patch by Mark Lawrence.

- **Issue #23521**: Corrected pure python implementation of timedelta division.

- Eliminated OverflowError from timedelta * float for some floats;
- Corrected rounding in timedelta true division.

- **Issue #21619**: Popen objects no longer leave a zombie after exit in the with statement if the pipe was broken. Patch by Martin Panter.
- **Issue #22936**: Make it possible to show local variables in tracebacks for both the traceback module and unittest.
- **Issue #15955**: Add an option to limit the output size in bz2.decompress(). Patch by Nikolaus Rath.
- **Issue #6639**: Module-level turtle functions no longer raise TclError after closing the window.
- Issues #814253, #9179: Group references and conditional group references now work in lookbehind assertions in regular expressions.
- **Issue #23215**: Multibyte codecs with custom error handlers that ignores errors consumed too much memory and raised SystemError or MemoryError. Original patch by Aleksi Torhamo.
- **Issue #5700**: io.FileIO() called flush() after closing the file. flush() was not called in close() if closefd=False.
- **Issue #23374**: Fixed pydoc failure with non-ASCII files when stdout encoding differs from file system encoding (e.g. on Mac OS).
- **Issue #23481**: Remove RC4 from the SSL module's default cipher list.
- **Issue #21548**: Fix pydoc.synopsis() and pydoc.apropos() on modules with empty docstrings.
- **Issue #22885**: Fixed arbitrary code execution vulnerability in the dbm.dumb module. Original patch by Claudiu Popa.
- **Issue #23239**: `ssl.match_hostname()` now supports matching of IP addresses.
- **Issue #23146**: Fix mishandling of absolute Windows paths with forward slashes in `pathlib`.
- **Issue #23096**: Pickle representation of floats with protocol 0 now is the same for both Python and C implementations.
- **Issue #19105**: `pprint` now more efficiently uses free space at the right.
- **Issue #14910**: Add `allow_abbrev` parameter to `argparse.ArgumentParser`. Patch by Jonathan Paugh, Steven Bethard, paul j3 and Daniel Eriksson.
- **Issue #21717**: `tarfile.open()` now supports ‘x’ (exclusive creation) mode.
- **Issue #23344**: `marshal.dumps()` is now 20-25% faster on average.
- **Issue #20416**: `marshal.dumps()` with protocols 3 and 4 is now 40-50% faster on average.
- **Issue #23421**: Fixed compression in `tarfile` CLI. Patch by wdv4758h.
- **Issue #23367**: Fix possible overflows in the `unicodedata` module.
- **Issue #23361**: Fix possible overflow in Windows subprocess creation code.
- `logging.handlers.QueueListener` now takes a `respect_handler_level` keyword argument which, if set to True, will pass messages to handlers taking handler levels into account.
- **Issue #19705**: `turtledemo` now has a visual sorting algorithm demo. Original patch from Jason Yeo.
- **Issue #23801**: Fix issue where `cgi.FieldStorage` did not always ignore the entire preamble to a multipart body.

### Build

- **Issue #23445**: `pydebug` builds now use “gcc -Og” where possible, to make the resulting executable faster.
- **Issue #23686**: Update OS X 10.5 installer build to use OpenSSL
1.0.2a.

C API

- **Issue #20204**: Deprecation warning is now raised for builtin types without the `__module__` attribute.

Windows

- **Issue #23465**: Implement PEP 486 - Make the Python Launcher aware of virtual environments. Patch by Paul Moore.
- **Issue #23437**: Make user scripts directory versioned on Windows. Patch by Paul Moore.
Python 3.5 alpha 1?

Release date: 2015-02-08

Core and Builtins

- **Issue #23285**: PEP 475 - EINTR handling.
- **Issue #22735**: Fix many edge cases (including crashes) involving custom mro() implementations.
- **Issue #22896**: Avoid using PyObject_AsCharBuffer(), PyObject_AsReadBuffer() and PyObject_AsWriteBuffer().
- **Issue #21295**: Revert some changes (issue #16795) to AST line numbers and column offsets that constituted a regression.
- **Issue #22986**: Allow changing an object's __class__ between a dynamic type and static type in some cases.
- **Issue #15859**: PyUnicode_EncodeFSDefault(), PyUnicode_EncodeMBCS() and PyUnicode_EncodeCodePage() now raise an exception if the object is not an Unicode object. For PyUnicode_EncodeFSDefault(), it was already the case on platforms other than Windows. Patch written by Campbell Barton.
- **Issue #21408**: The default __ne__() now returns NotImplemented if __eq__() returned NotImplemented. Original patch by Martin Panter.
- **Issue #23321**: Fixed a crash in str.decode() when error handler returned replacement string longer than malformed input data.
- **Issue #22286**: The “backslashreplace” error handlers now works with decoding and translating.
- **Issue #23253**: Delay-load ShellExecute[AW] in os.startfile for reduced startup overhead on Windows.
- **Issue #22038**: pyatomic.h now uses stdatomic.h or GCC built-in functions for atomic memory access if available. Patch written by Vitor de Lima and Gustavo Temple.
- **Issue #20284**: %-interpolation (aka printf) formatting added for
issue #23048: fix jumping out of an infinite while loop in the pdb.

issue #20335: bytes constructor now raises TypeError when encoding or errors is specified with non-string argument. Based on patch by Renaud Blanch.

issue #22834: if the current working directory ends up being set to a non-existent directory then import will no longer raise FileNotFoundError.

issue #22869: move the interpreter startup & shutdown code to a new dedicated pylifecycle.c module

issue #22847: improve method cache efficiency.

issue #22335: fix crash when trying to enlarge a bytearray to 0x7fffffff bytes on a 32-bit platform.

issue #22635: fix an assertion failure in debug mode when doing a reentrant dict insertion in debug mode.

issue #22643: fix integer overflow in Unicode case operations (upper, lower, title, swapcase, casefold).

issue #17636: circular imports involving relative imports are now supported.

issue #22604: fix assertion error in debug mode when dividing a complex number by (nan+0j).

issue #21052: do not raise ImportWarning when sys.path_hooks or sys.meta_path are set to None.

issue #16518: use ‘bytes-like object required’ in error messages that previously used the far more cryptic ‘“x” does not support the buffer protocol.

issue #22470: fixed integer overflow issues in “backslashreplace”, “xmlcharrefreplace”, and “surrogatetrans” error handlers.

issue #22540: speed up PyObject_IsInstance and PyObject_IsSubclass in the common case that the second argument has metaclass type.

issue #18711: add a new PyErr_FormatV function, similar to PyErr_Format but accepting a va_list argument.
- **Issue #22520**: Fix overflow checking when generating the repr of a unicode object.
- **Issue #22519**: Fix overflow checking in PyBytes_Repr.
- **Issue #22518**: Fix integer overflow issues in latin-1 encoding.
- **Issue #16324**: __charset parameter of MIMEText now also accepts email.charset.Charset instances. Initial patch by Claude Paroz.
- **Issue #1764286**: Fix inspect.getsource() to support decorated functions. Patch by Claudiu Popa.
- **Issue #18554**: os.__all__ includes posix functions.
- **Issue #21391**: Use os.path.abspath in the shutil module.
- **Issue #11471**: avoid generating a JUMP_FORWARD instruction at the end of an if-block if there is no else-clause. Original patch by Eugene Toder.
- **Issue #22215**: Now ValueError is raised instead of TypeError when str or bytes argument contains not permitted null character or byte.
- **Issue #22258**: Fix the internal function set_inheritable() on Illumos. This platform exposes the function ioctl(FIOCLEX), but calling it fails with errno is ENOTTY: “Inappropriate ioctl for device”. set_inheritable() now falls back to the slower fcntl() (F_GETFD and then F_SETFD).
- **Issue #21389**: Displaying the __qualname__ of the underlying function in the repr of a bound method.
- **Issue #22206**: Using pthread, PyThread_create_key() now sets errno to ENOMEM and returns -1 (error) on integer overflow.
- **Issue #20184**: Argument Clinic based signature introspection added for 30 of the builtin functions.
- **Issue #22116**: C functions and methods (of the ‘builtin_function_or_method’ type) can now be weakref’ed. Patch by Wei Wu.
- **Issue #22077**: Improve index error messages for bytarrays, bytes, lists, and tuples by adding ‘or slices’. Added ‘, not <typename>’ for bytarrays. Original patch by Claudiu Popa.
- **Issue #20179**: Apply Argument Clinic to bytes and bytearray.
Patch by Tal Einat.

- **Issue #22082**: Clear interned strings in slotdefs.
- Upgrade Unicode database to Unicode 7.0.0.
- **Issue #21897**: Fix a crash with the f_locals attribute with closure variables when frame.clear() has been called.
- **Issue #21205**: Add a new __qualname__ attribute to generator, the qualified name, and use it in the representation of a generator (repr(gen)). The default name of the generator (__name__ attribute) is now get from the function instead of the code. Use gen.gi_code.co_name to get the name of the code.
- **Issue #21669**: With the aid of heuristics in SyntaxError.__init__, the parser now attempts to generate more meaningful (or at least more search engine friendly) error messages when “exec” and “print” are used as statements.
- **Issue #21642**: In the conditional if-else expression, allow an integer written with no space between itself and the else keyword (e.g. True if 42else False) to be valid syntax.
- **Issue #21523**: Fix over-pessimistic computation of the stack effect of some opcodes in the compiler. This also fixes a quadratic compilation time issue noticeable when compiling code with a large number of “and” and “or” operators.
- **Issue #21418**: Fix a crash in the builtin function super() when called without argument and without current frame (ex: embedded Python).
- **Issue #21425**: Fix flushing of standard streams in the interactive interpreter.
- **Issue #21435**: In rare cases, when running finalizers on objects in cyclic trash a bad pointer dereference could occur due to a subtle flaw in internal iteration logic.
- **Issue #21377**: PyBytes_Concat() now tries to concatenate in-place when the first argument has a reference count of 1. Patch by Nikolaus Rath.
- **Issue #20355**: -W command line options now have higher priority than the PYTHONWARNINGS environment variable. Patch by
Arfrever.

- **Issue #21274**: Define PATH_MAX for GNU/Hurd in Python/pythonrun.c.
- **Issue #20904**: Support setting FPU precision on m68k.
- **Issue #21209**: Fix sending tuples to custom generator objects with the yield from syntax.
- **Issue #21193**: pow(a, b, c) now raises ValueError rather than TypeError when b is negative. Patch by Josh Rosenberg.
- **PEP 465 and Issue #21176**: Add the ‘@’ operator for matrix multiplication.
- **Issue #21134**: Fix segfault when str is called on an uninitialized UnicodeEncodeError, UnicodeDecodeError, or UnicodeTranslateError object.
- **Issue #19537**: Fix PyUnicode_DATA() alignment under m68k. Patch by Andreas Schwab.
- **Issue #20929**: Add a type cast to avoid shifting a negative number.
- **Issue #20731**: Properly position in source code files even if they are opened in text mode. Patch by Serhiy Storchaka.
- **Issue #20637**: Key-sharing now also works for instance dictionaries of subclasses. Patch by Peter Ingebretson.
- **Issue #8297**: Attributes missing from modules now include the module name in the error text. Original patch by ysj.ray.
- **Issue #19995**: %c, %o, %x, and %X now raise TypeError on non-integer input.
- **Issue #19655**: The ASDL parser - used by the build process to generate code for managing the Python AST in C - was rewritten. The new parser is self contained and does not require to carry long the spark.py parser-generator library; spark.py was removed from the source base.
- **Issue #12546**: Allow \x00 to be used as a fill character when using str, int, float, and complex __format__ methods.
- **Issue #20480**: Add ipaddress.reverse_pointer. Patch by Leon Weber.
- **Issue #13598**: Modify string.Formatter to support auto-numbering of replacement fields. It now matches the behavior of str.format() in this regard. Patches by Phil Elson and Ramchandra Apte.
- **Issue #8931**: Make alternate formatting ('#') for type 'c' raise an exception. In versions prior to 3.5, '#' with 'c' had no effect. Now specifying it is an error. Patch by Torsten Landschoff.
- **Issue #23165**: Perform overflow checks before allocating memory in the _Py_char2wchar function.

**Library**

- **Issue #23399**: pyvenv creates relative symlinks where possible.
- **Issue #20289**: cgi.FieldStorage() now supports the context management protocol.
- **Issue #13128**: Print response headers for CONNECT requests when debuglevel > 0. Patch by Demian Brecht.
- **Issue #15381**: Optimized io.BytesIO to make less allocations and copyings.
- **Issue #22818**: Splitting on a pattern that could match an empty string now raises a warning. Patterns that can only match empty strings are now rejected.
- **Issue #23099**: Closing io.BytesIO with exported buffer is rejected now to prevent corrupting exported buffer.
- **Issue #23326**: Removed __ne__ implementations. Since fixing default __ne__ implementation in issue #21408 they are redundant.
- **Issue #23363**: Fix possible overflow in itertools.permutations.
- **Issue #23364**: Fix possible overflow in itertools.product.
- **Issue #23366**: Fixed possible integer overflow in itertools.combinations.
- **Issue #23369**: Fixed possible integer overflow in _json.encode_basestring_ascii.
- **Issue #23353**: Fix the exception handling of generators in PyEval_EvalFrameEx(). At entry, save or swap the exception
state even if PyEval_EvalFrameEx() is called with throwflag=0. At exit, the exception state is now always restored or swapped, not only if why is WHY_YIELD or WHY_RETURN. Patch co-written with Antoine Pitrou.

- **Issue #14099**: Restored support of writing ZIP files to tellable but non-Seekable streams.
- **Issue #14099**: Writing to ZipFile and reading multiple ZipExtFiles is threadsafe now.
- **Issue #19361**: JSON decoder now raises JSONDecodeError instead of ValueError.
- **Issue #18518**: timeit now rejects statements which can’t be compiled outside a function or a loop (e.g. “return” or “break”).
- **Issue #23094**: Fixed readline with frames in Python implementation of pickle.
- **Issue #23268**: Fixed bugs in the comparison of ipaddress classes.
- **Issue #21408**: Removed incorrect implementations of __ne__() which didn’t returned NotImplemented if __eq__() returned NotImplemented. The default __ne__() now works correctly.
- **Issue #19996**: email.feedparser.FeedParser now handles (malformed) headers with no key rather than assuming the body has started.
- **Issue #20188**: Support Application-Layer Protocol Negotiation (ALPN) in the ssl module.
- **Issue #23133**: Pickling of ipaddress objects now produces more compact and portable representation.
- **Issue #23248**: Update ssl error codes from latest OpenSSL git master.
- **Issue #23266**: Much faster implementation of ipaddress.collapse_addresses() when there are many non-consecutive addresses.
- **Issue #23098**: 64-bit dev_t is now supported in the os module.
- **Issue #21817**: When an exception is raised in a task submitted to a ProcessPoolExecutor, the remote traceback is now displayed in the parent process. Patch by Claudiu Popa.
- **Issue #15955**: Add an option to limit output size when decompressing LZMA data. Patch by Nikolaus Rath and Martin Panter.
- **Issue #23250**: In the http.cookies module, capitalize “HttpOnly” and “Secure” as they are written in the standard.
- **Issue #23063**: In the disutils’ check command, fix parsing of reST with code or code-block directives.
- **Issue #23209, #23225**: selectors.BaseSelector.get_key() now raises a RuntimeError if the selector is closed. And selectors.BaseSelector.close() now clears its internal reference to the selector mapping to break a reference cycle. Initial patch written by Martin Richard.
- **Issue #17911**: Provide a way to seed the linecache for a PEP-302 module without actually loading the code.
- **Issue #17911**: Provide a new object API for traceback, including the ability to not lookup lines at all until the traceback is actually rendered, without any trace of the original objects being kept alive.
- **Issue #19777**: Provide a home() classmethod on Path objects. Contributed by Victor Salgado and Mayank Tripathi.
- **Issue #23206**: Make json.dumps(..., ensure_ascii=False) as fast as the default case of ensure_ascii=True. Patch by Naoki Inada.
- **Issue #23185**: Add math.inf and math.nan constants.
- **Issue #23186**: Add ssl.SSLObject.shared_ciphers() and ssl.SSLSocket.shared_ciphers() to fetch the client's list ciphers sent at handshake.
- **Issue #23143**: Remove compatibility with OpenSSLs older than 0.9.8.
- **Issue #23132**: Improve performance and introspection support of comparison methods created by functool.total_ordering.
- **Issue #19776**: Add an expanduser() method on Path objects.
- **Issue #23112**: Fix SimpleHTTPServer to correctly carry the query string and fragment when it redirects to add a trailing slash.
- **Issue #21793**: Added `http.HTTPStatus` enums (i.e. `HTTPStatus.OK`, `HTTPStatus.NOT_FOUND`). Patch by Demian Brecht.
- **Issue #23093**: In the `io` module allow more operations to work on detached streams.
- **Issue #23111**: In the `ftplib`, make `ssl.PROTOCOL_SSLv23` the default protocol version.
- **Issue #22585**: On OpenBSD 5.6 and newer, `os.urandom()` now calls `getentropy()`, instead of reading `/dev/urandom`, to get pseudo-random bytes.
- **Issue #19104**: `pprint` now produces evaluable output for wrapped strings.
- **Issue #23071**: Added missing names to `codecs.__all__`. Patch by Martin Panter.
- **Issue #22783**: Pickling now uses the `NEWOBJ` opcode instead of the `NEWOBJ_EX` opcode if possible.
- **Issue #15513**: Added a `__sizeof__` implementation for pickle classes.
- **Issue #19858**: `pickletools.optimize()` now aware of the `MEMOIZE` opcode, can produce more compact result and no longer produces invalid output if input data contains `MEMOIZE` opcodes together with `PUT` or `BINPUT` opcodes.
- **Issue #22095**: Fixed `HTTPConnection.set_tunnel` with default port. The port value in the host header was set to “None”. Patch by Demian Brecht.
- **Issue #23016**: A warning no longer produces an `AttributeError` when the program is run with `pythonw.exe`.
- **Issue #21775**: `shutil.copytree()`: fix crash when copying to VFAT. An exception handler assumed that that `OSERROR` objects always have a ‘winerror’ attribute. That is not the case, so the exception handler itself raised `AttributeError` when run on Linux (and, presumably, any other non-Windows OS). Patch by Greg Ward.
- **Issue #1218234**: Fix `inspect.getsource()` to load updated source of reloaded module. Initial patch by Berker Peksag.
- **Issue #21740**: Support wrapped callables in doctest. Patch by Claudiu Popa.
- **Issue #23009**: Make sure selectors.EpollSelector.select() works when no FD is registered.
- **Issue #22959**: In the constructor of http.client.HTTPSConnection, prefer the context’s check_hostname attribute over the check_hostname parameter.
- **Issue #22696**: Add function `sys.is_finalizing()` to know about interpreter shutdown.
- **Issue #16043**: Add a default limit for the amount of data xmlrpc.lib.gzip_decode will return. This resolves CVE-2013-1753.
- **Issue #14099**: ZipFile.open() no longer reopen the underlying file. Objects returned by ZipFile.open() can now operate independently of the ZipFile even if the ZipFile was created by passing in a file-like object as the first argument to the constructor.
- **Issue #22966**: Fix `__pycache__` pyc file name clobber when pyc_compile is asked to compile a source file containing multiple dots in the source file name.
- **Issue #21971**: Update turtledemo doc and add module to the index.
- **Issue #21032**: Fixed socket leak if HTTPConnection.getresponse() fails. Original patch by Martin Panter.
- **Issue #22407**: Deprecated the use of re.LOCALE flag with str patterns or re.ASCII. It was newer worked.
- **Issue #22902**: The “ip” command is now used on Linux to determine MAC address in uuid.getnode(). Patch by Bruno Cauet.
- **Issue #22960**: Add a context argument to xmlrpclib.ServerProxy constructor.
- **Issue #22389**: Add contextlib.redirect_stderr().
- **Issue #21356**: Make ssl.RAND_egd() optional to support LibreSSL. The availability of the function is checked during the compilation. Patch written by Bernard Spil.
- **Issue #22915**: SAX parser now supports files opened with file
descriptor or bytes path.

- **Issue #22609**: Constructors and update methods of mapping classes in the collections module now accept the self keyword argument.
- **Issue #22940**: Add readline.append_history_file.
- **Issue #19676**: Added the “namereplace” error handler.
- **Issue #22788**: Add `context` parameter to logging.handlers.HTTPHandler.
- **Issue #22921**: Allow SSLContext to take the `hostname` parameter even if OpenSSL doesn’t support SNI.
- **Issue #22894**: `TestCase.subTest()` would cause the test suite to be stopped when in failfast mode, even in the absence of failures.
- **Issue #22796**: HTTP cookie parsing is now stricter, in order to protect against potential injection attacks.
- **Issue #22370**: Windows detection in pathlib is now more robust.
- **Issue #22841**: Reject coroutines in asyncio add_signal_handler(). Patch by Ludovic.Gasc.
- **Issue #19494**: Added urllib.request.HTTPBasicPriorAuthHandler. Patch by Matej Cepl.
- **Issue #22578**: Added attributes to the re.error class.
- **Issue #22849**: Fix possible double free in the io.TextIOWrapper constructor.
- **Issue #12728**: Different Unicode characters having the same uppercase but different lowercase are now matched in case-insensitive regular expressions.
- **Issue #22821**: Fixed fcntl() with integer argument on 64-bit big-endian platforms.
- **Issue #21650**: Add an `-sort-keys` option to json.tool CLI.
- **Issue #22824**: Updated reprlib output format for sets to use set literals. Patch contributed by Berker Peksag.
- **Issue #22824**: Updated reprlib output format for arrays to display empty arrays without an unnecessary empty list. Suggested by Serhiy Storchaka.
- **Issue #22406**: Fixed the uu_codec codec incorrectly ported to 3.x.
Based on patch by Martin Panter.

- **Issue #17293**: `uuid.getnode()` now determines MAC address on AIX using `netstat`. Based on patch by Aivars Kalvāns.
- **Issue #22769**: Fixed `ttk.Treeview.tag_has()` when called without arguments.
- **Issue #22417**: Verify certificates by default in `httplib` (PEP 476).
- **Issue #22775**: Fixed unpickling of `http.cookies.SimpleCookie` with protocol 2 and above. Patch by Tim Graham.
- **Issue #22776**: Brought excluded code into the scope of a try block in `SysLogHandler.emit()`.
- **Issue #22665**: Add missing `get_terminal_size` and `SameFileError` to `shutil.__all__`.
- **Issue #6623**: Remove deprecated `Netrc` class in the `ftplib` module. Patch by Matt Chaput.
- **Issue #17381**: Fixed handling of case-insensitive ranges in regular expressions.
- **Issue #22410**: Module level functions in the `re` module now cache compiled locale-dependent regular expressions taking into account the locale.
- **Issue #22759**: Query methods on `pathlib.Path()` (`exists()`, `is_dir()`, etc.) now return False when the underlying `stat` call raises `NotADirectoryError`.
- **Issue #8876**: `distutils` now falls back to copying files when hard linking doesn’t work. This allows use with special filesystems such as VirtualBox shared folders.
- **Issue #22217**: Implemented reprs of classes in the `zipfile` module.
- **Issue #22457**: Honour `load_tests` in the `start_dir` of discovery.
- **Issue #18216**: `gettext` now raises an error when a `.mo` file has an unsupported major version number. Patch by Aaron Hill.
- **Issue #13918**: Provide a `locale.delocalize()` function which can remove locale-specific number formatting from a string representing a number, without then converting it to a specific type. Patch by Cédric Krier.
- **Issue #22676**: Make the pickling of global objects which don’t
have a __module__ attribute less slow.

- **Issue #18853**: Fixed ResourceWarning in shlex.__nain__.
- **Issue #9351**: Defaults set with set_defaults on an argparse subparser are no longer ignored when also set on the parent parser.
- **Issue #7559**: unittest test loading ImportErrors are reported as import errors with their import exception rather than as attribute errors after the import has already failed.
- **Issue #19746**: Make it possible to examine the errors from unittest discovery without executing the test suite. The new errors attribute on TestLoader exposes these non-fatal errors encountered during discovery.
- **Issue #21991**: Make email.headerregistry's header ‘params’ attributes be read-only (MappingProxyType). Previously the dictionary was modifiable but a new one was created on each access of the attribute.
- **Issue #22638**: SSLv3 is now disabled throughout the standard library. It can still be enabled by instantiating a SSLContext manually.
- **Issue #22641**: In asyncio, the default SSL context for client connections is now created using ssl.create_default_context(), for stronger security.
- **Issue #17401**: Include closefd in io.FileIO repr.
- **Issue #21338**: Add silent mode for compileall. quiet parameters of compile_{dir, file, path} functions now have a multilevel value. Also, -q option of the CLI now have a multilevel value. Patch by Thomas Kluyver.
- **Issue #20152**: Convert the array and cmath modules to Argument Clinic.
- **Issue #18643**: Add socket.socketpair() on Windows.
- **Issue #22435**: Fix a file descriptor leak when SocketServer bind fails.
- **Issue #13096**: Fixed segfault in CTYPES POINTER handling of large values.
• **Issue #11694**: Raise ConversionError in xdrlib as documented. Patch by Filip Gruszczynski and Claudiu Popa.
• **Issue #19380**: Optimized parsing of regular expressions.
• **Issue #1519638**: Now unmatched groups are replaced with empty strings in re.sub() and re.subn().
• **Issue #18615**: sndhdr.what/whathdr now return a namedtuple.
• **Issue #22462**: Fix pyexpat's creation of a dummy frame to make it appear in exception tracebacks.
• **Issue #21965**: Add support for in-memory SSL to the ssl module. Patch by Geert Jansen.
• **Issue #21173**: Fix len() on a WeakKeyDictionary when .clear() was called with an iterator alive.
• **Issue #11866**: Eliminated race condition in the computation of names for new threads.
• **Issue #21905**: Avoid RuntimeError in pickle.whichmodule() when sys.modules is mutated while iterating. Patch by Olivier Grisel.
• **Issue #11271**: concurrent.futures.Executor.map() now takes a chunksize argument to allow batching of tasks in child processes and improve performance of ProcessPoolExecutor. Patch by Dan O'Reilly.
• **Issue #21883**: os.path.join() and os.path.relpath() now raise a TypeError with more helpful error message for unsupported or mismatched types of arguments.
• **Issue #22219**: The zipfile module CLI now adds entries for directories (including empty directories) in ZIP file.
• **Issue #22449**: In the ssl.SSLContext.load_default_certs, consult the environmental variables SSL_CERT_DIR and SSL_CERT_FILE on Windows.
• **Issue #22508**: The email.__version__ variable has been removed; the email code is no longer shipped separately from the stdlib, and __version__ hasn’t been updated in several releases.
• **Issue #20076**: Added non derived UTF-8 aliases to locale aliases table.
• **Issue #20079**: Added locales supported in glibc 2.18 to locale
- **Issue #20218**: Added convenience methods `read_text/write_text` and `read_bytes/write_bytes` to `pathlib.Path` objects.
- **Issue #22437**: Number of capturing groups in regular expression is no longer limited by 100.
- **Issue #17442**: `InteractiveInterpreter` now displays the full chained traceback in its `showtraceback` method, to match the built in interactive interpreter.
- **Issue #23392**: Added tests for marshal C API that works with FILE*.
- **Issue #10510**: `distutils` register and upload methods now use HTML standards compliant CRLF line endings.
- **Issue #9850**: Fixed `macpath.join()` for empty first component. Patch by Oleg Oshmyan.
- **Issue #5309**: `distutils`’s `build` and `build_ext` commands now accept a `-j` option to enable parallel building of extension modules.
- **Issue #22448**: Improve canceled timer handles cleanup to prevent unbound memory usage. Patch by Joshua Moore-Oliva.
- **Issue #22427**: `TemporaryDirectory` no longer attempts to clean up twice when used in the with statement in generator.
- **Issue #22362**: Forbidden ambiguous octal escapes out of range 0-0o377 in regular expressions.
- **Issue #20912**: Now directories added to ZIP file have correct Unix and MS-DOS directory attributes.
- **Issue #21866**: `ZipFile.close()` no longer writes ZIP64 central directory records if `allowZip64` is false.
- **Issue #22278**: Fix `urljoin` problem with relative urls, a regression observed after changes to `issue22118` were submitted.
- **Issue #22415**: Fixed debugging output of the `GROUPREF_EXISTS` opcode in the `re` module. Removed trailing spaces in debugging output.
- **Issue #22423**: Unhandled exception in thread no longer causes unhandled `AttributeError` when `sys.stderr` is None.
- **Issue #21332**: Ensure that `bufsize=1` in `subprocess.Popen()`
selects line buffering, rather than block buffering. Patch by Akira Li.

- **Issue #21091**: Fix API bug: email.message.EmailMessage.is_attachment is now a method.
- **Issue #21079**: Fix email.message.EmailMessage.is_attachment to return the correct result when the header has parameters as well as a value.
- **Issue #22247**: Add NNTPError to nntplib.__all__.
- **Issue #22366**: urllib.request.urlopen will accept a context object (SSLContext) as an argument which will then used be for HTTPS connection. Patch by Alex Gaynor.
- **Issue #4180**: The warnings registries are now reset when the filters are modified.
- **Issue #22419**: Limit the length of incoming HTTP request in wsgiref server to 65536 bytes and send a 414 error code for higher lengths. Patch contributed by Devin Cook.
- **Lax cookie parsing in http.cookies could be a security issue when combined with non-standard cookie handling in some Web browsers. Reported by Sergey Bobrov.**
- **Issue #20537**: logging methods now accept an exception instance as well as a Boolean value or exception tuple. Thanks to Yury Selivanov for the patch.
- **Issue #22384**: An exception in Tkinter callback no longer crashes the program when it is run with pythonw.exe.
- **Issue #22168**: Prevent turtle AttributeError with non-default Canvas on OS X.
- **Issue #21147**: sqlite3 now raises an exception if the request contains a null character instead of truncate it. Based on patch by Victor Stinner.
- **Issue #13968**: The glob module now supports recursive search in subdirectories using the "**" pattern.
- **Issue #21951**: Fixed a crash in Tkinter on AIX when called Tcl command with empty string or tuple argument.
- **Issue #21951**: Tkinter now most likely raises MemoryError instead
of crash if the memory allocation fails.

- **Issue #22338**: Fix a crash in the json module on memory allocation failure.
- **Issue #12410**: imaplib.IMAP4 now supports the context management protocol. Original patch by Tarek Ziadé.
- **Issue #21270**: We now override tuple methods in mock.call objects so that they can be used as normal call attributes.
- **Issue #16662**: load_tests() is now unconditionally run when it is present in a package’s __init__.py. TestLoader.loadTestsFromModule() still accepts use_load_tests, but it is deprecated and ignored. A new keyword-only attribute pattern is added and documented. Patch given by Robert Collins, tweaked by Barry Warsaw.
- **Issue #22226**: First letter no longer is stripped from the “status” key in the result of Treeview.heading().
- **Issue #19524**: Fixed resource leak in the HTTP connection when an invalid response is received. Patch by Martin Panter.
- **Issue #20421**: Add a .version() method to SSL sockets exposing the actual protocol version in use.
- **Issue #19546**: configparser exceptions no longer expose implementation details. Chained KeyErrors are removed, which leads to cleaner tracebacks. Patch by Claudiu Popa.
- **Issue #22051**: turtledemo no longer reloads examples to re-run them. Initialization of variables and gui setup should be done in main(), which is called each time a demo is run, but not on import.
- **Issue #21933**: Turtledemo users can change the code font size with a menu selection or control(command) ‘-‘ or ‘+’ or control-mousewheel. Original patch by Lita Cho.
- **Issue #21597**: The separator between the turtledemo text pane and the drawing canvas can now be grabbed and dragged with a mouse. The code text pane can be widened to easily view or copy the full width of the text. The canvas can be widened on small screens. Original patches by Jan Kanis and Lita Cho.
- **Issue #18132**: Turtledemo buttons no longer disappear when the
window is shrunk. Original patches by Jan Kanis and Lita Cho.

- **Issue #22043**: time.monotonic() is now always available. threading.Lock.acquire(), threading.RLock.acquire() and socket operations now use a monotonic clock, instead of the system clock, when a timeout is used.

- **Issue #21527**: Add a default number of workers to ThreadPoolExecutor equal to 5 times the number of CPUs. Patch by Claudiu Popa.

- **Issue #22216**: smtplib now resets its state more completely after a quit. The most obvious consequence of the previous behavior was a STARTTLS failure during a connect/starttls/quit/connect/starttls sequence.

- **Issue #22098**: ctypes’ BigEndianStructure and LittleEndianStructure now define an empty __slots__ so that subclasses don’t always get an instance dict. Patch by Claudiu Popa.

- **Issue #22185**: Fix an occasional RuntimeError in threading.Condition.wait() caused by mutation of the waiters queue without holding the lock. Patch by Doug Zongker.

- **Issue #22287**: On UNIX, _PyTime_gettimeofday() now uses clock_gettime(CLOCK_REALTIME) if available. As a side effect, Python now depends on the librt library on Solaris and on Linux (only with glibc older than 2.17).

- **Issue #22182**: Use e.args to unpack exceptions correctly in distutils.file_util.move_file. Patch by Claudiu Popa.

- The webbrowser module now uses subprocess’s start_new_session=True rather than a potentially risky preexec_fn=os.setsid call.

- **Issue #22042**: signal.set_wakeup_fd(fd) now raises an exception if the file descriptor is in blocking mode.

- **Issue #16808**: inspect.stack() now returns a named tuple instead of a tuple. Patch by Daniel Shahaf.

- **Issue #22236**: Fixed Tkinter images copying operations in
NoDefaultRoot mode.

- **Issue #2527**: Add a `globals` argument to `timeit` functions, in order to override the `globals` namespace in which the timed code is executed. Patch by Ben Roberts.
- **Issue #22118**: Switch `urllib.parse` to use RFC 3986 semantics for the resolution of relative URLs, rather than RFCs 1808 and 2396. Patch by Demian Brecht.
- **Issue #21549**: Added the “members” parameter to `TarFile.list()`.
- **Issue #19628**: Allow `compileall` recursion depth to be specified with a `-r` option.
- **Issue #15696**: Add a `__sizeof__` implementation for `mmap` objects on Windows.
- **Issue #22068**: Avoided reference loops with Variables and Fonts in Tkinter.
- **Issue #22165**: `SimpleHTTPRequestHandler` now supports undecodable file names.
- **Issue #15381**: Optimized line reading in `io.BytesIO`.
- **Issue #8797**: Raise `HTTPError` on failed Basic Authentication immediately. Initial patch by Sam Bull.
- **Issue #20729**: Restored the use of lazy `iterkeys()`/`itervalues()`/`iteritems()` in the `mailbox` module.
- **Issue #21448**: Changed `FeedParser feed()` to avoid `O(N**2)` behavior when parsing long line. Original patch by Raymond Hettinger.
- **Issue #22184**: The `functools LRU Cache` decorator factory now gives an earlier and clearer error message when the user forgets the required parameters.
- **Issue #17923**: `glob()` patterns ending with a slash no longer match non-dirs on AIX. Based on patch by Delhallt.
- **Issue #21725**: Added support for RFC 6531 (SMTPUTF8) in `smtpd`.
- **Issue #22176**: Update the `ctypes` module’s `libffi` to v3.1. This release adds support for the Linux AArch64 and POWERPC ELF ABIv2 little-endian architectures.
- **Issue #5411**: Added support for the “xztar” format in the shutil module.
- **Issue #21121**: Don’t force 3rd party C extensions to be built with -Werror=declaration-after-statement.
- **Issue #20170**: Convert posixmodule to use Argument Clinic.
- **Issue #21539**: Add an exists_ok argument to Pathlib.mkdir() to mimic mkdir -p and os.makedirs() functionality. When true, ignore FileExistsErrors. Patch by Berker Peksag.
- **Issue #22127**: Bypass IDNA for pure-ASCII host names in the socket module (in particular for numeric IPs).
- **Issue #21047**: set the default value for the convert_charrefs argument of HTMLParser to True. Patch by Berker Peksag.
- **Issue #22127**: Bypass IDNA for pure-ASCII host names in the socket module (in particular for numeric IPs).
- **Issue #21047**: set the default value for the convert_charrefs argument of HTMLParser to True. Patch by Berker Peksag.
- **Issue #22003**: When initialized from a bytes object, io.BytesIO() now defers making a copy until it is mutated, improving performance and memory use on some use cases. Patch by David Wilson.
- **Issue #22018**: On Windows, signal.set_wakeup_fd() now also supports sockets. A side effect is that Python depends to the WinSock library.
- **Issue #22054**: Add os.get_blocking() and os.set_blocking() functions to get and set the blocking mode of a file descriptor (False if the O_NONBLOCK flag is set, True otherwise). These functions are not available on Windows.
• **Issue #17172**: Make turtledemo start as active on OS X even when run with subprocess. Patch by Lita Cho.

• **Issue #21704**: Fix build error for _multiprocessing when semaphores are not available. Patch by Arfrever Frehtes Taifersar Arahesis.

• **Issue #20173**: Convert sha1, sha256, sha512 and md5 to ArgumentClinic. Patch by Vajrasky Kok.

• Fix repr(_socket.socket) on Windows 64-bit: don’t fail with OverflowError on closed socket. repr(socket.socket) already works fine.

• **Issue #22033**: Reprs of most Python implemenened classes now contain actual class name instead of hardcoded one.

• **Issue #21947**: The dis module can now disassemble generator-iterator objects based on their gi_code attribute. Patch by Clement Rouault.

• **Issue #16133**: The asynchat.async_chat.handle_read() method now ignores BlockingIOError exceptions.

• **Issue #22044**: Fixed premature DECREF in call_tzinfo_method. Patch by Tom Flanagan.

• **Issue #19884**: readline: Disable the meta modifier key if stdout is not a terminal to not write the ANSI sequence "\033[1034h" into stdout. This sequence is used on some terminal (ex: TERM=xterm-256color") to enable support of 8 bit characters.

• **Issue #4350**: Removed a number of out-of-dated and non-working for a long time Tkinter methods.

• **Issue #6167**: Scrollbar.activate() now returns the name of active element if the argument is not specified. Scrollbar.set() now always accepts only 2 arguments.

• **Issue #15275**: Clean up and speed up the ntpath module.

• **Issue #21888**: plistlib’s load() and loads() now work if the fmt parameter is specified.

• **Issue #22032**: __qualname__ instead of __name__ is now always used to format fully qualified class names of Python implemented classes.
• **Issue #22031**: Reprs now always use hexadecimal format with the "0x" prefix when contain an id in form " at 0x...".
• **Issue #22018**: signal.set_wakeup_fd() now raises an OSError instead of a ValueError on fstat() failure.
• **Issue #21044**: tarfile.open() now handles fileobj with an integer 'name' attribute. Based on patch by Antoine Pietri.
• **Issue #21966**: Respect -q command-line option when code module is ran.
• **Issue #19076**: Don't pass the redundant 'file' argument to self.error().
• **Issue #16382**: Improve exception message of warnings.warn() for bad category. Initial patch by Phil Elson.
• **Issue #21932**: os.read() now uses a Py_ssize_t() type instead of int for the size to support reading more than 2 GB at once. On Windows, the size is truncated to INT_MAX. As any call to os.read(), the OS may read less bytes than the number of requested bytes.
• **Issue #21942**: Fixed source file viewing in pydoc's server mode on Windows.
• **Issue #11259**: asynchat.async_chat().set_terminator() now raises a ValueError if the number of received bytes is negative.
• **Issue #12523**: asynchat.async_chat.push() now raises a TypeError if it doesn't get a bytes string.
• **Issue #21707**: Add missing kwonlyargcount argument to ModuleFinder.replace_paths_in_code().
• **Issue #20639**: calling Path.with_suffix("") allows removing the suffix again. Patch by July Tikhonov.
• **Issue #21714**: Disallow the construction of invalid paths using Path.with_name(). Original patch by Antony Lee.
• **Issue #15014**: Added 'auth' method to smtplib to make implementing auth mechanisms simpler, and used it internally in the login method.
• **Issue #21151**: Fixed a segfault in the winreg module when None is passed as a REG_BINARY value to SetValueEx. Patch by John
Ehresman.

- **Issue #21090**: `io.FileIO.readall()` does not ignore I/O errors anymore. Before, it ignored I/O errors if at least the first C call `read()` succeed.
- **Issue #5800**: headers parameter of `wsgiref.headers.Headers` is now optional. Initial patch by Pablo Torres Navarrete and SilentGhost.
- **Issue #21781**: `ssl.RAND_add()` now supports strings longer than 2 GB.
- **Issue #21679**: Prevent extraneous `fstat()` calls during `open()`. Patch by Bohuslav Kabrda.
- **Issue #21863**: cProfile now displays the module name of C extension functions, in addition to their own name.
- **Issue #11453**: asyncore: emit a `ResourceWarning` when an unclosed file_wrapper object is destroyed. The destructor now closes the file if needed. The `close()` method can now be called twice: the second call does nothing.
- **Issue #21858**: Better handling of Python exceptions in the `sqlite3` module.
- **Issue #21476**: Make sure the `email.parser.BytesParser.TextIOWrapper` is discarded after parsing, so the input file isn't unexpectedly closed.
- **Issue #20295**: `imghdr` now recognizes OpenEXR format images.
- **Issue #21729**: Used the “with” statement in the `dbm.dumb` module to ensure files closing. Patch by Claudiu Popa.
- **Issue #21491**: socketserver: Fix a race condition in child processes reaping.
- **Issue #21719**: Added the `st_file_attributes` field to `os.stat_result` on Windows.
- **Issue #21832**: Require named tuple inputs to be exact strings.
- **Issue #21722**: The distutils “upload” command now exits with a non-zero return code when uploading fails. Patch by Martin Dengler.
- **Issue #21723**: `asyncio.Queue`: support any type of number (ex:
float) for the maximum size. Patch written by Vajrasky Kok.

- **Issue #21711**: support for “site-python” directories has now been removed from the site module (it was deprecated in 3.4).
- **Issue #17552**: new socket.sendfile() method allowing to send a file over a socket by using high-performance os.sendfile() on UNIX. Patch by Giampaolo Rodola’.
- **Issue #18039**: dbm.dump.open() now always creates a new database when the flag has the value ‘n’. Patch by Claudiu Popa.
- **Issue #21326**: Add a new is_closed() method to asyncio.BaseEventLoop. run_forever() and run_until_complete() methods of asyncio.BaseEventLoop now raise an exception if the event loop was closed.
- **Issue #21766**: Prevent a security hole in CGIHTTPServer by URL unquoting paths before checking for a CGI script at that path.
- **Issue #21310**: Fixed possible resource leak in failed open().
- **Issue #21256**: Printout of keyword args should be in deterministic order in a mock function call. This will help to write better doctests.
- **Issue #21677**: Fixed chaining nonnormalized exceptions in io close() methods.
- **Issue #11709**: Fix the pydoc.help function to not fail when sys.stdin is not a valid file.
- **Issue #21515**: tempfile.TemporaryFile now uses os.O_TMPFILE flag is available.
- **Issue #13223**: Fix pydoc.writedoc so that the HTML documentation for methods that use ‘self’ in the example code is generated correctly.
- **Issue #21463**: In urllib.request, fix pruning of the FTP cache.
- **Issue #21618**: The subprocess module could fail to close open fds that were inherited by the calling process and already higher than POSIX resource limits would otherwise allow. On systems with a functioning /proc/self/fd or /dev/fd interface the max is now ignored and all fds are closed.
- **Issue #20383**: Introduce importlib.util.module_from_spec() as the
preferred way to create a new module.

- **Issue #21552**: Fixed possible integer overflow of too long string lengths in the tkinter module on 64-bit platforms.
- **Issue #14315**: The zipfile module now ignores extra fields in the central directory that are too short to be parsed instead of letting a struct.unpack error bubble up as this “bad data” appears in many real world zip files in the wild and is ignored by other zip tools.
- **Issue #13742**: Added “key” and “reverse” parameters to heapq.merge(). (First draft of patch contributed by Simon Sapin.)
- **Issue #21402**: tkinter.ttk now works when default root window is not set.
- **Issue #3015**: _tkinter.create() now creates tkapp object with wantobject=1 by default.
- **Issue #10203**: sqlite3.Row now truly supports sequence protocol. In particular it supports reverse() and negative indices. Original patch by Claudiu Popa.
- **Issue #18807**: If copying (no symlinks) specified for a venv, then the python interpreter aliases (python, python3) are now created by copying rather than symlinking.
- **Issue #20197**: Added support for the WebP image type in the imghdr module. Patch by Fabrice Aneche and Claudiu Popa.
- **Issue #21513**: Speedup some properties of IP addresses (IPv4Address, IPv6Address) such as .is_private or .is_multicast.
- **Issue #21137**: Improve the repr for threading.Lock() and its variants by showing the “locked” or “unlocked” status. Patch by Berker Peksag.
- **Issue #21538**: The plistlib module now supports loading of binary plist files when reference or offset size is not a power of two.
- **Issue #21455**: Add a default backlog to socket.listen().
- **Issue #21525**: Most Tkinter methods which accepted tuples now accept lists too.
- **Issue #22166**: With the assistance of a new internal _codecs._forget_codec helping function, test_codecs now clears the encoding caches to avoid the appearance of a reference leak
- **Issue #22236**: Tkinter tests now don’t reuse default root window. New root window is created for every test class.
- **Issue #10744**: Fix PEP 3118 format strings on ctypes objects with a nontrivial shape.
- **Issue #20826**: Optimize `ipaddress.collapse_addresses()`.
- **Issue #21487**: Optimize `ipaddress.summarize_address_range()` and `ipaddress.{IPv4Network,IPv6Network}.subnets()`.
- **Issue #21486**: Optimize parsing of netmasks in `ipaddress.IPv4Network` and `ipaddress.IPv6Network`.
- **Issue #13916**: Disallowed the surrogatepass error handler for non UTF-* encodings.
- **Issue #20998**: Fixed `re.fullmatch()` of repeated single character pattern with ignore case. Original patch by Matthew Barnett.
- **Issue #21075**: `fileinput.FileInput` now reads bytes from standard stream if binary mode is specified. Patch by Sam Kimbrel.
- **Issue #19775**: Add a `samefile()` method to `pathlib` Path objects. Initial patch by Vajrasky Kok.
- **Issue #21226**: Set up modules properly in `PyImport_ExecCodeModuleObject` (and friends).
- **Issue #21398**: Fix an unicode error in the pydoc pager when the documentation contains characters not encodable to the stdout encoding.
- **Issue #16531**: `ipaddress.IPv4Network` and `ipaddress.IPv6Network` now accept an (address, netmask) tuple argument, so as to easily construct network objects from existing addresses.
- **Issue #21156**: `importlib.abc.InspectLoader.source_to_code()` is now a staticmethod.
- **Issue #21424**: Simplified and optimized `heapq.nlargest()` and `nsmallest()` to make fewer tuple comparisons.
- **Issue #21396**: Fix `TextIOWrapper(..., write_through=True)` to not force a `flush()` on the underlying binary stream. Patch by akira.
- **Issue #18314**: Unlink now removes junctions on Windows. Patch by Kim Gräsman
• **Issue #21088**: Bugfix for curses.window.addch() regression in 3.4.0. In porting to Argument Clinic, the first two arguments were reversed.

• **Issue #21407**: _decimal: The module now supports function signatures.

• **Issue #10650**: Remove the non-standard ‘watchexp’ parameter from the Decimal.quantize() method in the Python version. It had never been present in the C version.

• **Issue #21469**: Reduced the risk of false positives in robotparser by checking to make sure that robots.txt has been read or does not exist prior to returning True in can_fetch().

• **Issue #19414**: Have the OrderedDict mark deleted links as unusable. This gives an early failure if the link is deleted during iteration.

• **Issue #21421**: Add __slots__ to the MappingViews ABC. Patch by Josh Rosenberg.

• **Issue #21101**: Eliminate double hashing in the C speed-up code for collections.Counter().

• **Issue #21321**: itertools.islice() now releases the reference to the source iterator when the slice is exhausted. Patch by Anton Afanasyev.

• **Issue #21057**: TextIOWrapper now allows the underlying binary stream’s read() or read1() method to return an arbitrary bytes-like object (such as a memoryview). Patch by Nikolaus Rath.

• **Issue #20951**: SSLSocket.send() now raises either SSLWantReadError or SSLWantWriteError on a non-blocking socket if the operation would block. Previously, it would return 0. Patch by Nikolaus Rath.

• **Issue #13248**: removed previously deprecated asyncore.dispatcher.__getattr__ cheap inheritance hack.

• **Issue #9815**: assertRaises now tries to clear references to local variables in the exception’s traceback.

• **Issue #19940**: ssl.cert_time_to_seconds() now interprets the given time string in the UTC timezone (as specified in RFC 5280),
• Issue #13204: Calling sys.flags.__new__ would crash the interpreter, now it raises a TypeError.

• Issue #19385: Make operations on a closed dbm.dumb database always raise the same exception.

• Issue #21207: Detect when the os.urandom cached fd has been closed or replaced, and open it anew.

• Issue #21291: subprocess's Popen.wait() is now thread safe so that multiple threads may be calling wait() or poll() on a Popen instance at the same time without losing the Popen.returncode value.

• Issue #21127: Path objects can now be instantiated from str subclass instances (such as numpy.str_).

• Issue #15002: urllib.response object to use _TemporaryFileWrapper (and _TemporaryFileCloser) facility. Provides a better way to handle file descriptor close. Patch contributed by Christian Theune.

• Issue #12220: mindom now raises a custom ValueError indicating it doesn’t support spaces in URIs instead of letting a ‘split’ ValueError bubble up.

• Issue #21068: The ssl.PROTOCOL* constants are now enum members.

• Issue #21276: posixmodule: Don’t define USE_XATTRS on KFreeBSD and the Hurd.

• Issue #21262: New method assert_not_called for Mock. It raises AssertionError if the mock has been called.

• Issue #21238: New keyword argument unsafe to Mock. It raises AttributeError incase of an attribute startswith assert or asset.

• Issue #20896: ssl.get_server_certificate() now uses PROTOCOL_SSLv23, not PROTOCOL_SSLv3, for maximum compatibility.

• Issue #21239: patch.stopall() didn’t work deterministically when the same name was patched more than once.
- **Issue #21203**: Updated fileConfig and dictConfig to remove inconsistencies. Thanks to Jure Koren for the patch.
- **Issue #21222**: Passing name keyword argument to mock.create_autospec now works.
- **Issue #21197**: Add lib64 -> lib symlink in venvs on 64-bit non-OS X POSIX.
- **Issue #17498**: Some SMTP servers disconnect after certain errors, violating strict RFC conformance. Instead of losing the error code when we issue the subsequent RSET, smtplib now returns the error code and defers raising the SMTPServerDisconnected error until the next command is issued.
- **Issue #17826**: setting an iterable side_effect on a mock function created by create_autospec now works. Patch by Kushal Das.
- **Issue #7776**: Fix Host: header and reconnection when using http.client.HTTPConnection.set_tunnel(). Patch by Nikolaus Rath.
- **Issue #20968**: unittest.mock.MagicMock now supports division. Patch by Johannes Baiter.
- Fix arbitrary memory access in JSONDecoder.raw_decode with a negative second parameter. Bug reported by Guido Vranken.
- **Issue #21169**: getpass now handles non-ascii characters that the input stream encoding cannot encode by re-encoding using the replace error handler.
- **Issue #21171**: Fixed undocumented filter API of the rot13 codec. Patch by Berker Peksag.
- **Issue #20539**: Improved math.factorial error message for large positive inputs and changed exception type (OverflowError -> ValueError) for large negative inputs.
- **Issue #21172**: isinstance check relaxed from dict to collections.Mapping.
- **Issue #21155**: asyncio.EventLoop.create_unix_server() now raises a ValueError if path and sock are specified at the same time.
- **Issue #21136**: Avoid unnecessary normalization of Fractions resulting from power and other operations. Patch by Raymond
Hettinger.

- **Issue #17621**: Introduce importlib.util.LazyLoader.
- **Issue #21076**: signal module constants were turned into enums. Patch by Giampaolo Rodola’.
- **Issue #20636**: Improved the repr of Tkinter widgets.
- **Issue #19505**: The items, keys, and values views of OrderedDict now support reverse iteration using reversed().
- **Issue #21149**: Improved thread-safety in logging cleanup during interpreter shutdown. Thanks to Devin Jeanpierre for the patch.
- **Issue #21058**: Fix a leak of file descriptor in tempfile.NamedTemporaryFile(), close the file descriptor if io.open() fails.
- **Issue #21200**: Return None from pkgutil.get_loader() when __spec__ is missing.
- **Issue #21013**: Enhance ssl.create_default_context() when used for server side sockets to provide better security by default.
- **Issue #20145**: assertRaisesRegex and assertWarnsRegex now raise a TypeError if the second argument is not a string or compiled regex.
- **Issue #20633**: Replace relative import by absolute import.
- **Issue #20980**: Stop wrapping exception when using ThreadPool.
- **Issue #21082**: In os.makedirs, do not set the process-wide umask. Note this changes behavior of makedirs when exist_ok=True.
- **Issue #20990**: Fix issues found by pyflakes for multiprocessing.
- **Issue #21015**: SSL contexts will now automatically select an elliptic curve for ECDH key exchange on OpenSSL 1.0.2 and later, and otherwise default to “prime256v1”.
- **Issue #21000**: Improve the command-line interface of json.tool.
- **Issue #20995**: Enhance default ciphers used by the ssl module to enable better security an prioritize perfect forward secrecy.
- **Issue #20884**: Don’t assume that __file__ is defined on importlib.__init__.
- **Issue #21499**: Ignore __builtins__ in several
- **Issue #20627**: `xmlrpc.client.ServerProxy` is now a context manager.
- **Issue #19165**: The formatter module now raises `DeprecationWarning` instead of `PendingDeprecationWarning`.
- **Issue #13936**: Remove the ability of `datetime.time` instances to be considered false in boolean contexts.
- **Issue #18931**: Selectors module now supports `/dev/poll` on Solaris. Patch by Giampaolo Rodola.
- **Issue #19977**: When the LC_TYPE locale is the POSIX locale (C locale), `sys.stdin` and `sys.stdout` are now using the surrogateescape error handler, instead of the strict error handler.
- **Issue #20574**: Implement incremental decoder for cp65001 code (Windows code page 65001, Microsoft UTF-8).
- **Issue #20879**: Delay the initialization of encoding and decoding tables for base32, ascii85 and base85 codecs in the base64 module, and delay the initialization of the `unquote_to_bytes()` table of the `urllib.parse` module, to not waste memory if these modules are not used.
- **Issue #19157**: Include the broadcast address in the usable hosts for IPv6 in `ipaddress`.
- **Issue #11599**: When an external command (e.g. compiler) fails, `distutils` now prints out the whole command line (instead of just the command name) if the environment variable `DISTUTILS_DEBUG` is set.
- **Issue #4931**: `distutils` should not produce unhelpful “error: None” messages anymore. `distutils.util.grok_environment_error` is kept but doc-deprecated.
- **Issue #20875**: Prevent possible gzip “‘read’ is not defined” `NameError`. Patch by Claudiu Popa.
- **Issue #11558**: `email.message.Message.attach` now returns a more useful error message if `attach` is called on a message for which `is_multipart` is False.
- **Issue #20283**: RE pattern methods now accept the string keyword parameters as documented. The pattern and source keyword parameters are left as deprecated aliases.
- **Issue #20778**: Fix modulefinder to work with bytecode-only modules.
- **Issue #20791**: copy.copy() now doesn’t make a copy when the input is a bytes object. Initial patch by Peter Otten.
- **Issue #19748**: On AIX, time.mktime() now raises an OverflowError for year outsize range [1902; 2037].
- **Issue #19573**: inspect.signature: Use enum for parameter kind constants.
- **Issue #20726**: inspect.signature: Make Signature and Parameter picklable.
- **Issue #17373**: Add inspect.Signature.from_callable method.
- **Issue #20378**: Improve repr of inspect.Signature and inspect.Parameter.
- **Issue #20816**: Fix inspect.getcallargs() to raise correct TypeError for missing keyword-only arguments. Patch by Jeremiah Lowin.
- **Issue #20817**: Fix inspect.getcallargs() to fail correctly if more than 3 arguments are missing. Patch by Jeremiah Lowin.
- **Issue #6676**: Ensure a meaningful exception is raised when attempting to parse more than one XML document per pyexpat xmlparser instance. (Original patches by Hirokazu Yamamoto and Amaury Forgeot d’Arc, with suggested wording by David Gutteridge)
- **Issue #21117**: Fix inspect.signature to better support functools.partial. Due to the specifics of functools.partial implementation, positional-or-keyword arguments passed as keyword arguments become keyword-only.
- **Issue #20334**: inspect.Signature and inspect.Parameter are now hashable. Thanks to Antony Lee for bug reports and suggestions.
- **Issue #15916**: doctest.DocTestSuite returns an empty unittest.TestSuite instead of raising ValueError if it finds no tests
- **Issue #21209**: Fix asyncio.tasks.CoroWrapper to workaround a
bug in yield-from implementation in CPython's prior to 3.4.1.

- asyncio: Add gi_{frame,running,code} properties to CoroWrapper (upstream issue #163).
- **Issue #21311**: Avoid exception in _osx_support with non-standard compiler configurations. Patch by John Szakmeister.
- **Issue #11571**: Ensure that the turtle window becomes the topmost window when launched on OS X.
- **Issue #21801**: Validate that __signature__ is None or an instance of Signature.
- **Issue #21923**: Prevent AttributeError in distutils.sysconfig.customize_compiler due to possible uninitialized _config_vars.
- **Issue #21323**: Fix http.server to again handle scripts in CGI subdirectories, broken by the fix for security issue #19435. Patch by Zach Byrne.
- **Issue #22733**: Fix ffi_prep_args not zero-extending argument values correctly on 64-bit Windows.
- **Issue #23302**: Default to TCP_NODELAY=1 upon establishing an HTTPConnection. Removed use of hard-coded MSS as it's an optimization that's no longer needed with Nagle disabled.

**IDLE**

- **Issue #20577**: Configuration of the max line length for the FormatParagraph extension has been moved from the General tab of the Idle preferences dialog to the FormatParagraph tab of the Config Extensions dialog. Patch by Tal Einat.
- **Issue #16893**: Update Idle doc chapter to match current Idle and add new information.
- **Issue #3068**: Add Idle extension configuration dialog to Options menu. Changes are written to HOME/.idlerc/config-extensions.cfg. Original patch by Tal Einat.
- **Issue #16233**: A module browser (File : Class Browser, Alt+C) requires an editor window with a filename. When Class Browser is
requested otherwise, from a shell, output window, or ‘Untitled’ editor, Idle no longer displays an error box. It now pops up an Open Module box (Alt+M). If a valid name is entered and a module is opened, a corresponding browser is also opened.

- **Issue #4832**: Save As to type Python files automatically adds .py to the name you enter (even if your system does not display it). Some systems automatically add .txt when type is Text files.
- **Issue #21986**: Code objects are not normally pickled by the pickle module. To match this, they are no longer pickled when running under Idle.
- **Issue #17390**: Adjust Editor window title; remove ‘Python’, move version to end.
- **Issue #14105**: Idle debugger breakpoints no longer disappear when insetting or deleting lines.
- **Issue #17172**: Turtledemo can now be run from Idle. Currently, the entry is on the Help menu, but it may move to Run. Patch by Ramchandra Apt and Lita Cho.
- **Issue #21765**: Add support for non-ascii identifiers to HyperParser.
- **Issue #21940**: Add unittest for WidgetRedirector. Initial patch by Saimadhav Heblikar.
- **Issue #18592**: Add unittest for SearchDialogBase. Patch by Phil Webster.
- **Issue #21694**: Add unittest for ParenMatch. Patch by Saimadhav Heblikar.
- **Issue #21686**: add unittest for HyperParser. Original patch by Saimadhav Heblikar.
- **Issue #12387**: Add missing upper(lower)case versions of default Windows key bindings for Idle so Caps Lock does not disable them. Patch by Roger Serwy.
- **Issue #21695**: Closing a Find-in-files output window while the search is still in progress no longer closes Idle.
- **Issue #18910**: Add unittest for textView. Patch by Phil Webster.
- **Issue #18292**: Add unittest for AutoExpand. Patch by Saimadhav
Heblikar.

- **Issue #18409**: Add unittest for AutoComplete. Patch by Phil Webster.
- **Issue #21477**: htest.py - Improve framework, complete set of tests. Patches by Saimadhav Heblikar
- **Issue #18104**: Add idlelib/idle_test/htest.py with a few sample tests to begin consolidating and improving human-validated tests of Idle. Change other files as needed to work with htest. Running the module as __main__ runs all tests.
- **Issue #21139**: Change default paragraph width to 72, the PEP 8 recommendation.
- **Issue #21284**: Paragraph reformat test passes after user changes reformat width.
- **Issue #17654**: Ensure IDLE menus are customized properly on OS X for non-framework builds and for all variants of Tk.
- **Issue #23180**: Rename IDLE “Windows” menu item to “Window”. Patch by Al Sweigart.

Build

- **Issue #15506**: Use standard PKG_PROG_PKG_CONFIG autoconf macro in the configure script.
- **Issue #22935**: Allow the ssl module to be compiled if openssl doesn’t support SSL 3.
- **Issue #22592**: Drop support of the Borland C compiler to build Python. The distutils module still supports it to build extensions.
- **Issue #22591**: Drop support of MS-DOS, especially of the DJGPP compiler (MS-DOS port of GCC).
- **Issue #16537**: Check whether self.extensions is empty in setup.py. Patch by Jonathan Hosmer.
- **Issue #22359**: Remove incorrect uses of recursive make. Patch by Jonas Wagner.
- **Issue #21958**: Define HAVE_ROUND when building with Visual Studio 2013 and above. Patch by Zachary Turner.
• **Issue #18093**: the programs that embed the CPython runtime are now in a separate “Programs” directory, rather than being kept in the Modules directory.

• **Issue #15759**: “make suspicious”, “make linkcheck” and “make doctest” in Doc/ now display special message when and only when there are failures.

• **Issue #21141**: The Windows build process no longer attempts to find Perl, instead relying on OpenSSL source being configured and ready to build. The PCbuild\build_ssl.py script has been re-written and re-named to PCbuild\prepare_ssl.py, and takes care of configuring OpenSSL source for both 32 and 64 bit platforms. OpenSSL sources obtained from svn.python.org will always be pre-configured and ready to build.

• **Issue #21037**: Add a build option to enable AddressSanitizer support.

• **Issue #19962**: The Windows build process now creates “python.bat” in the root of the source tree, which passes all arguments through to the most recently built interpreter.

• **Issue #21285**: Refactor and fix curses configure check to always search in a ncursesw directory.

• **Issue #15234**: For BerkelyDB and Sqlite, only add the found library and include directories if they aren’t already being searched. This avoids an explicit runtime library dependency.

• **Issue #17861**: Tools/scripts/generate_opcode_h.py automatically regenerates Include(opcode.h from Lib/opcode.py if the later gets any change.

• **Issue #20644**: OS X installer build support for documentation build changes in 3.4.1: assume externally supplied sphinx-build is available in /usr/bin.

• **Issue #20022**: Eliminate use of deprecated bundlebuilder in OS X builds.

• **Issue #15968**: Incorporated Tcl, Tk, and Tix builds into the Windows build solution.

• **Issue #17095**: Fix Modules/Setup shared support.
- **Issue #21811**: Anticipated fixes to support OS X versions > 10.9.
- **Issue #21166**: Prevent possible segfaults and other random failures of python –generate-posix-vars in pybuilddir.txt build target.
- **Issue #18096**: Fix library order returned by python-config.
- **Issue #17219**: Add library build dir for Python extension cross-builds.
- **Issue #22919**: Windows build updated to support VC 14.0 (Visual Studio 2015), which will be used for the official release.
- **Issue #21236**: Build _msi.pyd with cabinet.lib instead of fci.lib
- **Issue #17128**: Use private version of OpenSSL for OS X 10.5+ installer.

**C API**

- **Issue #14203**: Remove obsolete support for view==NULL in PyBuffer_FillInfo(), bytearray_getbuffer(), bytesiobuf_getbuffer() and array_buffer_getbuf(). All functions now raise BufferError in that case.
- **Issue #22445**: PyBuffer_IsContiguous() now implements precise contiguity tests, compatible with NumPy's NPY_RELAXED_STRIDES_CHECKING compilation flag. Previously the function reported false negatives for corner cases.
- **Issue #22079**: PyType_Ready() now checks that statically allocated type has no dynamically allocated bases.
- **Issue #22453**: Removed non-documented macro PyObject_REPR().
- **Issue #18395**: Rename _Py_char2wchar() to Py_DecodeLocale(), rename _Py_wchar2char() to Py_EncodeLocale(), and document these functions.
- **Issue #21233**: Add new C functions: PyMem_RawCalloc(), PyMem_Calloc(), PyObject_Calloc(), _PyObject_GC_Calloc(). bytes(int) is now using calloc() instead of malloc() for large
objects which is faster and use less memory.

- **Issue #20942**: PyImport_ImportFrozenModuleObject() no longer sets __file__ to match what importlib does; this affects _frozen_importlib as well as any module loaded using imp.init_frozen().

**Documentation**

- **Issue #19548**: Update the codecs module documentation to better cover the distinction between text encodings and other codecs, together with other clarifications. Patch by Martin Panter.
- **Issue #22394**: Doc/Makefile now supports make venv PYTHON=../python to create a venv for generating the documentation, e.g., make html PYTHON=venv/bin/python3.
- **Issue #21514**: The documentation of the json module now refers to new JSON RFC 7159 instead of obsoleted RFC 4627.
- **Issue #21777**: The binary sequence methods on bytes and bytearray are now documented explicitly, rather than assuming users will be able to derive the expected behaviour from the behaviour of the corresponding str methods.
- **Issue #6916**: undocument deprecated asynchat.fifo class.
- **Issue #17386**: Expanded functionality of the Doc/make.bat script to make it much more comparable to Doc/Makefile.
- **Issue #21312**: Update the thread_foobar.h template file to include newer threading APIs. Patch by Jack McCracken.
- **Issue #21043**: Remove the recommendation for specific CA organizations and to mention the ability to load the OS certificates.
- **Issue #20765**: Add missing documentation for PurePath.with_name() and PurePath.with_suffix().
- **Issue #19407**: New package installation and distribution guides based on the Python Packaging Authority tools. Existing guides
have been retained as legacy links from the distutils docs, as they still contain some required reference material for tool developers that isn’t recorded anywhere else.

- **Issue #19697**: Document cases where `__main__.__spec__` is None.

### Tests

- **Issue #18982**: Add tests for CLI of the calendar module.
- **Issue #19548**: Added some additional checks to `test_codecs` to ensure that statements in the updated documentation remain accurate. Patch by Martin Panter.
- **Issue #22838**: All `test_re` tests now work with unittest test discovery.
- **Issue #22173**: Update `lib2to3` tests to use unittest test discovery.
- **Issue #16000**: Convert `test_curses` to use unittest.
- **Issue #21456**: Skip two tests in `test_urllib2net.py` if `_ssl` module not present. Patch by Remi Pointel.
- **Issue #20746**: Fix `test_pdb` to run in refleak mode (`-R`). Patch by Xavier de Gaye.
- **Issue #22060**: `test_ctypes` has been somewhat cleaned up and simplified; it now uses unittest test discovery to find its tests.
- **Issue #22104**: `regrtest.py` no longer holds a reference to the suite of tests loaded from test modules that don’t define `test_main()`.
- **Issue #22111**: Assorted cleanups in `test_imaplib`. Patch by Milan Oberkirch.
- **Issue #22002**: Added `load_package_tests` function to `test.support` and used it to implement/augment test discovery in `test_asyncio`, `test_email`, `test_importlib`, `test_json`, and `test_tools`.
- **Issue #21976**: Fix `test_ssl` to accept LibreSSL version strings. Thanks to William Orr.
- **Issue #21918**: Converted `test_tools` from a module to a package containing separate test files for each tested script.
- **Issue #9554**: Use modern unittest features in `test_argparse`. Initial
patch by Denver Coneybeare and Radu Voicilas.

- **Issue #20155**: Changed HTTP method names in failing tests in `test_httpservers` so that packet filtering software (specifically Windows Base Filtering Engine) does not interfere with the transaction semantics expected by the tests.

- **Issue #19493**: Refactored the ctypes test package to skip tests explicitly rather than silently.

- **Issue #18492**: All resources are now allowed when tests are not run by `regrtest.py`.

- **Issue #21634**: Fix pystone micro-benchmark: use floor division instead of true division to benchmark integers instead of floating point numbers. Set pystone version to 1.2. Patch written by Lennart Regebro.

- **Issue #21605**: Added tests for Tkinter images.

- **Issue #21493**: Added test for `ntpath.expanduser()`. Original patch by Claudiu Popa.

- **Issue #19925**: Added tests for the `spwd` module. Original patch by Vajrasky Kok.

- **Issue #21522**: Added Tkinter tests for `Listbox.itemconfigure()`, `PanedWindow.paneconfigure()`, and `Menu.entryconfigure()`.

- **Issue #17756**: Fix `test_code` test when run from the installed location.

- **Issue #17752**: Fix distutils tests when run from the installed location.

- **Issue #18604**: Consolidated checks for GUI availability. All platforms now at least check whether Tk can be instantiated when the GUI resource is requested.

- **Issue #21275**: Fix a socket test on KFreeBSD.

- **Issue #21223**: Pass `test_site/test_startup_imports` when some of the extensions are built as builtins.

- **Issue #20635**: Added tests for Tk geometry managers.

- Add test case for `freeze`.

- **Issue #20743**: Fix a reference leak in `test_tcl`.

- **Issue #21097**: Move `test_namespace_pkgs` into `test_importlib`. 
• **Issue #21503**: Use test_both() consistently in test_importlib.
• **Issue #20668**: asyncio tests no longer rely on tests.txt file. (Patch by Vajrasky Kok)
• **Issue #21093**: Prevent failures of ctypes test_macholib on OS X if a copy of libz exists in $HOME/lib or /usr/local/lib.
• **Issue #22770**: Prevent some Tk segfaults on OS X when running gui tests.
• **Issue #23211**: Workaround test_logging failure on some OS X 10.6 systems.
• **Issue #23345**: Prevent test_ssl failures with large OpenSSL patch level values (like 0.9.8zc).

**Tools/Demos**

• **Issue #22314**: pydoc now works when the LINES environment variable is set.
• **Issue #22615**: Argument Clinic now supports the “type” argument for the int converter. This permits using the int converter with enums and typedefs.
• **Issue #20076**: The makelocalealias.py script no longer ignores UTF-8 mapping.
• **Issue #20079**: The makelocalealias.py script now can parse the SUPPORTED file from glibc sources and supports command line options for source paths.
• **Issue #22201**: Command-line interface of the zipfile module now correctly extracts ZIP files with directory entries. Patch by Ryan Wilson.
• **Issue #22120**: For functions using an unsigned integer return converter, Argument Clinic now generates a cast to that type for the comparison to -1 in the generated code. (This supresses a compilation warning.)
- **Issue #18974**: Tools/scripts/diff.py now uses argparse instead of optparse.
- **Issue #21906**: Make Tools/scripts/md5sum.py work in Python 3. Patch by Zachary Ware.
- **Issue #21629**: Fix Argument Clinic’s “–converters” feature.
- Add support for `yield from` to `2to3`.
- Add support for the PEP 465 matrix multiplication operator to `2to3`.
- **Issue #16047**: Fix module exception list and `__file__` handling in `freeze`. Patch by Meador Inge.
- **Issue #11824**: Consider ABI tags in `freeze`. Patch by Meador Inge.
- **Issue #20535**: PYTHONWARNING no longer affects the run_tests.py script. Patch by Arfrever Frehtes Taifersar Arahesis.

**Windows**

- **Issue #23260**: Update Windows installer
- The bundled version of Tcl/Tk has been updated to 8.6.3. The most visible result of this change is the addition of new native file dialogs when running on Windows Vista or newer. See Tcl/Tk’s TIP 432 for more information. Also, this version of Tcl/Tk includes support for Windows 10.
- **Issue #17896**: The Windows build scripts now expect external library sources to be in `PCbuild\..\externals` rather than `PCbuild\..\...
- **Issue #17717**: The Windows build scripts now use a copy of NASM pulled from svn.python.org to build OpenSSL.
- **Issue #21907**: Improved the batch scripts provided for building Python.
- **Issue #22644**: The bundled version of OpenSSL has been updated to 1.0.1j.
- **Issue #10747**: Use versioned labels in the Windows start menu. Patch by Olive Kilburn.
• **Issue #22980**: .pyd files with a version and platform tag (for example, ".cp35-win32.pyd") will now be loaded in preference to those without tags.
Python 3.4.0?

Release date: 2014-03-16

Library


Documentation

- Merge in all documentation changes since branching 3.4.0rc1.
Python 3.4.0 release candidate 3?

Release date: 2014-03-09

Core and Builtins

- **Issue #20786**: Fix signatures for dict.__delitem__ and property.__delete__ builtins.

Library

- **Issue #20839**: Don’t trigger a DeprecationWarning in the still supported pkgutil.get_loader() API when __loader__ isn’t set on a module (nor when pkgutil.find_loader() is called directly).

Build

- **Issue #14512**: Launch pydoc -b instead of pydocgui.pyw on Windows.
- **Issue #20748**: Uninstalling pip does not leave behind the pyc of the uninstaller anymore.
- **Issue #20568**: The Windows installer now installs the unversioned pip command in addition to the versioned pip3 and pip3.4 commands.
- **Issue #20757**: The ensurepip helper for the Windows uninstaller now skips uninstalling pip (rather than failing) if the user has updated pip to a different version from the one bundled with ensurepip.
- **Issue #20465**: Update OS X and Windows installer builds to use SQLite 3.8.3.1.
Python 3.4.0 release candidate 2?

Release date: 2014-02-23

Core and Builtins

- **Issue #20625**: Parameter names in `__annotations__` were not mangled properly. Discovered by Jonas Wielicki, patch by Yury Selivanov.
- **Issue #20261**: In pickle, lookup `__getnewargs__` and `__getnewargs_ex__` on the type of the object.
- **Issue #20619**: Give the AST nodes of keyword-only arguments a column and line number.
- **Issue #20526**: Revert changes of issue #19466 which introduces a regression: don’t clear anymore the state of Python threads early during the Python shutdown.

Library

- **Issue #20710**: The pydoc summary line no longer displays the “self” parameter for bound methods.
- **Issue #20566**: Change asyncio.as_completed() to use a Queue, to avoid $O(N^2)$ behavior.
- **Issue #20704**: Implement new debug API in asyncio. Add new methods `BaseEventLoop.set_debug()` and `BaseEventLoop.get_debug()`. Add support for setting `asyncio.tasks._DEBUG` variable with ‘PYTHONASYNCIODEBUG’ environment variable.
- asyncio: Refactoring and fixes: `BaseEventLoop.sock_connect()` raises an error if the address is not resolved; use `__slots__` in `Handle` and `TimerHandle`; `as_completed()` and `wait()` raise `TypeError` if the passed list of Futures is a single Future;
call_soon() and other ‘call_*()’ functions raise TypeError if the passed callback is a coroutine function; _ProactorBasePipeTransport uses _FlowControlMixin; WriteTransport.set_write_buffer_size() calls _maybe_pause_protocol() to consider pausing receiving if the watermark limits have changed; fix _check_resolved_address() for IPv6 address; and other minor improvements, along with multiple documentation updates.

- **Issue #20684**: Fix inspect.getfullargspec() to not to follow __wrapped__ chains. Make its behaviour consistent with bound methods first argument. Patch by Nick Coghlan and Yury Selivanov.
- **Issue #20681**: Add new error handling API in asyncio. New APIs: loop.set_exception_handler(), loop.default_exception_handler(), and loop.call_exception_handler().
- **Issue #20673**: Implement support for UNIX Domain Sockets in asyncio. New APIs: loop.create_unix_connection(), loop.create_unix_server(), streams.open_unix_connection(), and streams.start_unix_server().
- **Issue #20616**: Add a format() method to tracemalloc.Traceback.
- **Issue #19744**: the ensurepip installation step now just prints a warning to stderr rather than failing outright if SSL/TLS is unavailable. This allows local installation of POSIX builds without SSL/TLS support.
- **Issue #20594**: Avoid name clash with the libc function posix_close.

**Build**

- **Issue #20641**: Run MSI custom actions (pip installation, pyc compilation) with the NoImpersonate flag, to support elevated execution (UAC).
- **Issue #20221**: Removed conflicting (or circular) hypot definition when compiled with VS 2010 or above. Initial patch by Tabrez
Mohammed.

- **Issue #20609**: Restored the ability to build 64-bit Windows binaries on 32-bit Windows, which was broken by the change in issue #19788.
Python 3.4.0 release candidate 1?

Release date: 2014-02-10

Core and Builtins

- **Issue #19255**: The builtins module is restored to initial value before cleaning other modules. The sys and builtins modules are cleaned last.
- **Issue #20588**: Make Python-ast.c C89 compliant.
- **Issue #20437**: Fixed 22 potential bugs when deleting objects references.
- **Issue #20500**: Displaying an exception at interpreter shutdown no longer risks triggering an assertion failure in PyObject_Str.
- **Issue #20538**: UTF-7 incremental decoder produced inconsistent string when input was truncated in BASE64 section.
- **Issue #20404**: io.TextIOWrapper (and hence the open() builtin) now uses the internal codec marking system added for issue #19619 to throw LookupError for known non-text encodings at stream construction time. The existing output type checks remain in place to deal with unmarked third party codecs.
- **Issue #17162**: Add PyType_GetSlot.
- **Issue #20162**: Fix an alignment issue in the siphash24() hash function which caused a crash on PowerPC 64-bit (ppc64).

Library

- **Issue #20530**: The signatures for slot builtins have been updated to reflect the fact that they only accept positional-only arguments.
- **Issue #20517**: Functions in the os module that accept two filenames now register both filenames in the exception on failure.
- **Issue #20563**: The ipaddress module API is now considered
stable.

- **Issue #14983**: email.generator now always adds a line end after each MIME boundary marker, instead of doing so only when there is an epilogue. This fixes an RFC compliance bug and solves an issue with signed MIME parts.
- **Issue #20540**: Fix a performance regression (vs. Python 3.2) when layering a multiprocessing Connection over a TCP socket. For small payloads, Nagle’s algorithm would introduce idle delays before the entire transmission of a message.
- **Issue #16983**: the new email header parsing code will now decode encoded words that are (incorrectly) surrounded by quotes, and register a defect.
- **Issue #19772**: email.generator no longer mutates the message object when doing a down-transform from 8bit to 7bit CTEs.
- **Issue #20536**: the statistics module now correctly handle Decimal instances with positive exponents.
- **Issue #18805**: the netmask/hostmask parsing in ipaddress now more reliably filters out illegal values and correctly allows any valid prefix length.
- **Issue #20481**: For at least Python 3.4, the statistics module will require that all inputs for a single operation be of a single consistent type, or else a mixed of ints and a single other consistent type. This avoids some interoperability issues that arose with the previous approach of coercing to a suitable common type.
- **Issue #20478**: the statistics module now treats collections.Counter inputs like any other iterable.
- **Issue #17369**: get_filename was raising an exception if the filename parameter’s RFC2231 encoding was broken in certain ways. This was a regression relative to python2.
- **Issue #20013**: Some imap servers disconnect if the current mailbox is deleted, and imaplib did not handle that case gracefully. Now it handles the ‘bye’ correctly.
- **Issue #20531**: Revert 3.4 version of fix for #19063, and apply the
3.3 version. That is, do not raise an error if unicode is passed to email.message.Message.set_payload.

- **Issue #20476**: If a non-compat32 policy is used with any of the email parsers, EmailMessage is now used as the factory class. The factory class should really come from the policy; that will get fixed in 3.5.
- **Issue #19920**: TarFile.list() no longer fails when outputs a listing containing non-encodable characters. Based on patch by Vajrasky Kok.
- **Issue #20515**: Fix NULL pointer dereference introduced by issue #20368.
- **Issue #19186**: Restore namespacing of expat symbols inside the pyexpat module.
- **Issue #20053**: ensurepip (and hence venv) are no longer affected by the settings in the default pip configuration file.
- **Issue #20426**: When passing the re.DEBUG flag, re.compile() displays the debug output every time it is called, regardless of the compilation cache.
- **Issue #20368**: The null character now correctly passed from Tcl to Python. Improved error handling in variables-related commands.
- **Issue #20435**: Fix _pyio.StringIO.getvalue() to take into account newline translation settings.
- **tracemalloc**: Fix slicing traces and fix slicing a traceback.
- **Issue #20354**: Fix an alignment issue in the tracemalloc module on 64-bit platforms. Bug seen on 64-bit Linux when using “make profile-opt”.
- **Issue #17159**: inspect.signature now accepts duck types of functions, which adds support for Cython functions. Initial patch by Stefan Behnel.
- **Issue #18801**: Fix inspect.classify_class_attrs to correctly classify object.__new__ and object.__init__.

Fixed cmath.isinf’s name in its argument parsing code.

**Issue #20311, #20452**: poll and epoll now round the timeout away from zero, instead of rounding towards zero, in select and
selectors modules: select.epoll.poll(), selectors.PollSelector.poll() and selectors.EpollSelector.poll(). For example, a timeout of one microsecond (1e-6) is now rounded to one millisecond (1e-3), instead of being rounded to zero. However, the granularity property and asyncio's resolution feature were removed again.

- asyncio: Some refactoring; various fixes; add write flow control to unix pipes; Future.set_exception() instantiates the exception argument if it is a class; improved proactor pipe transport; support wait_for(f, None); don’t log broken/disconnected pipes; use ValueError instead of assert for forbidden subprocess_{shell,exec} arguments; added a convenience API for subprocess management; added StreamReader.at_eof(); properly handle duplicate coroutines/futures in gather(), wait(), as_completed(); use a bytearray for buffering in StreamReader; and more.

  - Issue #20288: fix handling of invalid numeric charrefs in HTMLParser.
  - Issue #20424: Python implementation of io.StringIO now supports lone surrogates.
  - Issue #20308: inspect.signature now works on classes without user-defined __init__ or __new__ methods.
  - Issue #20372: inspect.getfile (and a bunch of other inspect functions that use it) doesn’t crash with unexpected AttributeError on classes defined in C without __module__.
  - Issue #20356: inspect.signature formatting uses ‘/’ to separate positional-only parameters from others.
  - Issue #20223: inspect.signature now supports methods defined with functools.partialmethod.
  - Issue #19456: ntpath.join() now joins relative paths correctly when a drive is present.
  - Issue #20394: Silence Coverity warning in audioop module.
  - Issue #20367: Fix behavior of concurrent.futures.as_completed()
for duplicate arguments. Patch by Glenn Langford.

- **Issue #8260**: The read(), readline() and readlines() methods of codecs.StreamReader returned incomplete data when were called after readline() or read(size). Based on patch by Amaury Forgeot d'Arc.
- **Issue #20105**: the codec exception chaining now correctly sets the traceback of the original exception as its __traceback__ attribute.
- **Issue #17481**: inspect.getfullargspec() now uses inspect.signature() API.
- **Issue #15304**: concurrent.futures.wait() can block forever even if Futures have completed. Patch by Glenn Langford.
- **Issue #14455**: plistlib: fix serializing integers in the range of an unsigned long long but outside of the range of signed long long for binary plist files.

**IDLE**

- **Issue #20406**: Use Python application icons for Idle window title bars. Patch mostly by Serhiy Storchaka.
- Update the python.gif icon for the Idle classbrowser and pathbowser from the old green snake to the new blue and yellow snakes.
- **Issue #17721**: Remove non-functional configuration dialog help button until we make it actually gives some help when clicked. Patch by Guilherme Simões.

**Tests**

- **Issue #20532**: Tests which use _testcapi now are marked as CPython only.
- **Issue #19920**: Added tests for TarFile.list(). Based on patch by Vajrasky Kok.
• **Issue #19990**: Added tests for the imghdr module. Based on patch by Claudiu Popa.
• **Issue #20474**: Fix test_socket “unexpected success” failures on OS X 10.7+.

**Tools/Demos**

• **Issue #20530**: Argument Clinic’s signature format has been revised again. The new syntax is highly human readable while still preventing false positives. The syntax also extends Python syntax to denote “self” and positional-only parameters, allowing inspect.Signature objects to be totally accurate for all supported builtins in Python 3.4.
• **Issue #20456**: Argument Clinic now observes the C preprocessor conditional compilation statements of the C files it parses. When a Clinic block is inside a conditional code, it adjusts its output to match, including automatically generating an empty methoddef macro.
• **Issue #20456**: Cloned functions in Argument Clinic now use the correct name, not the name of the function they were cloned from, for text strings inside generated code.
• **Issue #20456**: Fixed Argument Clinic’s test suite and “–converters” feature.
• **Issue #20456**: Argument Clinic now allows specifying different names for a parameter in Python and C, using “as” on the parameter line.
• **Issue #20326**: Argument Clinic now uses a simple, unique signature to annotate text signatures in docstrings, resulting in fewer false positives. “self” parameters are also explicitly marked, allowing inspect.Signature() to authoritatively detect (and skip) said parameters.
• **Issue #20326**: Argument Clinic now generates separate checksums for the input and output sections of the block, allowing external tools to verify that the input has not changed (and thus
the output is not out-of-date).

Build

- **Issue #20465**: Update SQLite shipped with OS X installer to 3.8.3.

C-API

- **Issue #20517**: Added new functions allowing OSError exceptions to reference two filenames instead of one: `PyErr_SetFromErrnoWithFilenameObjects()` and `PyErr_SetExcFromWindowsErrWithFilenameObjects()`.

Documentation

- **Issue #20488**: Change wording to say `importlib` is the implementation of import instead of just an implementation.
- **Issue #6386**: Clarify in the tutorial that specifying a symlink to execute means the directory containing the executed script and not the symlink is added to `sys.path`. 
Python 3.4.0 Beta 3?

Release date: 2014-01-26

Core and Builtins

- **Issue #20189**: Four additional builtin types (PyTypeObject, PyMethodDescr_Type, _PyMethodWrapper_Type, and PyWrapperDescr_Type) have been modified to provide introspection information for builtins.
- **Issue #17825**: Cursor “^” is correctly positioned for SyntaxError and IndentationError.
- **Issue #2382**: SyntaxError cursor “^” is now written at correct position in most cases when multibyte characters are in line (before “^”). This still not works correctly with wide East Asian characters.
- **Issue #18960**: The first line of Python script could be executed twice when the source encoding was specified on the second line. Now the source encoding declaration on the second line isn’t effective if the first line contains anything except a comment. ‘python -x’ works now again with files with the source encoding declarations, and can be used to make Python batch files on Windows.

Library

- asyncio: Various improvements and small changes not all covered by issues listed below. E.g. wait_for() now cancels the inner task if the timeout occurs; tweaked the set of exported symbols; renamed Empty/Full to QueueEmpty/QueueFull; “with (yield from lock)” now uses a separate context manager; readexactly() raises if not enough data was read; PTY support tweaks.
- **Issue #20311**: asyncio: Add a granularity attribute to BaseEventLoop: maximum between the resolution of the BaseEventLoop.time() method and the resolution of the selector. The granduarility is used in the scheduler to round time and deadline.

- **Issue #20311**: selectors: Add a resolution attribute to BaseSelector.

- **Issue #20189**: unittest.mock now no longer assumes that any object for which it could get an inspect.Signature is a callable written in Python. Fix courtesy of Michael Foord.

- **Issue #20317**: ExitStack.__exit__ could create a self-referential loop if an exception raised by a cleanup operation already had its context set correctly (for example, by the @contextmanager decorator). The infinite loop this caused is now avoided by checking if the expected context is already set before trying to fix it.

- **Issue #20374**: Fix build with GNU readline >= 6.3.

- **Issue #20262**: Warnings are raised now when duplicate names are added in the ZIP file or too long ZIP file comment is truncated.

- **Issue #20165**: The unittest module no longer considers tests marked with @expectedFailure successful if they pass.

- **Issue #18574**: Added missing newline in 100-Continue reply from http.server.BaseHTTPRequestHandler. Patch by Nikolaus Rath.

- **Issue #20270**: urllib.urlparse now supports empty ports.

- **Issue #20243**: TarFile no longer raise ReadError when opened in write mode.

- **Issue #20238**: TarFile opened with external fileobj and “w:gz” mode didn’t write complete output on close.

- **Issue #20245**: The open functions in the tarfile module now correctly handle empty mode.

- **Issue #20242**: Fixed basicConfig() format strings for the alternative formatting styles. Thanks to kespindler for the bug report and patch.

- **Issue #20246**: Fix buffer overflow in socket.recvfrom_into.
• **Issues #20206 and #5803:** Fix edge case in email.quoprimime.encode where it truncated lines ending in a character needing encoding but no newline by using a more efficient algorithm that doesn’t have the bug.

• **Issue #19082:** Working xmlrpc.server and xmlrpc.client examples. Both in modules and in documentation. Initial patch contributed by Vajrasky Kok.

• **Issue #20138:** The wsgiref.application_uri() and wsgiref.request_uri() functions now conform to PEP 3333 when handle non-ASCII URLs.

• **Issue #19097:** Raise the correct Exception when cgi.FieldStorage is given an invalid fileobj.

• **Issue #20152:** Ported Python/import.c over to Argument Clinic.

• **Issue #13107:** argparse and optparse no longer raises an exception when output a help on environment with too small COLUMNS. Based on patch by Elazar Gershuni.

• **Issue #20207:** Always disable SSLv2 except when PROTOCOL_SSLv2 is explicitly asked for.

• **Issue #18960:** The tokenize module now ignore the source encoding declaration on the second line if the first line contains anything except a comment.

• **Issue #20078:** Reading malformed zipfiles no longer hangs with 100% CPU consumption.

• **Issue #20113:** os.readv() and os.writev() now raise an OSError exception on error instead of returning -1.

• **Issue #19719:** Make importlib.abc.MetaPathFinder.find_module(), PathEntryFinder.find_loader(), and Loader.load_module() use PEP 451 APIs to help with backwards-compatibility.

• **Issue #20144:** inspect.Signature now supports parsing simple symbolic constants as parameter default values in __text_signature__.

• **Issue #20072:** Fixed multiple errors in tkinter with wantobjects is False.

• **Issue #20229:** Avoid plistlib deprecation warning in
platform.mac_ver().

- **Issue #14455**: Fix some problems with the new binary plist support in plistlib.

**IDLE**

- **Issue #17390**: Add Python version to Idle editor window title bar. Original patches by Edmond Burnett and Kent Johnson.
- **Issue #18960**: IDLE now ignores the source encoding declaration on the second line if the first line contains anything except a comment.

**Tests**

- **Issue #20358**: Tests for curses.window.overlay and curses.window.overwrite no longer specify \( \min\{\text{row, col}\} > \max\{\text{row, col}\} \).
- **Issue #19804**: The test_find_mac test in test_uuid is now skipped if the ifconfig executable is not available.
- **Issue #19886**: Use better estimated memory requirements for bigmem tests.

**Tools/Demos**

- **Issue #20390**: Argument Clinic’s “file” output preset now defaults to “{dirname}/clinic/{basename}.h”.
- **Issue #20390**: Argument Clinic’s “class” directive syntax has been extended with two new required arguments: “typedef” and “type_object”.
- **Issue #20390**: Argument Clinic: If __new__ or __init__ functions didn’t use kwargs (or args), the PyArg_NoKeywords (or PyArg_NoPositional) calls generated are only run when the type object is an exact match.
• **Issue #20390**: Argument Clinic now fails if you have required parameters after optional parameters.

• **Issue #20390**: Argument Clinic converters now have a new template they can inject code into: “modifiers”. Code put there is run in the parsing function after argument parsing but before the call to the impl.

• **Issue #20376**: Argument Clinic now escapes backslashes in docstrings.

• **Issue #20381**: Argument Clinic now sanity checks the default argument when c_default is also specified, providing a nice failure message for disallowed values.

• **Issue #20189**: Argument Clinic now ensures that parser functions for __new__ are always of type newfunc, the type of the tp_new slot. Similarly, parser functions for __init__ are now always of type initproc, the type of tp_init.

• **Issue #20189**: Argument Clinic now suppresses the docstring for __new__ and __init__ functions if no docstring is provided in the input.

• **Issue #20189**: Argument Clinic now suppresses the “self” parameter in the impl for @staticmethod functions.

• **Issue #20294**: Argument Clinic now supports argument parsing for __new__ and __init__ functions.

• **Issue #20299**: Argument Clinic custom converters may now change the default value of c_default and py_default with a class member.

• **Issue #20287**: Argument Clinic’s output is now configurable, allowing delaying its output or even redirecting it to a separate file.

• **Issue #20226**: Argument Clinic now permits simple expressions (e.g. “sys.maxsize - 1”) as default values for parameters.

• **Issue #19936**: Added executable bits or shebang lines to Python scripts which requires them. Disable executable bits and shebang lines in test and benchmark files in order to prevent using a random system python, and in source files of modules which don’t provide command line interface. Fixed shebang lines in the
unittestgui and checkpip scripts.

- **Issue #20268**: Argument Clinic now supports cloning the parameters and return converter of existing functions.
- **Issue #20228**: Argument Clinic now has special support for class special methods.
- **Issue #20214**: Fixed a number of small issues and documentation errors in Argument Clinic (see issue for details).
- **Issue #20196**: Fixed a bug where Argument Clinic did not generate correct parsing code for functions with positional-only parameters where all arguments are optional.
- **Issue #18960**: 2to3 and the findnocoding.py script now ignore the source encoding declaration on the second line if the first line contains anything except a comment.
- **Issue #19723**: The marker comments Argument Clinic uses have been changed to improve readability.
- **Issue #20157**: When Argument Clinic renames a parameter because its name collides with a C keyword, it no longer exposes that rename to PyArg_Parse.
- **Issue #20141**: Improved Argument Clinic's support for the PyArg_Parse "O!" format unit.
- **Issue #20144**: Argument Clinic now supports simple symbolic constants as parameter default values.
- **Issue #20143**: The line numbers reported in Argument Clinic errors are now more accurate.
- **Issue #20142**: Py_buffer variables generated by Argument Clinic are now initialized with a default value.

**Build**

- **Issue #12837**: Silence a tautological comparison warning on OS X under Clang in socketmodule.c.
Python 3.4.0 Beta 2?

Release date: 2014-01-05

Core and Builtins

- **Issue #17432**: Drop UCS2 from names of Unicode functions in python3.def.
- **Issue #19526**: Exclude all new API from the stable ABI. Exceptions can be made if a need is demonstrated.
- **Issue #19969**: PyBytes_FromFormatV() now raises an OverflowError if “%c” argument is not in range [0; 255].
- **Issue #19995**: %c, %o, %x, and %X now issue a DeprecationWarning on non-integer input; reworded docs to clarify that an integer type should define both __int__ and __index__.
- **Issue #19787**: PyThread_set_key_value() now always set the value. In Python 3.3, the function did nothing if the key already exists (if the current value is a non-NULL pointer).
- **Issue #14432**: Remove the thread state field from the frame structure. Fix a crash when a generator is created in a C thread that is destroyed while the generator is still used. The issue was that a generator contains a frame, and the frame kept a reference to the Python state of the destroyed C thread. The crash occurs when a trace function is setup.
- **Issue #19576**: PyGILState_Ensure() now initializes threads. At startup, Python has no concrete GIL. If PyGILState_Ensure() is called from a new thread for the first time and PyEval_InitThreads() was not called yet, a GIL needs to be created.
- **Issue #17576**: Deprecation warning emitted now when __int__() or __index__() return not int instance.
- **Issue #19932**: Fix typo in import.h, missing whitespaces in
function prototypes.

- **Issue #19736**: Add module-level statvfs constants defined for GNU/glibc based systems.
- **Issue #20097**: Fix bad use of “self” in importlib’s WindowsRegistryFinder.
- **Issue #19729**: In str.format(), fix recursive expansion in format spec.
- **Issue #19638**: Fix possible crash / undefined behaviour from huge (more than 2 billion characters) input strings in _Py_dg_strtod.

Library

- **Issue #20154**: Deadlock in asyncio.StreamReader.readexactly().
- **Issue #16113**: Remove sha3 module again.
- **Issue #20111**: pathlib.Path.with_suffix() now sanity checks the given suffix.
- Fix breakage in TestSuite.countTestCases() introduced by issue #11798.
- **Issue #20108**: Avoid parameter name clash in inspect.getcallargs().
- **Issue #19918**: Fix PurePath.relative_to() under Windows.
- **Issue #19422**: Explicitly disallow non- SOCK_STREAM sockets in the ssl module, rather than silently let them emit clear text data.
- **Issue #20046**: Locale alias table no longer contains entities which can be calculated. Generalized support of the euro modifier.
- **Issue #20027**: Fixed locale aliases for devanagari locales.
- **Issue #20067**: Tkinter variables now work when wantobjects is false.
- **Issue #19020**: Tkinter now uses splitlist() instead of split() in configure methods.
- **Issue #19744**: ensurepip now provides a better error message when Python is built without SSL/TLS support (pip currently requires that support to run, even if only operating with local wheel files).
- **Issue #19734**: ensurepip now ignores all pip environment variables to avoid odd behaviour based on user configuration settings.
- Fix TypeError on “setup.py upload –show-response”.
- **Issue #20045**: Fix “setup.py register –list-classifiers”.
- **Issue #18879**: When a method is looked up on a temporary file, avoid closing the file before the method is possibly called.
- **Issue #20037**: Avoid crashes when opening a text file late at interpreter shutdown.
- **Issue #19967**: Thanks to the PEP 442, asyncio.Future now uses a destructor to log uncaught exceptions, instead of the dedicated _TracebackLogger class.
- Added a Task.current_task() class method to asyncio.
- **Issue #19850**: Set SA_RESTART in asyncio when registering a signal handler to limit EINTR occurrences.
- Implemented write flow control in asyncio for proactor event loop (Windows).
- Change write buffer in asyncio use to avoid O(N**2) behavior. Make write()/sendto() accept bytearray/memoryview.
- **Issue #20034**: Updated alias mapping to most recent locale.alias file from X.org distribution using makelocalealias.py.
- **Issue #5815**: Fixed support for locales with modifiers. Fixed support for locale encodings with hyphens.
- **Issue #20026**: Fix the sqlite module to handle correctly invalid isolation level (wrong type).
- **Issue #18829**: csv.Dialect() now checks type for delimiter, escapechar and quotechar fields. Original patch by Vajrasky Kok.
- **Issue #19855**: uuid.getnode() on Unix now looks on the PATH for the executables used to find the mac address, with /sbin and /usr/sbin as fallbacks.
- **Issue #20007**: HTTPResponse.read(0) no more prematurely closes connection. Original patch by Simon Sapin.
- **Issue #19946**: multiprocessing now uses runpy to initialize __main__ in child processes when necessary, allowing it to
correctly handle scripts without suffixes and submodules that use explicit relative imports or otherwise rely on parent modules being correctly imported prior to execution.

- **Issue #19921**: When Path.mkdir() is called with parents=True, any missing parent is created with the default permissions, ignoring the mode argument (mimicking the POSIX “mkdir -p” command).
- **Issue #19887**: Improve the Path.resolve() algorithm to support certain symlink chains.
- **Issue #19912**: Fixed numerous bugs in ntpath.splitunc().
- **Issue #19911**: ntpath.splitdrive() now correctly processes the ‘İ’ character (U+0130, LATIN CAPITAL LETTER I WITH DOT ABOVE).
- **Issue #19532**: python -m compileall with no filename/directory arguments now respects the -f and -q flags instead of ignoring them.
- **Issue #19623**: Fixed writing to unseekable files in the aifc module.
- **Issue #19946**: multiprocessing.spawn now raises ImportError when the module to be used as the main module cannot be imported.
- **Issue #17919**: select.poll.register() again works with poll.POLLNVAL on AIX. Fixed integer overflow in the eventmask parameter.
- **Issue #19063**: if a Charset's body_encoding was set to None, the email package would generate a message claiming the Content-Transfer-Encoding was 7bit, and produce garbage output for the content. This now works. A couple of other set_payload mishandlings of non-ASCII are also fixed. In addition, calling set_payload with a string argument without specifying a charset now raises an error (this is a new error in 3.4).
- **Issue #15475**: Add __sizeof__ implementations for itertools objects.
- **Issue #19944**: Fix importlib.find_spec() so it imports parents as needed and move the function to importlib.util.
- **Issue #19880**: Fix a reference leak in unittest.TestCase. Explicitly
break reference cycles between frames and the _Outcome instance.

- **Issue #17429**: platform.linux_distribution() now decodes files from the UTF-8 encoding with the surrogateescape error handler, instead of decoding from the locale encoding in strict mode. It fixes the function on Fedora 19 which is probably the first major distribution release with a non-ASCII name. Patch written by Toshio Kuratomi.

- **Issue #19343**: Expose FreeBSD-specific APIs in resource module. Original patch by Koobs.

- **Issue #19929**: Call os.read with 32768 within subprocess.Popen.communicate rather than 4096 for efficiency. A microbenchmark shows Linux and OS X both using ~50% less cpu time this way.

- **Issue #19506**: Use a memoryview to avoid a data copy when piping data to stdin within subprocess.Popen.communicate. 5-10% less cpu usage.

- **Issue #19876**: selectors unregister() no longer raises ValueError or OSError if the FD is closed (as long as it was registered).

- **Issue #19908**: pathlib now joins relative Windows paths correctly when a drive is present. Original patch by Antoine Pitrou.

- **Issue #19296**: Silence compiler warning in dbm_open

- **Issue #6784**: Strings from Python 2 can now be unpickled as bytes objects by setting the encoding argument of Unpickler to be ‘bytes’. Initial patch by Merlijn van Deen.

- **Issue #19839**: Fix regression in bz2 module’s handling of non-bzip2 data at EOF, and analogous bug in lzma module.

- **Issue #19881**: Fix pickling bug where cpickle would emit bad pickle data for large bytes string (i.e., with size greater than 2**32-1).

- **Issue #19138**: doctest’s IGNORE_EXCEPTION_DETAIL now allows a match when no exception detail exists (no colon following the exception’s name, or a colon does follow but no text follows the colon).
- **Issue #19927**: Add `__eq__` to path-based loaders in importlib.
- **Issue #19827**: On UNIX, `setblocking()` and `settimeout()` methods of `socket.socket` can now avoid a second syscall if the `ioctl()` function can be used, or if the non-blocking flag of the socket is unchanged.
- **Issue #19785**: `smtplib` now supports `SSLContext.check_hostname` and server name indication for TLS/SSL connections.
- **Issue #19784**: `poplib` now supports `SSLContext.check_hostname` and server name indication for TLS/SSL connections.
- **Issue #19783**: `nntplib` now supports `SSLContext.check_hostname` and server name indication for TLS/SSL connections.
- **Issue #19782**: `imaplib` now supports `SSLContext.check_hostname` and server name indication for TLS/SSL connections.
- **Issue #20123**: Fix `pydoc.synopsis()` for “binary” modules.
- **Issue #19834**: Support unpickling of exceptions pickled by Python 2.
- **Issue #19781**: `ftplib` now supports `SSLContext.check_hostname` and server name indication for TLS/SSL connections.
- **Issue #19509**: Add `SSLContext.check_hostname` to match the peer’s certificate with `server_hostname` on handshake.
- **Issue #15798**: Fixed `subprocess.Popen()` to no longer fail if file descriptor 0, 1 or 2 is closed.
- **Issue #17897**: Optimized unpickle prefetching.
- **Issue #3693**: Make the error message more helpful when the `array.array()` constructor is given a str. Move the array module typecode documentation to the docstring of the constructor.
- **Issue #19088**: Fixed incorrect caching of the `copyreg` module in `object.__reduce__()` and `object.__reduce_ex__()`.  
- **Issue #19698**: Removed `exec_module()` methods from `importlib.machinery.BuiltinImporter` and `ExtensionFileLoader`.
- **Issue #18864**: Added a setter for `ModuleSpec.has_location`.
- **Fixed _pickle.Unpickler** to not fail when loading empty strings as
persistent IDs.

- **Issue #11480**: Fixed copy.copy to work with classes with custom metaclasses. Patch by Daniel Urban.
- **Issue #6477**: Added support for pickling the types of built-in singletons (i.e., Ellipsis, NotImplemented, None).
- **Issue #19713**: Add remaining PEP 451-related deprecations and move away from using find_module/find_loaer/load_module.
- **Issue #19708**: Update pkgutil to use the new importer APIs.
- **Issue #19703**: Update pydoc to use the new importer APIs.
- **Issue #19851**: Fixed a regression in reloading sub-modules.
- ssl.create_default_context() sets OP_NO_COMPRESSION to prevent CRIME.
- **Issue #19802**: Add socket.SO_PRIORITY.
- **Issue #11508**: Fixed uuid.getnode() and uuid.uuid1() on environment with virtual interface. Original patch by Kent Frazier.
- **Issue #11489**: JSON decoder now accepts lone surrogates.
- **Issue #19545**: Avoid chained exceptions while passing stray % to time.strptime(). Initial patch by Claudiu Popa.

**IDLE**

- **Issue #20058**: sys.stdin.readline() in IDLE now always returns only one line.
- **Issue #19481**: print() of string subclass instance in IDLE no longer hangs.
- **Issue #18270**: Prevent possible IDLE AttributeError on OS X when no initial shell window is present.

**Tests**

- **Issue #20055**: Fix test_shutil under Windows with symlink privileges held. Patch by Vajrasky Kok.
- **Issue #20070**: Don’t run test_urlib2net when network resources
are not enabled.

- **Issue #19938**: Re-enabled test_bug_1333982 in test_dis, which had been disabled since 3.0 due to the changes in listcomp handling.
- **Issue #19320**: test_tcl no longer fails when wantobjects is false.
- **Issue #19919**: Fix flaky SSL test. connect_ex() sometimes returns EWOULDBLOCK on Windows or VMs hosted on Windows.
- **Issue #19912**: Added tests for ntpath.splitunc().
- **Issue #19828**: Fixed test_site when the whole suite is run with -S.
- **Issue #19928**: Implemented a test for repr() of cell objects.
- **Issue #19535**: Fixed test_docxmlrpc, test_functools, test_inspect, and test_statistics when python is run with -OO.
- **Issue #19926**: Removed unneeded test_main from test_abstract_numbers. Patch by Vajrasky Kok.
- **Issue #19572**: More skipped tests explicitly marked as skipped.
- **Issue #19595**, #19987: Re-enabled a long-disabled test in test_winsound.
- **Issue #19588**: Fixed tests in test_random that were silently skipped most of the time. Patch by Julian Gindi.

**Build**

- **Issue #19728**: Enable pip installation by default on Windows.
- **Issue #16136**: Remove VMS support
- **Issue #18215**: Add script Tools/ssl/test_multiple_versions.py to compile and run Python's unit tests with multiple versions of OpenSSL.
- **Issue #19922**: define _INCLUDE__STDC_A1_SOURCE in HP-UX to include mbstate_t for mbrtowc().
- **Issue #19788**: kill_python(_d).exe is now run as a PreBuildEvent on the pythoncore sub-project. This should prevent build errors due a previous build's python(_d).exe still running.
Documentation

- **Issue #20265**: Updated some parts of the Using Windows document.
- **Issue #20266**: Updated some parts of the Windows FAQ.
- **Issue #20255**: Updated the about and bugs pages.
- **Issue #20253**: Fixed a typo in the ipaddress docs that advertised an illegal attribute name. Found by INADA Naoki.
- **Issue #18840**: Introduce the json module in the tutorial, and de-emphasize the pickle module.
- **Issue #19845**: Updated the Compiling Python on Windows section.
- **Issue #19795**: Improved markup of True/False constants.

Tools/Demos

- **Issue #19659**: Added documentation for Argument Clinic.
- **Issue #19976**: Argument Clinic METH_NOARGS functions now always take two parameters.
Python 3.4.0 Beta 1?

Release date: 2013-11-24

Core and Buitlins

- Use the repr of a module name in more places in import, especially exceptions.
- **Issue #19619**: str.encode, bytes.decode and bytearray.decode now use an internal API to throw LookupError for known non-text encodings, rather than attempting the encoding or decoding operation and then throwing a TypeError for an unexpected output type. (The latter mechanism remains in place for third party non-text encodings)
- **Issue #19183**: Implement PEP 456 ‘secure and interchangeable hash algorithm’. Python now uses SipHash24 on all major platforms.
- **Issue #12892**: The utf-16* and utf-32* encoders no longer allow surrogate code points (U+D800-U+DFFF) to be encoded. The utf-32* decoders no longer decode byte sequences that correspond to surrogate code points. The surrogatepass error handler now works with the utf-16* and utf-32* codecs. Based on patches by Victor Stinner and Kang-Hao (Kenny) Lu.
- **Issue #17806**: Added keyword-argument support for “tabsize” to str/bytes.expandtabs().
- **Issue #17828**: Output type errors in str.encode(), bytes.decode() and bytearray.decode() now direct users to codecs.encode() or codecs.decode() as appropriate.
- **Issue #17828**: The interpreter now attempts to chain errors that occur in codec processing with a replacement exception of the same type that includes the codec name in the error message. It ensures it only does this when the creation of the replacement exception won’t lose any information.
• **Issue #19466**: Clear the frames of daemon threads earlier during the Python shutdown to call objects destructors. So “unclosed file” resource warnings are now correctly emitted for daemon threads.

• **Issue #19514**: Deduplicate some _Py_IDENTIFIER declarations. Patch by Andrei Dorian Duma.

• **Issue #17936**: Fix O(n**2) behaviour when adding or removing many subclasses of a given type.

• **Issue #19428**: zipimport now handles errors when reading truncated or invalid ZIP archive.

• **Issue #18408**: Add a new PyFrame_FastToLocalsWithError() function to handle exceptions when merging fast locals into f_locals of a frame. PyEval_GetLocals() now raises an exception and return NULL on failure.

• **Issue #19369**: Optimized the usage of __length_hint__().

• **Issue #18603**: Ensure that PyOS_mystricmp and PyOS_mystrnicmp are in the Python executable and not removed by the linker’s optimizer.

• **Issue #19306**: Add extra hints to the faulthandler module’s stack dumps that these are “upside down”.

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**Library**

• **Issue #3158**: doctest can now find doctests in functions and methods written in C.

• **Issue #13477**: Added command line interface to the tarfile module. Original patch by Berker Peksag.

• **Issue #19674**: inspect.signature() now produces a correct signature for some builtins.

• **Issue #19722**: Added opcode.stack_effect(), which computes the stack effect of bytecode instructions.

• **Issue #19735**: Implement private function ssl._create_stdlib_context() to create SSLContext objects in Python’s stdlib module. It provides a single configuration point and makes use of SSLContext.load_default_certs().
- **Issue #16203**: Add re.fullmatch() function and regex.fullmatch() method, which anchor the pattern at both ends of the string to match. Original patch by Matthew Barnett.
- **Issue #13592**: Improved the repr for regular expression pattern objects. Based on patch by Hugo Lopes Tavares.
- **Issue #19641**: Added the audioop.byteswap() function to convert big-endian samples to little-endian and vice versa.
- **Issue #15204**: Deprecated the ‘U’ mode in file-like objects.
- **Issue #17810**: Implement PEP 3154, pickle protocol 4.
- **Issue #19668**: Added support for the cp1125 encoding.
- **Issue #19689**: Add ssl.create_default_context() factory function. It creates a new SSLContext object with secure default settings.
- **Issue #19727**: os.utime(..., None) is now potentially more precise under Windows.
- **Issue #17201**: ZIP64 extensions now are enabled by default. Patch by William Mallard.
- **Issue #19292**: Add SSLContext.load_default_certs() to load default root CA certificates from default stores or system stores. By default the method loads CA certs for authentication of server certs.
- **Issue #19673**: Add pathlib to the stdlib as a provisional module (PEP 428).
- **Issue #16596**: pdb in a generator now properly skips over yield and yield from rather than stepping out of the generator into its caller. (This is essential for stepping through asyncio coroutines.)
- **Issue #17916**: Added dis.Bytecode.from_traceback() and dis.Bytecode.current_offset to easily display “current instruction” markers in the new disassembly API (Patch by Claudiu Popa).
- **Issue #19552**: venv now supports bootstrapping pip into virtual environments
- **Issue #17134**: Finalize interface to Windows’ certificate store. Cert and CRL enumeration are now two functions. enum_certificates() also returns purpose flags as set of OIDs.
- **Issue #19555**: Restore sysconfig.get_config_var(‘SO’), (and the
distutils equivalent) with a DeprecationWarning pointing people at $EXT_SUFFIX.

- **Issue #8813**: Add SSLContext.verify_flags to change the verification flags of the context in order to enable certification revocation list (CRL) checks or strict X509 rules.
- **Issue #18294**: Fix the zlib module to make it 64-bit safe.
- **Issue #19682**: Fix compatibility issue with old version of OpenSSL that was introduced by Issue #18379.
- **Issue #14455**: plistlib now supports binary plists and has an updated API.
- **Issue #19633**: Fixed writing not compressed 16- and 32-bit wave files on big-endian platforms.
- **Issue #18379**: SSLSocket.getpeercert() returns CA issuer AIA fields, OCSP and CRL distribution points.
- **Issue #18138**: Implement cadata argument of SSLContext.load_verify_location() to load CA certificates and CRL from memory. It supports PEM and DER encoded strings.
- **Issue #18775**: Add name and block_size attribute to HMAC object. They now provide the same API elements as non-keyed cryptographic hash functions.
- **Issue #17276**: MD5 as default digestmod for HMAC is deprecated. The HMAC module supports digestmod names, e.g. hmac.HMAC(‘sha1’).
- **Issue #19449**: in csv’s writerow, handle non-string keys when generating the error message that certain keys are not in the ‘fieldnames’ list.
- **Issue #13633**: Added a new convert_charrefs keyword arg to HTMLParser that, when True, automatically converts all character references.
- **Issue #2927**: Added the unescape() function to the html module.
- **Issue #8402**: Added the escape() function to the glob module.
- **Issue #17618**: Add Base85 and Ascii85 encoding/decoding to the base64 module.
- **Issue #19634**: time.strftime(“%y”) now raises a ValueError on AIX
when given a year before 1900.

- Fix test.support.bind_port() to not cause an error when Python was compiled on a system with SO_REUSEPORT defined in the headers but run on a system with an OS kernel that does not support that reasonably new socket option.
- Fix compilation error under gcc of the ctypes module bundled libffi for arm.
- **Issue #19448**: Add private API to SSL module to lookup ASN.1 objects by OID, NID, short name and long name.
- **Issue #19282**: dbm.open now supports the context management protocol. (Initial patch by Claudiu Popa)
- **Issue #8311**: Added support for writing any bytes-like objects in the aifc, sunau, and wave modules.
- **Issue #5202**: Added support for unseekable files in the wave module.
- **Issue #19544** and **Issue #1180**: Restore global option to ignore ~/.pydistutils.cfg in Distutils, accidentally removed in backout of distutils2 changes.
- **Issue #19523**: Closed FileHandler leak which occurred when delay was set.
- **Issue #19544** and **Issue #6516**: Restore support for –user and –group parameters to sdist command accidentally rolled back as part of the distutils2 rollback.
- **Issue #13674**: Prevented time.strptime from crashing on Windows when given a year before 1900 and a format of %y.
- **Issue #19406**: implementation of the ensurepip module (part of PEP 453). Patch by Donald Stufft and Nick Coghlan.
- **Issue #19544** and **Issue #6286**: Restore use of urllib over http allowing use of http_proxy for Distutils upload command, a feature accidentally lost in the rollback of distutils2.
- **Issue #19544** and **Issue #7457**: Restore the read_pkg_file method to distutils.dist.DistributionMetadata accidentally removed in the undo of distutils2.
- **Issue #16685**: Added support for any bytes-like objects in the
audioop module. Removed support for strings.

- **Issue #7171**: Add Windows implementation of `inet_ntop` and `inet_pton` to socket module. Patch by Atsuo Ishimoto.
- **Issue #19261**: Added support for writing 24-bit samples in the sunau module.
- **Issue #1097797**: Added CP273 encoding, used on IBM mainframes in Germany and Austria. Mapping provided by Michael Bierenfeld.
- **Issue #1575020**: Fixed support of 24-bit wave files on big-endian platforms.
- **Issue #19378**: Fixed a number of cases in the dis module where the new “file” parameter was not being honoured correctly
- **Issue #19378**: Removed the “dis.Bytecode.show_info” method
- **Issue #19378**: Renamed the “dis.Bytecode.display_code” method to “dis.Bytecode.dis” and converted it to returning a string rather than printing output.
- **Issue #19378**: the “line_offset” parameter in the new “dis.get_instructions” API has been renamed to “first_line” (and the default value and usage changed accordingly). This should reduce confusion with the more common use of “offset” in the dis docs to refer to bytecode offsets.
- **Issue #18678**: Corrected spwd struct member names in spwd module: `sp_nam->sp_namp`, and `sp_pwd->sp_pwdp`. The old names are kept as extra structseq members, for backward compatibility.
- **Issue #6157**: Fixed tkinter.Text.debug(). tkinter.Text.bbox() now raises TypeError instead of TclError on wrong number of arguments. Original patch by Guilherme Polo.
- **Issue #10197**: Rework subprocess.get[status]output to use subprocess functionality and thus to work on Windows. Patch by Nick Coghlan
- **Issue #6160**: The bbox() method of tkinter.Spinbox now returns a tuple of integers instead of a string. Based on patch by Guilherme Polo.
- **Issue #19403**: `contextlib.redirect_stdout` is now reentrant.
- **Issue #19286**: Directories in `package_data` are no longer added to the filelist, preventing failure outlined in the ticket.
- **Issue #19480**: `HTMLParser` now accepts all valid start-tag names as defined by the HTML5 standard.
- **Issue #15114**: The `html.parser` module now raises a `DeprecationWarning` when the `strict` argument of `HTMLParser` or the `HTMLParser.error` method are used.
- **Issue #19410**: Undo the special-casing removal of " for `importlib.machinery.FileFinder`.
- **Issue #19424**: Fix the warnings module to accept filename containing surrogate characters.
- **Issue #19435**: Fix directory traversal attack on `CGIHTTPRequestHandler`.
- **Issue #19227**: Remove `pthread_atfork()` handler. The handler was added to solve #18747 but has caused issues.
- **Issue #19420**: Fix reference leak in module initialization code of `_hashopenssl.c`
- **Issue #19329**: Optimized compiling charsets in regular expressions.
- **Issue #19227**: Try to fix deadlocks caused by re-seeding then OpenSSL pseudo-random number generator on `fork()`.
- **Issue #16037**: `HTTPMessage.readheaders()` raises an `HTTPException` when more than 100 headers are read. Adapted from patch by Jyrki Pulliainen.
- **Issue #16040**: CVE-2013-1752: `nntplib`: Limit maximum line lengths to 2048 to prevent `readline()` calls from consuming too much memory. Patch by Jyrki Pulliainen.
- **Issue #16041**: CVE-2013-1752: `poplib`: Limit maximum line lengths to 2048 to prevent `readline()` calls from consuming too much memory. Patch by Jyrki Pulliainen.
- **Issue #17997**: Change behavior of `ssl.match_hostname()` to follow RFC 6125, for security reasons. It now doesn’t match multiple wildcards nor wildcards inside IDN fragments.
- **Issue #16039**: CVE-2013-1752: Change use of readline in imaplib module to limit line length. Patch by Emil Lind.
- **Issue #19330**: The unnecessary wrapper functions have been removed from the implementations of the new contextlib.redirect_stdout and contextlib.suppress context managers, which also ensures they provide reasonable help() output on instances.
- **Issue #19393**: Fix symtable.symtable function to not be confused when there are functions or classes named “top”.
- **Issue #18685**: Restore re performance to pre-PEP 393 levels.
- **Issue #19339**: Telnetlib module is now using time.monotonic() when available to compute timeout.
- **Issue #19399**: Fix sporadic test_subprocess failure.
- **Issue #13234**: Fix os.listdir to work with extended paths on Windows. Patch by Santoso Wijaya.
- **Issue #19375**: The site module adding a “site-python” directory to sys.path, if it exists, is now deprecated.
- **Issue #19379**: Lazily import linecache in the warnings module, to make startup with warnings faster until a warning gets printed.
- **Issue #19288**: Fixed the “in” operator of dbm.gnu databases for string argument. Original patch by Arfrever Frehtes Taifersar Arahesis.
- **Issue #19287**: Fixed the “in” operator of dbm.ndbm databases for string argument. Original patch by Arfrever Frehtes Taifersar Arahesis.
- **Issue #19327**: Fixed the working of regular expressions with too big charset.
- **Issue #17400**: New ‘is_global’ attribute for ipaddress to tell if an address is allocated by IANA for global or private networks.
- **Issue #19350**: Increasing the test coverage of macurl2path. Patch by Colin Williams.
- **Issue #19365**: Optimized the parsing of long replacement string in re.sub*() functions.
- **Issue #19352**: Fix unittest discovery when a module can be
reached through several paths (e.g. under Debian/Ubuntu with virtualenv).

- **Issue #15207**: Fix mimetypes to read from correct part of Windows registry Original patch by Dave Chambers
- **Issue #16595**: Add prlimit() to resource module.
- **Issue #19324**: Expose Linux-specific constants in resource module.
- Load SSL's error strings in hashlib.
- **Issue #18527**: Upgrade internal copy of zlib to 1.2.8.
- **Issue #19274**: Add a filterfunc parameter to PyZipFile.writepy.
- **Issue #8964**: fix platform._sys_version to handle IronPython 2.6+. Patch by Martin Matusiak.
- **Issue #19413**: Restore pre-3.3 reload() semantics of re-finding modules.
- **Issue #18958**: Improve error message for json.load(s) while passing a string that starts with a UTF-8 BOM.
- **Issue #19307**: Improve error message for json.load(s) while passing objects of the wrong type.
- **Issue #16038**: CVE-2013-1752: ftplib: Limit amount of data read by limiting the call to readline(). Original patch by Michał Jastrzębski and Giampaolo Rodola.
- **Issue #17087**: Improved the repr for regular expression match objects.

Tests

- **Issue #19664**: test_userdict's repr test no longer depends on the order of dict elements.
- **Issue #19440**: Clean up test_capi by removing an unnecessary __future__ import, converting from test_main to unittest.main, and running the _testcapi module tests as subTests of a unittest TestCase method.
- **Issue #19378**: the main dis module tests are now run with both stdout redirection and passing an explicit file parameter
• **Issue #19378**: removed the not-actually-helpful assertInstructionMatches and assertBytecodeExactlyMatches helpers from bytecode_helper
• **Issue #18702**: All skipped tests now reported as skipped.
• **Issue #19439**: interpreter embedding tests are now executed on Windows (Patch by Zachary Ware)
• **Issue #19085**: Added basic tests for all tkinter widget options.
• **Issue #19384**: Fix test_py_compile for root user, patch by Claudiu Popa.

**Documentation**

• **Issue #18326**: Clarify that list.sort’s arguments are keyword-only. Also, attempt to reduce confusion in the glossary by not saying there are different “types” of arguments and parameters.

**Build**

• **Issue #19358**: “make clinic” now runs the Argument Clinic preprocessor over all CPython source files.
• Update SQLite to 3.8.1, xz to 5.0.5, and Tcl/Tk to 8.6.1 on Windows.
• **Issue #16632**: Enable DEP and ASLR on Windows.
• **Issue #17791**: Drop PREFIX and EXEC_PREFIX definitions from PC/pyconfig.h
• Add workaround for VS 2010 nmake clean issue. VS 2010 doesn’t set up PATH for nmake.exe correctly.
• **Issue #19550**: Implement Windows installer changes of PEP 453 (ensurepip).
• **Issue #19520**: Fix compiler warning in the _sha3 module on 32bit Windows.
• **Issue #19356**: Avoid using a C variable named “_self”, it’s a reserved word in some C compilers.
• **Issue #15792**: Correct build options on Win64. Patch by Jeremy Kloth.

• **Issue #19373**: Apply upstream change to Tk 8.5.15 fixing OS X 10.9 screen refresh problem for OS X installer build.

• **Issue #19649**: On OS X, the same set of file names are now installed in bin directories for all configurations: non-framework vs framework, and single arch vs universal builds. pythonx.y-32 is now always installed for 64-bit/32-bit universal builds. The obsolete and undocumented pythonw* symlinks are no longer installed anywhere.

• **Issue #19553**: PEP 453 - “make install” and “make altinstall” now install or upgrade pip by default, using the bundled pip provided by the new ensurepip module. A new configure option, --with-ensurepip=[=upgrade|install|no], is available to override the default ensurepip “–upgrade” option. The option can also be set with “make [alt]install ENSUREPIP=[=upgrade|install|no]”.

• **Issue #19551**: PEP 453 - the OS X installer now installs pip by default.

• Update third-party libraries for OS X installers: xz 5.0.3 -> 5.0.5, SQLite 3.7.13 -> 3.8.1

• **Issue #15663**: Revert OS X installer built-in Tcl/Tk support for 3.4.0b1. Some third-party projects, such as Matplotlib and PIL/Pillow, depended on being able to build with Tcl and Tk frameworks in /Library/Frameworks.

### Tools/Demos

• **Issue #19730**: Argument Clinic now supports all the existing PyArg “format units” as legacy converters, as well as two new features: “self converters” and the “version” directive.

• **Issue #19552**: pyenv now bootstraps pip into virtual environments by default (pass --without-pip to request the old behaviour)

• **Issue #19390**: Argument Clinic no longer accepts malformed
Python and C ids.
Python 3.4.0 Alpha 4?

Release date: 2013-10-20

Core and Builtins

- **Issue #19301**: Give classes and functions that are explicitly marked global a global qualname.
- **Issue #19279**: UTF-7 decoder no longer produces illegal strings.
- **Issue #16612**: Add “Argument Clinic”, a compile-time preprocessor for C files to generate argument parsing code. (See PEP 436.)
- **Issue #18810**: Shift stat calls in importlib.machinery.FileFinder such that the code is optimistic that if something exists in a directory named exactly like the possible package being searched for that it’s in actuality a directory.
- **Issue #18416**: importlib.machinery.PathFinder now treats ” as the cwd and importlib.machinery.FileFinder no longer special-cases ‘ ‘ to ‘.’. This leads to modules imported from cwd to now possess an absolute file path for __file__ (this does not affect modules specified by path on the CLI but it does affect -m/runpy). It also allows FileFinder to be more consistent by not having an edge case.
- **Issue #4555**: All exported C symbols are now prefixed with either “Py” or “_Py”.
- **Issue #19219**: Speed up marshal.loads(), and make pyc files slightly (5% to 10%) smaller.
- **Issue #19221**: Upgrade Unicode database to version 6.3.0.
- **Issue #16742**: The result of the C callback PyOS_ReadlineFunctionPointer must now be a string allocated by PyMem_RawMalloc() or PyMem_RawRealloc() (or NULL if an error occurred), instead of a string allocated by PyMem_Malloc() or PyMem_Realloc().
• **Issue #19199**: Remove PyThreadState.tick_counter field
  Fix macro expansion of _PyErr_OCCURRED(), and make sure to use it in at least one place so as to avoid regressions.
• **Issue #19087**: Improve bytearray allocation in order to allow cheap popping of data at the front (slice deletion).
• **Issue #19014**: memoryview.cast() is now allowed on zero-length views.
• **Issue #18690**: memoryview is now automatically registered with collections.abc.Sequence
• **Issue #19078**: memoryview now correctly supports the reversed builtin (Patch by Claudiu Popa)

Library

• **Issue #17457**: unittest test discovery now works with namespace packages. Patch by Claudiu Popa.
• **Issue #18235**: Fix the sysconfig variables LDSHARED and BLDSHARED under AIX. Patch by David Edelsohn.
• **Issue #18606**: Add the new “statistics” module (PEP 450). Contributed by Steven D'Aprano.
• **Issue #12866**: The audioop module now supports 24-bit samples.
• **Issue #19254**: Provide an optimized Python implementation of pbkdf2_hmac.
• Issues #19201, **Issue #19222**, **Issue #19223**: Add “x” mode (exclusive creation) in opening file to bz2, gzip and lzma modules. Patches by Tim Heaney and Vajrasky Kok.
• Fix a reference count leak in _sre.
• **Issue #19262**: Initial check in of the ‘asyncio’ package (a.k.a. Tulip, a.k.a. PEP 3156). There are no docs yet, and the PEP is slightly out of date with the code. This module will have provisional status in Python 3.4.
• **Issue #19276**: Fixed the wave module on 64-bit big-endian platforms.
• **Issue #19266**: Rename the new-in-3.4 contextlib.ignore
context manager to `contextlib.suppress` in order to be more consistent with existing descriptions of that operation elsewhere in the language and standard library documentation (Patch by Zero Piraeus).

- **Issue #18891**: Completed the new email package (provisional) API additions by adding new classes `EmailMessage`, `MIMEPart`, and `ContentManager`.
- **Issue #18281**: Unused stat constants removed from `tarfile`.
- **Issue #18999**: Multiprocessing now supports ‘contexts’ with the same API as the module, but bound to specified start methods.
- **Issue #18468**: The `re.split`, `re.findall`, and `re.sub` functions and the `group()` and `groups()` methods of match object now always return a string or a bytes object.
- **Issue #18725**: The textwrap module now supports truncating multiline text.
- **Issue #18776**: atexit callbacks now display their full traceback when they raise an exception.
- **Issue #17827**: Add the missing documentation for `codecs.encode` and `codecs.decode`.
- **Issue #19218**: Rename `collections.abc` to `_collections_abc` in order to speed up interpreter start.
- **Issue #18582**: Add ‘pbkdf2_hmac’ to the `hashlib` module. It implements PKCS#5 password-based key derivation functions with HMAC as pseudorandom function.
- **Issue #19131**: The aifc module now correctly reads and writes sampwidth of compressed streams.
- **Issue #19209**: Remove import of `copyreg` from the `os` module to speed up interpreter startup. `stat_result` and `statvfs_result` are now hard-coded to reside in the `os` module.
- **Issue #19205**: Don’t import the ‘re’ module in site and `sysconfig` module to speed up interpreter start.
- **Issue #9548**: Add a minimal “`_bootlocale`” module that is imported by the `_io` module instead of the full `locale` module.
- **Issue #18764**: Remove the ‘print’ alias for the PDB ‘p’ command
so that it no longer shadows the print function.

- **Issue #19158**: A rare race in BoundedSemaphore could allow .release() too often.
- **Issue #15805**: Add contextlib.redirect_stdout().
- **Issue #18716**: Deprecate the formatter module.
- **Issue #10712**: 2to3 has a new “asserts” fixer that replaces deprecated names of unittest methods (e.g. failUnlessEqual -> assertEqual).
- **Issue #18037**: 2to3 now escapes '\u' and '\U' in native strings.
- **Issue #17839**: base64.decodebytes and base64.encodebytes now accept any object that exports a 1 dimensional array of bytes (this means the same is now also true for base64_codec)
- **Issue #19132**: The pprint module now supports compact mode.
- **Issue #19137**: The pprint module now correctly formats instances of set and frozenset subclasses.
- **Issue #10042**: functools.total_ordering now correctly handles NotImplemented being returned by the underlying comparison function (Patch by Katie Miller)
- **Issue #19092**: contextlib.ExitStack now correctly reraises exceptions from the __exit__ callbacks of inner context managers (Patch by Hrvoje Nikšić)
- **Issue #12641**: Avoid passing “-mno-cygwin” to the mingw32 compiler, except when necessary. Patch by Oscar Benjamin.
- **Issue #5845**: In site.py, only load readline history from ~/.python_history if no history has been read already. This avoids double writes to the history file at shutdown.
- Properly initialize all fields of a SSL object after allocation.
- **Issue #19095**: SSLSocket.getpeercert() now raises ValueError when the SSL handshake hasn’t been done.
- **Issue #4366**: Fix building extensions on all platforms when –enable-shared is used.
- **Issue #19030**: Fixed inspect.getmembers and inspect.classify_class_attrs to attempt activating
descriptors before falling back to a \_dict\_ search for faulty descriptors. inspect.classify_class_attrs no longer returns Attributes whose home class is None.

C API

- **Issue #1772673**: The type of char* arguments now changed to const char*.
- **Issue #16129**: Added a Py_SetStandardStreamEncoding pre-initialization API to allow embedding applications like Blender to force a particular encoding and error handler for the standard IO streams (initial patch by Bastien Montagne)

Tests

- **Issue #19275**: Fix test_site on AMD64 Snow Leopard
- **Issue #14407**: Fix unittest test discovery in test_concurrent_futures.
- **Issue #18919**: Unified and extended tests for audio modules: aifc, sunau and wave.
- **Issue #18714**: Added tests for pdb.find_function().

Documentation

- **Issue #18758**: Fixed and improved cross-references.
- **Issue #18972**: Modernize email examples and use the argparse module in them.

Build

- **Issue #19130**: Correct PCbuild/readme.txt, Python 3.3 and 3.4 require VS 2010.
• **Issue #15663**: Update OS X 10.6+ installer to use Tcl/Tk 8.5.15.

• **Issue #14499**: Fix several problems with OS X universal build support:
  1. ppc arch detection for extension module builds broke with Xcode 5
  2. ppc arch detection in configure did not work on OS X 10.4
  3. -sysroot and -arch flags were unnecessarily duplicated
  4. there was no obvious way to configure an intel-32 only build.

• **Issue #19019**: Change the OS X installer build script to use CFLAGS instead of OPT for special build options. By setting OPT, some compiler-specific options like -fwrapv were overridden and thus not used, which could result in broken interpreters when building with clang.
Python 3.4.0 Alpha 3?

Release date: 2013-09-29

Core and Builtins

- **Issue #18818**: The “encodingname” part of PYTHONIOENCODING is now optional.
- **Issue #19098**: Prevent overflow in the compiler when the recursion limit is set absurdly high.

Library

- **Issue #18929**: inspect.classify_class_attrs() now correctly finds class attributes returned by dir() that are located in the metaclass.
- **Issue #18950**: Fix miscellaneous bugs in the sunau module. Au_read.readframes() now updates current file position and reads correct number of frames from multichannel stream. Au_write.writeframesraw() now correctly updates current file position. Au_read.getnframes() now returns an integer (as in Python 2). Au_read and Au_write now correctly works with file object if start file position is not a zero.
- **Issue #18594**: The fast path for collections.Counter() was never taken due to an over-restrictive type check.
- **Issue #19053**: ZipExtFile.read1() with non-zero argument no more returns empty bytes until end of data.
- logging: added support for Unix domain sockets to SocketHandler and DatagramHandler.
- **Issue #18996**: TestCase.assertEqual() now more cleverly shorten differing strings in error report.
- **Issue #19034**: repr() for tkinter.Tcl_Obj now exposes string
• Issue #18978: urllib.request.Request now allows the method to be indicated on the class and no longer sets it to None in __init__.
• Issue #18626: the inspect module now offers a basic command line introspection interface (Initial patch by Claudiu Popa)
• Issue #3015: Fixed tkinter with wantobject=False. Any Tcl command call returned empty string.
• Issue #19037: The mailbox module now makes all changes to maildir files before moving them into place, to avoid race conditions with other programs that may be accessing the maildir directory.
• Issue #14984: On POSIX systems, when netrc is called without a filename argument (and therefore is reading the user’s $HOME/.netrc file), it now enforces the same security rules as typical ftp clients: the .netrc file must be owned by the user that owns the process and must not be readable by any other user.
• Issue #18873: The tokenize module now detects Python source code encoding only in comment lines.
• Issue #17764: Enable http.server to bind to a user specified network interface. Patch contributed by Malte Swart.
• Issue #18937: Add an assertLogs() context manager to unittest.TestCase to ensure that a block of code emits a message using the logging module.
• Issue #17324: Fix http.server’s request handling case on trailing ‘/’. Patch contributed by Vajrasky Kok.
• Issue #19018: The heapq.merge() function no longer suppresses IndexError in the underlying iterables.
• Issue #18784: The uuid module no longer attempts to load libc via ctypes.CDLL if all the necessary functions have already been found in libuuid. Patch by Evgeny Sologubov.
• The PYTHONFAULTHANDLER environment variable now only enables the faulthandler module if the variable is non-empty.

Same behaviour than other variables like
PYTHONDONTWRITEBYTECODE.

- **Issue #1565525**: New function `traceback.clear_frames` will clear the local variables of all the stack frames referenced by a traceback object.

Tests

- **Issue #18952**: Fix regression in support data downloads introduced when `test.support` was converted to a package. Regression noticed by Zachary Ware.

IDLE

- **Issue #18873**: IDLE now detects Python source code encoding only in comment lines.
- **Issue #18988**: The “Tab” key now works when a word is already autocompleted.

Documentation

- **Issue #17003**: Unified the size argument names in the `io` module with common practice.

Build

- **Issue #18596**: Support the use of address sanity checking in recent versions of clang and GCC by appropriately marking known false alarms in the small object allocator. Patch contributed by Dhiru Kholia.

Tools/Demos
• **Issue #18873**: 2to3 and the findnocoding.py script now detect Python source code encoding only in comment lines.
Python 3.4.0 Alpha 2?

Release date: 2013-09-09

Core and Builtins

- **Issue #18942**: sys._debugmallocstats() output was damaged on Windows.
- **Issue #18571**: Implementation of the PEP 446: file descriptors and file handles are now created non-inheritable; add functions os.get/set_inheritable(), os.get/set_handle_inheritable() and socket.socket.get/set_inheritable().
- **Issue #11619**: The parser and the import machinery do not encode Unicode filenames anymore on Windows.
- **Issue #18808**: Non-daemon threads are now automatically joined when a sub-interpreter is shutdown (it would previously dump a fatal error).
- Remove support for compiling on systems without getcwd().
- **Issue #18774**: Remove last bits of GNU PTH thread code and thread_pth.h.
- **Issue #18771**: Add optimization to set object lookups to reduce the cost of hash collisions. The core idea is to inspect a second key/hash pair for each cache line retrieved.
- **Issue #16105**: When a signal handler fails to write to the file descriptor registered with signal.set_wakeup_fd(), report an exception instead of ignoring the error.
- **Issue #18722**: Remove uses of the “register” keyword in C code.
- **Issue #18667**: Add missing “HAVE_FCHOWNAT” symbol to posix._have_functions.
- **Issue #16499**: Add command line option for isolated mode.
- **Issue #15301**: Parsing fd, uid, and gid parameters for builtins in Modules/posixmodule.c is now far more robust.
• **Issue #18368**: PyOS_StdioReadline() no longer leaks memory when realloc() fail.

• **Issue #17934**: Add a clear() method to frame objects, to help clean up expensive details (local variables) and break reference cycles.

• **Issue #18780**: %-formatting codes %d, %i, and %u now treat int-subclasses as int (displays value of int-subclass instead of str(int-subclass)).

**Library**

• **Issue #18808**: Thread.join() now waits for the underlying thread state to be destroyed before returning. This prevents unpredictable aborts in Py_EndInterpreter() when some non-daemon threads are still running.

• **Issue #18458**: Prevent crashes with newer versions of libedit. Its readline emulation has changed from 0-based indexing to 1-based like gnu readline.

• **Issue #18852**: Handle case of readline.__doc__ being None in the new readline activation code in site.py.

• **Issue #18672**: Fixed format specifiers for Py_ssize_t in debugging output in the _sre module.

• **Issue #18830**: inspect.getclasstree() no longer produces duplicate entries even when input list contains duplicates.

• **Issue #18878**: sunau.open now supports the context management protocol. Based on patches by Claudiu Popa and R. David Murray.

• **Issue #18909**: Fix _tkinter.tkapp.interpaddr() on Windows 64-bit, don’t cast 64-bit pointer to long (32 bits).

• **Issue #18876**: The FileIO.mode attribute now better reflects the actual mode under which the file was opened. Patch by Erik Bray.

• **Issue #16853**: Add new selectors module.

• **Issue #18882**: Add threading.main_thread() function.

• **Issue #18901**: The sunau getparams method now returns a
namedtuple rather than a plain tuple. Patch by Claudiu Popa.

- **Issue #17487**: The result of the wave getparams method now is pickleable again. Patch by Claudiu Popa.
- **Issue #18756**: os.urandom() now uses a lazily-opened persistent file descriptor, so as to avoid using many file descriptors when run in parallel from multiple threads.
- **Issue #18418**: After fork(), reinit all threads states, not only active ones. Patch by A. Jesse Jiryu Davis.
- **Issue #17974**: Switch unittest from using getopt to using argparse.
- **Issue #11798**: TestSuite now drops references to own tests after execution.
- **Issue #16611**: http.cookie now correctly parses the ‘secure’ and ‘httponly’ cookie flags.
- **Issue #11973**: Fix a problem in kevent. The flags and fflags fields are now properly handled as unsigned.
- **Issue #18807**: pyvenv now takes a –copies argument allowing copies instead of symlinks even where symlinks are available and the default.
- **Issue #18538**: python -m dis now uses argparse for argument processing. Patch by Michele Orrù.
- **Issue #18394**: Close cgi.FieldStorage’s optional file.
- **Issue #17702**: On error, os.environb now suppresses the exception context when raising a new KeyError with the original key.
- **Issue #16809**: Fixed some tkinter incompatibilities with Tcl/Tk 8.6.
- **Issue #16809**: Tkinter’s splitlist() and split() methods now accept Tcl_Obj argument.
- **Issue #18324**: set_payload now correctly handles binary input. This also supersedes the previous fixes for #14360, #1717, and #16564.
- **Issue #18794**: Add a fileno() method and a closed attribute to select.devpoll objects.
- **Issue #17119**: Fixed integer overflows when processing large strings and tuples in the tkinter module.
• **Issue #18747**: Re-seed OpenSSL's pseudo-random number generator after fork. A pthread_atfork() parent handler is used to seed the PRNG with pid, time and some stack data.

• **Issue #8865**: Concurrent invocation of select.poll.poll() now raises a RuntimeError exception. Patch by Christian Schubert.

• **Issue #18777**: The ssl module now uses the new CRYPTO_THREADID API of OpenSSL 1.0.0+ instead of the deprecated CRYPTO id callback function.

• **Issue #18768**: Correct doc string of RAND_edg(). Patch by Vajrasky Kok.

• **Issue #18178**: Fix ctypes on BSD. dmalloc.c was compiled twice which broke malloc weak symbols.

• **Issue #18709**: Fix CVE-2013-4238. The SSL module now handles NULL bytes inside subjectAltName correctly. Formerly the module has used OpenSSL’s GENERAL_NAME_print() function to get the string representation of ASN.1 strings for rfc822Name (email), dNSName (DNS) and uniformResourceIdentifier (URI).

• **Issue #18701**: Remove support of old CPython versions (<3.0) from C code.

• **Issue #18756**: Improve error reporting in os.urandom() when the failure is due to something else than /dev/urandom not existing (for example, exhausting the file descriptor limit).

• **Issue #18673**: Add O_TMPFILE to os module. O_TMPFILE requires Linux kernel 3.11 or newer. It’s only defined on system with 3.11 uapi headers, too.

• **Issue #18532**: Change the builtin hash algorithms’ names to lower case names as promised by hashlib’s documentation.

• **Issue #8713**: add new spwan and forkserver start methods, and new functions get_all_start_methods, get_start_method, and set_start_method, to multiprocessing.

• **Issue #18405**: Improve the entropy of crypt.mksalt().

• **Issue #12015**: The tempfile module now uses a suffix of 8 random characters instead of 6, to reduce the risk of filename collision. The entropy was reduced when uppercase letters were removed
from the charset used to generate random characters.

- **Issue #18585**: Add `textwrap.shorten()` to collapse and truncate a piece of text to a given length.
- **Issue #18598**: Tweak exception message for `importlib.import_module()` to include the module name when a key argument is missing.
- **Issue #19151**: Fix docstring and use of `_get_supported_file_loaders()` to reflect 2-tuples.
- **Issue #19152**: Add `ExtensionFileLoader.get_filename()`.
- **Issue #18676**: Change ‘positive’ to ‘non-negative’ in `queue.py` put and get docstrings and `ValueError` messages. Patch by Zhongyue Luo
- Fix refcounting issue with extension types in `tkinter`.
- **Issue #8112**: `xmlrpc.server`’s `DocXMLRPCServer` server no longer raises an error if methods have annotations; it now correctly displays the annotations.
- **Issue #18600**: Added `policy` argument to `email.message.Message.as_string`, and `as_bytes` and `__bytes__` methods to `Message`.
- **Issue #18671**: Output more information when logging exceptions occur.
- **Issue #18621**: Prevent the site module’s patched builtins from keeping too many references alive for too long.
- **Issue #4885**: Add weakref support to `mmap` objects. Patch by Valerie Lambert.
- **Issue #8860**: Fixed rounding in `timedelta` constructor.
- **Issue #18849**: Fixed a Windows-specific tempfile bug where collision with an existing directory caused `mkstemp` and related APIs to fail instead of retrying. Report and fix by Vlad Shcherbina.
- **Issue #18920**: `argparse`’s default destination for the version action (`-v`, `--version`) has also been changed to `stdout`, to match the Python executable.

Tests
• **Issue #18623**: Factor out the `_SuppressCoreFiles` context manager into `test.support`. Patch by Valerie Lambert.

• **Issue #12037**: Fix `test_email` for desktop Windows.

• **Issue #15507**: `test_subprocess`'s `test_send_signal` could fail if the test runner were run in an environment where the process inherited an ignore setting for SIGINT. Restore the SIGINT handler to the desired `KeyboardInterrupt` raising one during that test.

• **Issue #16799**: Switched from `getopt` to `argparse` style in `regrtest`'s argument parsing. Added more tests for `regrtest`'s argument parsing.

• **Issue #18792**: Use “127.0.0.1” or “::1” instead of “localhost” as much as possible, since “localhost” goes through a DNS lookup under recent Windows versions.

**IDLE**

• **Issue #18489**: Add tests for `SearchEngine`. Original patch by Phil Webster.

**Documentation**

• **Issue #18743**: Fix references to non-existant “StringIO” module.

• **Issue #18783**: Removed existing mentions of Python long type in docstrings, error messages and comments.

**Build**

• **Issue #1584**: Provide configure options to override default search paths for Tcl and Tk when building `_tkinter`.

• **Issue #15663**: Tcl/Tk 8.5.14 is now included with the OS X 10.6+ 64-/32-bit installer. It is no longer necessary to install a third-party
version of Tcl/Tk 8.5 to work around the problems in the Apple-supplied Tcl/Tk 8.5 shipped in OS X 10.6 and later releases.

**Tools/Demos**

- **Issue #18922**: Now The Lib/smtpd.py and Tools/i18n/msgfmt.py scripts write their version strings to stdout, and not to stderr.
Python 3.4.0 Alpha 1?

Release date: 2013-08-03

Core and Builtins

- **Issue #16741**: Fix an error reporting in int().
- **Issue #17899**: Fix rare file descriptor leak in os.listdir().
- **Issue #10241**: Clear extension module dict copies at interpreter shutdown. Patch by Neil Schemenauer, minimally modified.
- **Issue #9035**: ismount now recognises volumes mounted below a drive root on Windows. Original patch by Atsuo Ishimoto.
- **Issue #18214**: Improve finalization of Python modules to avoid setting their globals to None, in most cases.
- **Issue #18112**: PEP 442 implementation (safe object finalization).
- **Issue #18552**: Check return value of PyArena_AddPyObject() in obj2ast_object().
- **Issue #18560**: Fix potential NULL pointer dereference in sum().
- **Issue #18520**: Add a new PyStructSequence_InitType2() function, same than PyStructSequence_InitType() except that it has a return value (0 on success, -1 on error).
- **Issue #15905**: Fix theoretical buffer overflow in handling of sys.argv[0], prefix and exec_prefix if the operation system does not obey MAXPATHLEN.
- **Issue #18408**: Fix many various bugs in code handling errors, especially on memory allocation failure (MemoryError).
- **Issue #18344**: Fix potential ref-leaks in _bufferedreader_read_all().
- **Issue #18342**: Use the repr of a module name when an import fails when using from ... import ....
- **Issue #17872**: Fix a segfault in marshal.load() when input stream returns more bytes than requested.
• **Issue #18338**: python --version now prints version string to stdout, and not to stderr. Patch by Berker Peksag and Michael Dickens.

• **Issue #18426**: Fix NULL pointer dereference in C extension import when PyModule_GetDef() returns an error.

• **Issue #17206**: On Windows, increase the stack size from 2 MB to 4.2 MB to fix a stack overflow in the marshal module (fix a crash in test_marshal). Patch written by Jeremy Kloth.

• **Issue #3329**: Implement the PEP 445: Add new APIs to customize Python memory allocators.

• **Issue #18328**: Reorder ops in PyThreadState_Delete*() functions. Now the tstate is first removed from TLS and then deallocated.

• **Issue #13483**: Use VirtualAlloc in obmalloc on Windows.

• **Issue #18184**: PyUnicode_FromFormat() and PyUnicode_FromFormatV() now raise OverflowError when an argument of %c format is out of range.

• **Issue #18111**: The min() and max() functions now support a default argument to be returned instead of raising a ValueError on an empty sequence. (Contributed by Julian Berman.)

• **Issue #18137**: Detect integer overflow on precision in float.__format__() and complex.__format__().

• **Issue #18183**: Fix various unicode operations on strings with large unicode codepoints.

• **Issue #18180**: Fix ref leak in _PyImport_GetDynLoadWindows().

• **Issue #18038**: SyntaxError raised during compilation sources with illegal encoding now always contains an encoding name.

• **Issue #17931**: Resolve confusion on Windows between pids and process handles.

• Tweak the exception message when the magic number or size value in a bytecode file is truncated.

• **Issue #17932**: Fix an integer overflow issue on Windows 64-bit in iterators: change the C type of seqiterobject.it_index from long to Py_ssize_t.

• **Issue #18065**: Don't set __path__ to the package name for frozen
packages.

- **Issue #18088**: When reloading a module, unconditionally reset all relevant attributes on the module (e.g. `__name__`, `__loader__`, `__package__`, `__file__`, `__cached__`).
- **Issue #17937**: Try harder to collect cyclic garbage at shutdown.
- **Issue #12370**: Prevent class bodies from interfering with the `__class__` closure.
- **Issue #17644**: Fix a crash in `str.format` when curly braces are used in square brackets.
- **Issue #17237**: Fix crash in the ASCII decoder on m68k.
- **Issue #17927**: Frame objects kept arguments alive if they had been copied into a cell, even if the cell was cleared.
- **Issue #1545463**: At shutdown, defer finalization of codec modules so that stdout remains usable.
- **Issue #7330**: Implement width and precision (ex: “%5.3s”) for the format string of `PyUnicode_FromFormat()` function, original patch written by Ysj Ray.
- **Issue #1545463**: Global variables caught in reference cycles are now garbage-collected at shutdown.
- **Issue #17094**: Clear stale thread states after `fork()`. Note that this is a potentially disruptive change since it may release some system resources which would otherwise remain perpetually alive (e.g. database connections kept in thread-local storage).
- **Issue #17408**: Avoid using an obsolete instance of the `copyreg` module when the interpreter is shutdown and then started again.
- **Issue #5845**: Enable tab-completion in the interactive interpreter by default, thanks to a new `sys.__interactivehook__`.
- **Issue #17115,17116**: Module initialization now includes setting `__package__` and `__loader__` attributes to None.
- **Issue #17853**: Ensure locals of a class that shadow free variables always win over the closures.
- **Issue #17863**: In the interactive console, don’t loop forever if the encoding can’t be fetched from stdin.
- **Issue #17867**: Raise an `ImportError` if `__import__` is not found in
__builtins__.

- **Issue #18698**: Ensure importlib.reload() returns the module out of sys.modules.
- **Issue #17857**: Prevent build failures with pre-3.5.0 versions of sqlite3, such as was shipped with Centos 5 and Mac OS X 10.4.
- **Issue #17413**: sys.settrace callbacks were being passed a string instead of an exception instance for the ‘value’ element of the arg tuple if the exception originated from C code; now an exception instance is always provided.
- **Issue #17782**: Fix undefined behaviour on platforms where struct timespec's “tv_nsec” member is not a C long.
- **Issue #17722**: When looking up `__round__`, resolve descriptors.
- **Issue #16061**: Speed up `str.replace()` for replacing 1-character strings.
- **Issue #17715**: Fix segmentation fault from raising an exception in a `__trunc__` method.
- **Issue #17643**: Add `__callback__` attribute to weakref.ref.
- **Issue #16447**: Fixed potential segmentation fault when setting `__name__` on a class.
- **Issue #17669**: Fix crash involving finalization of generators using `yield from`.
- **Issue #14439**: Python now prints the traceback on runpy failure at startup.
- **Issue #17469**: Fix `Py_GetAllocatedBlocks()` and `sys.getallocatedblocks()` when running on valgrind.
- **Issue #17619**: Make `input()` check for Ctrl-C correctly on Windows.
- **Issue #17357**: Add missing verbosity messages for `-v/-vv` that were lost during the importlib transition.
- **Issue #17610**: Don't rely on non-standard behavior of the C `qsort()` function.
- **Issue #17323**: The “[X refs, Y blocks]” printed by debug builds has been disabled by default. It can be re-enabled with the `-X showrefcount` option.
• Issue #17328: Fix possible refleak in dict.setdefault.
• Issue #17275: Corrected class name in init error messages of the C version of BufferedWriter and BufferedReader.
• Issue #7963: Fixed misleading error message that issued when object is called without arguments.
• Issue #8745: Small speed up zipimport on Windows. Patch by Catalin Iacob.
• Issue #5308: Raise ValueError when marshalling too large object (a sequence with size >= 2**31), instead of producing illegal marshal data.
• Issue #12983: Bytes literals with invalid \x escape now raise a SyntaxError and a full traceback including line number.
• Issue #16967: In function definition, evaluate positional defaults before keyword-only defaults.
• Issue #17173: Remove uses of locale-dependent C functions (isalpha() etc.) in the interpreter.
• Issue #17137: When an Unicode string is resized, the internal wide character string (wstr) format is now cleared.
• Issue #17043: The unicode-internal decoder no longer read past the end of input buffer.
• Issue #17098: All modules now have __loader__ set even if they pre-exist the bootstrapping of importlib.
• Issue #16979: Fix error handling bugs in the unicode-escape-decode decoder.
• Issue #16772: The base argument to the int constructor no longer accepts floats, or other non-integer objects with an __int__ method. Objects with an __index__ method are now accepted.
• Issue #10156: In the interpreter’s initialization phase, unicode globals are now initialized dynamically as needed.
• Issue #16980: Fix processing of escaped non-ascii bytes in the unicode-escape-decode decoder.
• Issue #16975: Fix error handling bug in the escape-decode bytes decoder.
• Issue #14850: Now a charmap decoder treats U+FFFE as
“undefined mapping” in any mapping, not only in a string.

- **Issue #16613**: Add \( m \) argument to collections.Chainmap.new_child to allow the new child map to be specified explicitly.

- **Issue #16730**: importlib.machinery.FileFinder now no longer raises an exception when trying to populate its cache and it finds out the directory is unreadable or has turned into a file. Reported and diagnosed by David Pritchard.

- **Issue #16906**: Fix a logic error that prevented most static strings from being cleared.

- **Issue #11461**: Fix the incremental UTF-16 decoder. Original patch by Amaury Forgeot d'Arc.

- **Issue #16856**: Fix a segmentation fault from calling \( \text{repr()} \) on a dict with a key whose \( \text{repr} \) raise an exception.

- **Issue #16367**: Fix \( \text{FileIO.readall()} \) on Windows for files larger than 2 GB.

- **Issue #16761**: Calling \( \text{int()} \) with base argument only now raises TypeError.

- **Issue #16759**: Support the full DWORD (unsigned long) range in Reg2Py when retrieving a REG_DWORD value. This corrects functions like winreg.QueryValueEx that may have been returning truncated values.

- **Issue #14420**: Support the full DWORD (unsigned long) range in Py2Reg when passed a REG_DWORD value. Fixes OverflowError in winreg.SetValueEx.

- **Issue #11939**: Set the \( \text{st_dev} \) attribute of \( \text{stat_result} \) to allow Windows to take advantage of the os.path.samefile/sameopenfile/samestat implementations used by other platforms.

- **Issue #16772**: The \( \text{int()} \) constructor’s second argument (base) no longer accepts non-integer values. Consistent with the behavior in Python 2.

- **Issue #14470**: Remove \w9xpopen support per PEP 11.

- **Issue #9856**: Replace deprecation warning with raising TypeError.
in object.__format__. Patch by Florent Xicluna.

- **Issue #16597**: In buffered and text IO, call close() on the underlying stream if invoking flush() fails.
- **Issue #16722**: In the bytes() constructor, try to call __bytes__ on the argument before __index__.
- **Issue #16421**: loading multiple modules from one shared object is now handled correctly (previously, the first module loaded from that file was silently returned). Patch by Václav Šmilauer.
- **Issue #16602**: When a weakref’s target was part of a long deallocation chain, the object could remain reachable through its weakref even though its refcount had dropped to zero.
- **Issue #16495**: Remove extraneous NULL encoding check from bytes_decode().
- **Issue #16619**: Create NameConstant AST class to represent None, True, and False literals. As a result, these constants are never loaded at runtime from builtins.
- **Issue #16455**: On FreeBSD and Solaris, if the locale is C, the ASCII/surrogateescape codec is now used (instead of the locale encoding) to decode the command line arguments. This change fixes inconsistencies with os.fsencode() and os.fsdecode(), because these operating systems announce an ASCII locale encoding, but actually use the ISO-8859-1 encoding in practice.
- **Issue #16562**: Optimize dict equality testing. Patch by Serhiy Storchaka.
- **Issue #16588**: Silence unused-but-set warnings in Python/thread_pthread
- **Issue #16592**: stringlib_bytes_join doesn’t raise MemoryError on allocation failure.
- **Issue #16546**: Fix: ast.YieldFrom argument is now mandatory.
- **Issue #16514**: Fix regression causing a traceback when sys.path[0] is None (actually, any non-string or non-bytes type).
- **Issue #16306**: Fix multiple error messages when unknown command line parameters where passed to the interpreter. Patch by Hieu Nguyen.
• **Issue #16215**: Fix potential double memory free in `str.replace()`. Patch by Serhiy Storchaka.

• **Issue #16290**: A float return value from the `__complex__` special method is no longer accepted in the `complex()` constructor.

• **Issue #16416**: On Mac OS X, operating system data are now always encoded/decoded to/from UTF-8/surrogateescape, instead of the locale encoding (which may be ASCII if no locale environment variable is set), to avoid inconsistencies with `os.fsencode()` and `os.fsdecode()` functions which are already using UTF-8/surrogateescape.

• **Issue #16453**: Fix equality testing of dead weakref objects.

• **Issue #9535**: Fix pending signals that have been received but not yet handled by Python to not persist after `os.fork()` in the child process.

• **Issue #14794**: Fix `slice.indices` to return correct results for huge values, rather than raising `OverflowError`.

• **Issue #15001**: Fix segfault on “`del sys.modules['__main__']`”. Patch by Victor Stinner.

• **Issue #8271**: the utf-8 decoder now outputs the correct number of U+FFFD characters when used with the ‘replace’ error handler on invalid utf-8 sequences. Patch by Serhiy Storchaka, tests by Ezio Melotti.

• **Issue #5765**: Apply a hard recursion limit in the compiler instead of blowing the stack and segfaulting. Initial patch by Andrea Griffini.

• **Issue #16402**: When slicing a range, fix shadowing of exceptions from `__index__`.

• **Issue #16336**: fix input checking in the surrogatepass error handler. Patch by Serhiy Storchaka.

• **Issue #8401**: assigning an int to a bytearray slice (e.g. `b[3:4] = 5`) now raises an error.

• **Issue #7317**: Display full tracebacks when an error occurs asynchronously. Patch by Alon Horev with update by Alexey Kachayev.
- **Issue #16309**: Make PYTHONPATH="" behavior the same as if PYTHONPATH not set at all.
- **Issue #10189**: Improve the error reporting of SyntaxErrors related to global and nonlocal statements.
- Fix segfaults on setting __qualname__ on builtin types and attempting to delete it on any type.
- **Issue #14625**: Rewrite the UTF-32 decoder. It is now 3x to 4x faster. Patch written by Serhiy Storchaka.
- **Issue #16345**: Fix an infinite loop when fromkeys on a dict subclass received a nonempty dict from the constructor.
- **Issue #16271**: Fix strange bugs that resulted from __qualname__ appearing in a class's __dict__ and on type.
- **Issue #12805**: Make bytes.join and bytearray.join faster when the separator is empty. Patch by Serhiy Storchaka.
- **Issue #6074**: Ensure cached bytecode files can always be updated by the user that created them, even when the source file is read-only.
- **Issue #15958**: bytes.join and bytearray.join now accept arbitrary buffer objects.
- **Issue #14783**: Improve int() docstring and switch docstrings for str(), range(), and slice() to use multi-line signatures.
- **Issue #16160**: Subclass support now works for types.SimpleNamespace.
- **Issue #16148**: Implement PEP 424, adding operator.length_hint and PyObject_LengthHint.
- Upgrade Unicode data (UCD) to version 6.2.
- **Issue #15379**: Fix passing of non-BMP characters as integers for the charmap decoder (already working as unicode strings). Patch by Serhiy Storchaka.
- **Issue #15144**: Fix possible integer overflow when handling pointers as integer values, by using Py_uintptr_t instead of size_t. Patch by Serhiy Storchaka.
- **Issue #15965**: Explicitly cast AT_FDCWD as (int). Required on Solaris 10 (which defines AT_FDCWD as 0xffd19553), harmless
on other platforms.

- **Issue #15839**: Convert SystemErrors in `super()` to RuntimeErrors.
- **Issue #15448**: Buffered IO now frees the buffer when closed, instead of when deallocating.
- **Issue #15846**: Fix SystemError which happened when using `ast.parse()` in an exception handler on code with syntax errors.
- **Issue #15897**: `zipimport.c` doesn’t check return value of `fseek()`. Patch by Felipe Cruz.
- **Issue #15801**: Make sure mappings passed to ‘%’ formatting are actually subscriptable.
- **Issue #15111**: `__import__` should propagate ImportError when raised as a side-effect of a module triggered from using `fromlist`.
- **Issue #15022**: Add pickle and comparison support to `types.SimpleNamespace`.

**Library**

- **Issue #4331**: Added `functools.partialmethod` (Initial patch by Alon Horev)
- **Issue #13461**: Fix a crash in the `TextIOWrapper.tell` method on 64-bit platforms. Patch by Yogesh Chaudhari.
- **Issue #18681**: Fix a NameError in `importlib.reload()` (noticed by Weizhao Li).
- **Issue #14323**: Expanded the number of digits in the coefficients for the RGB – YIQ conversions so that they match the FCC NTSC versions.
- **Issue #17998**: Fix an internal error in regular expression engine.
- **Issue #17557**: Fix `os.getgroups()` to work with the modified behavior of `getgroups(2)` on OS X 10.8. Original patch by Mateusz Lenik.
- **Issue #18608**: Avoid keeping a strong reference to the locale module inside the `_io` module.
- **Issue #18619**: Fix atexit leaking callbacks registered from sub-interpreters, and make it GC-aware.
- **Issue #15699**: The readline module now uses PEP 3121-style module initialization, so as to reclaim allocated resources (Python callbacks) at shutdown. Original patch by Robin Schreiber.
- **Issue #17616**: `wave.open` now supports the context management protocol.
- **Issue #18599**: Fix name attribute of `_sha1.sha1()` object. It now returns ‘SHA1’ instead of ‘SHA’.
- **Issue #13266**: Added `inspect.unwrap` to easily unravel `__wrapped__` chains (initial patch by Daniel Urban and Aaron Iles)
- **Issue #18561**: Skip name in `ctypes` `_build_callargs()` if name is NULL.
- **Issue #18559**: Fix NULL pointer dereference error in `_pickle` module
- **Issue #18556**: Check the return type of `PyUnicode_AsWideChar()` in `ctypes.U_set()`.
- **Issue #17818**: `aifc.getparams` now returns a `namedtuple`.
- **Issue #18549**: Eliminate dead code in `socket_ntohl()`
- **Issue #18530**: Remove additional stat call from `posixpath.ismount`. Patch by Alex Gaynor.
- **Issue #18514**: Fix unreachable `Py_DECREF()` call in `PyCData_FromBaseObj()`
- **Issue #9177**: Calling `read()` or `write()` now raises `ValueError`, not `AttributeError`, on a closed SSL socket. Patch by Senko Rasic.
- **Issue #18513**: Fix behaviour of `cmath.rect` w.r.t. signed zeros on OS X 10.8 + gcc.
- **Issue #18479**: Changed `venv Activate.ps1` to make `deactivate` a function, and removed `Deactivate.ps1`.
- **Issue #18480**: Add missing call to `PyType_Ready` to the `_elementtree` extension.
- **Issue #17778**: Fix test discovery for `test_multiprocessing`. (Patch by Zachary Ware.)
• **Issue #18393:** The private module _gestalt and private functions platform._mac_ver_gestalt, platform._mac_ver_lookup and platform._bcd2str have been removed. This does not affect the public interface of the platform module.

• **Issue #17482:** functools.update_wrapper (and functools.wraps) now set the __wrapped__ attribute correctly even if the underlying function has a __wrapped__ attribute set.

• **Issue #18431:** The new email header parser now decodes RFC2047 encoded words in structured headers.

• **Issue #18432:** The sched module’s queue method was incorrectly returning an iterator instead of a list.

• **Issue #18044:** The new email header parser was mis-parsing encoded words where an encoded character immediately followed the ‘?’ that follows the CTE character, resulting in a decoding failure. They are now decoded correctly.

• **Issue #18101:** Tcl.split() now process strings nested in a tuple as it do with byte strings.

• **Issue #18116:** getpass was always getting an error when testing /dev/tty, and thus was always falling back to stdin, and would then raise an exception if stdin could not be used (such as /dev/null). It also leaked an open file. All of these issues are now fixed.

• **Issue #17198:** Fix a NameError in the dbm module. Patch by Valentina Mukhamedzhanova.

• **Issue #18013:** Fix cgi.FieldStorage to parse the W3C sample form.

• **Issue #18020:** improve html.escape speed by an order of magnitude. Patch by Matt Bryant.

• **Issue #18347:** ElementTree’s html serializer now preserves the case of closing tags.

• **Issue #17261:** Ensure multiprocessing’s proxies use proper address.

• **Issue #18343:** faulthandler.register() now keeps the previous signal handler when the function is called twice, so faulthandler.unregister() restores correctly the original signal
handler.

- **Issue #17097**: Make multiprocessing ignore EINTR.
- **Issue #18339**: Negative ints keys in unpickler.memo dict no longer cause a segfault inside the _pickle C extension.
- **Issue #18240**: The HMAC module is no longer restricted to bytes and accepts any bytes-like object, e.g. memoryview. Original patch by Jonas Borgström.
- **Issue #18224**: Removed pydoc script from created venv, as it causes problems on Windows and adds no value over and above python -m pydoc ...
- **Issue #18155**: The csv module now correctly handles csv files that use a delimiter character that has a special meaning in regexes, instead of throwing an exception.
- **Issue #14360**: encode_quopri can now be successfully used as an encoder when constructing a MIMEApplication object.
- **Issue #11390**: Add -o and -f command line options to the doctest CLI to specify doctest options (and convert it to using argparse).
- **Issue #18135**: ssl.SSLSocket.write() now raises an OverflowError if the input string in longer than 2 gigabytes, and ssl.SSLContext.load_cert_chain() raises a ValueError if the password is longer than 2 gigabytes. The ssl module does not support partial write.
- **Issue #11016**: Add C implementation of the stat module as _stat.
- **Issue #18248**: Fix libffi build on AIX.
- **Issue #18259**: Declare sethostname in socketmodule.c for AIX
- **Issue #18147**: Add diagnostic functions to ssl.SSLContext(). get_ca_list() lists all loaded CA certificates and cert_store_stats() returns amount of loaded X.509 certs, X.509 CA certs and CRLs.
- **Issue #18167**: cgi.FieldStorage no longer fails to handle multipart/form-data when \r\n appears at end of 65535 bytes without other newlines.
- **Issue #18076**: Introduce importlib.util.decode_source().
- **Issue #18357**: add tests for dictview set difference. Patch by Fraser Tweedale.
• importlib.abc.SourceLoader.get_source() no longer changes SyntaxError or UnicodeDecodeError into ImportError.

• **Issue #18058, 18057**: Make the namespace package loader meet the importlib.abc.InspectLoader ABC, allowing for namespace packages to work with runpy.

• **Issue #17177**: The imp module is pending deprecation.

• subprocess: Prevent a possible double close of parent pipe fds when the subprocess exec runs into an error. Prevent a regular multi-close of the /dev/null fd when any of stdin, stdout and stderr was set to DEVNULL.

• **Issue #18194**: Introduce importlib.util.cache_from_source() and source_from_cache() while documenting the equivalent functions in imp as deprecated.

• **Issue #17907**: Document imp.new_module() as deprecated in favour of types.ModuleType.

• **Issue #18192**: Introduce importlib.util.MAGIC_NUMBER and document as deprecated imp.get_magic().

• **Issue #18149**: Add filecmp.clear_cache() to manually clear the filecmp cache. Patch by Mark Levitt

• **Issue #18193**: Add importlib.reload().

• **Issue #18157**: Stop using imp.load_module() in pydoc.

• **Issue #16102**: Make uuid._netbios_getnode() work again on Python 3.

• **Issue #17134**: Add ssl.enum_cert_store() as interface to Windows’ cert store.

• **Issue #18143**: Implement ssl.get_default_verify_paths() in order to debug the default locations for cafile and capath.

• **Issue #17314**: Move multiprocessing.forking over to importlib.

• **Issue #11959**: SMTPServer and SMTPChannel now take an optional map, use of which avoids affecting global state.

• **Issue #18109**: os.uname() now decodes fields from the locale encoding, and socket.gethostname() now decodes the hostname from the locale encoding, instead of using the UTF-8 encoding in strict mode.
• **Issue #18089:** Implement `importlib.abc.InspectLoader.load_module`.

• **Issue #18088:** Introduce `importlib.abc.Loader.init_module_attrs` for setting module attributes. Leads to the pending deprecation of `importlib.util.module_for_loader`.

• **Issue #17403:** `urllib.parse.robotparser` normalizes the urls before adding to ruleline. This helps in handling certain types invalid urls in a conservative manner. Patch contributed by Mher Movsisyan.

• **Issue #18070:** Have `importlib.util.module_for_loader()` set attributes unconditionally in order to properly support reloading. Added `importlib.util.module_to_load` to return a context manager to provide the proper module object to load.

• **Issue #18025:** Fixed a segfault in `io.BufferedIOBase.readinto()` when raw stream’s `read()` returns more bytes than requested.

• **Issue #18011:** As was originally intended, `base64.b32decode()` now raises a `binascii.Error` if there are non-b32-alphabet characters present in the input string, instead of a `TypeError`.

• **Issue #18072:** Implement `importlib.abc.InspectLoader.get_code()` and `importlib.abc.ExecutionLoader.get_code()`.

• **Issue #8240:** Set the `SSL_MODE_ACCEPT_MOVING_WRITE_BUFFER` flag on SSL sockets.

• **Issue #17269:** Workaround for `socket.getaddrinfo` crash on MacOS X with port None or “0” and flags `AI_NUMERICSERV`.

• **Issue #16986:** `ElementTree` now correctly works with string input when the internal XML encoding is not UTF-8 or US-ASCII.

• **Issue #17996:** `socket` module now exposes `AF_LINK` constant on BSD and OSX.

• **Issue #17900:** Allowed pickling of recursive `OrderedDicts`. Decreased pickled size and pickling time.

• **Issue #17914:** Add `os.cpu_count()`. Patch by Yogesh Chaudhari, based on an initial patch by Trent Nelson.

• **Issue #17812:** Fixed quadratic complexity of `base64.b32encode()`. Optimize `base64.b32encode()` and `base64.b32decode()` (speed
up to 3x).

- **Issue #17980**: Fix possible abuse of ssl.match_hostname() for denial of service using certificates with many wildcards (CVE-2013-2099).
- **Issue #15758**: Fix FileIO.readall() so it no longer has O(n**2) complexity.
- **Issue #14596**: The struct.Struct() objects now use a more compact implementation.
- **Issue #17981**: logging's SysLogHandler now closes the socket when it catches socket OSErrors.
- **Issue #17964**: Fix os.sysconf(): the return type of the C sysconf() function is long, not int.
- Fix typos in the multiprocessing module.
- **Issue #17754**: Make ctypes.util.find_library() independent of the locale.
- **Issue #17968**: Fix memory leak in os.listdirattr().
- **Issue #17606**: Fixed support of encoded byte strings in the XMLGenerator characters() and ignorableWhitespace() methods. Original patch by Sebastian Ortiz Vasquez.
- **Issue #17732**: Ignore distutils.cfg options pertaining to install paths if a virtual environment is active.
- **Issue #17915**: Fix interoperability of xml.sax with file objects returned by codecs.open().
- **Issue #16601**: Restarting iteration over tarfile really restarts rather than continuing from where it left off. Patch by Michael Birtwell.
- **Issue #17289**: The readline module now plays nicer with external modules or applications changing the rl_completer_word_break_characters global variable. Initial patch by Bradley Froehle.
- **Issue #12181**: select module: Fix struct kevent definition on OpenBSD 64-bit platforms. Patch by Federico Schwindt.
- **Issue #11816**: multiple improvements to the dis module: get_instructions generator, ability to redirect output to a file, Bytecode and Instruction abstractions. Patch by Nick Coghlan,
Ryan Kelly and Thomas Kluyver.

- **Issue #13831**: Embed stringification of remote traceback in local traceback raised when pool task raises an exception.
- **Issue #15528**: Add weakref.finalize to support finalization using weakref callbacks.
- **Issue #14173**: Avoid crashing when reading a signal handler during interpreter shutdown.
- **Issue #15902**: Fix imp.load_module() accepting None as a file when loading an extension module.
- **Issue #13721**: SSLSocket.getpeercert() and SSLSocket.do_handshake() now raise an OSErr or with ENOTCONN, instead of an AttributeError, when the SSLSocket is not connected.
- **Issue #14679**: add an __all__ (that contains only HTMLParser) to html.parser.
- **Issue #17802**: Fix an UnboundLocalError in html.parser. Initial tests by Thomas Barlow.
- **Issue #17358**: Modules loaded by imp.load_source() and load_compiled() (and by extention load_module()) now have a better chance of working when reloaded.
- **Issue #17804**: New function struct.iter_unpack allows for streaming struct unpacking.
- **Issue #17830**: When keyword.py is used to update a keyword file, it now preserves the line endings of the original file.
- **Issue #17272**: Making the urllib.request’s Request.full_url a descriptor. Fixes bugs with assignment to full_url. Patch by Demian Brecht.
- **Issue #17353**: Plistlib emitted empty data tags with deeply nested datastructures
- **Issue #11714**: Use ‘with’ statements to assure a Semaphore releases a condition variable. Original patch by Thomas Rachel.
- **Issue #16624**: subprocess.check_output now accepts an input argument, allowing the subprocess’s stdin to be provided as a (byte) string. Patch by Zack Weinberg.
• Issue #17795: Reverted backwards-incompatible change in SysLogHandler with Unix domain sockets.
• Issue #16694: Add a pure Python implementation of the operator module. Patch by Zachary Ware.
• Issue #11182: remove the unused and undocumented pydoc.Scanner class. Patch by Martin Morrison.
• Issue #17741: Add ElementTree.XMLPullParser, an event-driven parser for non-blocking applications.
• Issue #17555: Fix ForkAwareThreadLock so that size of after fork registry does not grow exponentially with generation of process.
• Issue #17707: fix regression in multiprocessing.Queue’s get() method where it did not block for short timeouts.
• Issue #17720: Fix the Python implementation of pickle.Unpickler to correctly process the APPENDS opcode when it is used on non-list objects.
• Issue #17012: shutil.which() no longer falls back to the PATH environment variable if an empty path argument is specified. Patch by Serhiy Storchaka.
• Issue #17710: Fix pickle raising a SystemError on bogus input.
• Issue #17341: Include the invalid name in the error messages from re about invalid group names.
• Issue #17702: os.environ now raises KeyError with the original environment variable name (str on UNIX), instead of using the encoded name (bytes on UNIX).
• Issue #16163: Make the importlib based version of pkgutil.iter_importers work for submodules. Initial patch by Berker Peksag.
• Issue #16804: Fix a bug in the ‘site’ module that caused running ‘python -S -m site’ to incorrectly throw an exception.
• Issue #15480: Remove the deprecated and unused TYPE_INT64 code from marshal. Initial patch by Daniel Riti.
• Issue #2118: SMTPException is now a subclass of OSError.
• Issue #17016: Get rid of possible pointer wraparounds and integer overflows in the re module. Patch by Nickolai Zeldovich.
• **Issue #16658**: add missing return to HTTPConnection.send(). Patch by Jeff Knupp.
• **Issue #9556**: the logging package now allows specifying a time-of-day for a TimedRotatingFileHandler to rotate.
• **Issue #14971**: unittest test discovery no longer gets confused when a function has a different `__name__` than its name in the TestCase class dictionary.
• **Issue #17487**: The wave getparams method now returns a namedtuple rather than a plain tuple.
• **Issue #17675**: socket `repr()` provides local and remote addresses (if any). Patch by Giampaolo Rodola'
• **Issue #17093**: Make the ABCs in importlib.abc provide default values or raise reasonable exceptions for their methods to make them more amenable to `super()` calls.
• **Issue #17566**: Make importlib.abc.Loader.module_repr() optional instead of an abstractmethod; now it raises `NotImplementedError` so as to be ignored by default.
• **Issue #17678**: Remove the use of deprecated method in http/cookiejar.py by changing the call to `get_origin_req_host()` to `origin_req_host`.
• **Issue #17666**: Fix reading gzip files with an extra field.
• **Issue #16475**: Support object instancing, recursion and interned strings in marshal
• **Issue #17502**: Process DEFAULT values in mock side_effect that returns iterator.
• **Issue #16795**: On the `ast.arguments` object, unify `vararg` with `varargannotation` and `kwarg` and `kwargannotation`. Change the column offset of `ast.Attribute` to be at the attribute name.
• **Issue #17434**: Properly raise a SyntaxError when a string occurs between future imports.
• **Issue #17117**: Import and `@importlib.util.set_loader` now set `__loader__` when it has a value of None or the attribute doesn’t exist.
• **Issue #17032**: The “global” in the “NameError: global name ‘x’ is
not defined" error message has been removed. Patch by Ram Rachum.

- **Issue #18080**: When building a C extension module on OS X, if the compiler is overridden with the CC environment variable, use the new compiler as the default for linking if LDSHARED is not also overridden. This restores Distutils behavior introduced in 3.2.3 and inadvertently dropped in 3.3.0.

- **Issue #18113**: Fixed a refcount leak in the curses.panel module's set_userptr() method. Reported by Atsuo Ishimoto.

- Implement PEP 443 “Single-dispatch generic functions”.

- Implement PEP 435 “Adding an Enum type to the Python standard library”.

- **Issue #15596**: Faster pickling of unicode strings.

- **Issue #17572**: Avoid chained exceptions when passing bad directives to time.strptime(). Initial patch by Claudiu Popa.

- **Issue #17435**: threading.Timer’s __init__ method no longer uses mutable default values for the args and kwargs parameters.

- **Issue #17526**: fix an IndexError raised while passing code without filename to inspect.findsource(). Initial patch by Tyler Doyle.

- **Issue #17540**: Added style parameter to logging formatter configuration by dict.

- **Issue #16692**: The ssl module now supports TLS 1.1 and TLS 1.2. Initial patch by Michele Orrù.

- **Issue #17025**: multiprocessing: Reduce Queue and SimpleQueue contention.

- **Issue #17536**: Add to webbrowser’s browser list: www-browser, x-www-browser, iceweasel, iceape.

- **Issue #17150**: pprint now uses line continuations to wrap long string literals.

- **Issue #17488**: Change the subprocess.Popen bufsize parameter default value from unbuffered (0) to buffering (-1) to match the behavior existing code expects and match the behavior of the subprocess module in Python 2 to avoid introducing hard to track down bugs.
- **Issue #17521**: Corrected non-enabling of logger following two calls to `fileConfig()`.
- **Issue #17508**: Corrected logging MemoryHandler configuration in `dictConfig()` where the target handler wasn’t configured first.
- **Issue #17209**: `curses.window.get_wch()` now correctly handles `KeyboardInterrupt` (CTRL+c).
- **Issue #5713**: `smtplib` now handles 421 (closing connection) error codes when sending mail by closing the socket and reporting the 421 error code via the exception appropriate to the command that received the error response.
- **Issue #16997**: `unittest.TestCase` now provides a `subTest()` context manager to procedurally generate, in an easy way, small test instances.
- **Issue #17485**: Also delete the Request Content-Length header if the data attribute is deleted. (Follow on to issue **Issue #16464**).
- **Issue #15927**: `CVS` now correctly parses escaped newlines and carriage when parsing with quoting turned off.
- **Issue #17467**: add `readline` and `readlines` support to `mock_open` in `unittest.mock`.
- **Issue #13248**: removed deprecated and undocumented `difflib.isbjunk, isbpopular`.
- **Issue #17192**: Update the `ctypes` module’s `libffi` to v3.0.13. This specifically addresses a stack misalignment issue on x86 and issues on some more recent platforms.
- **Issue #8862**: Fixed curses cleanup when `getkey` is interrupted by a signal.
- **Issue #17443**: `imaplib.IMAP4_stream` was using the default unbuffered IO in subprocess, but the imap code assumes buffered IO. In Python2 this worked by accident. `IMAP4_stream` now explicitly uses buffered IO.
- **Issue #17476**: Fixed regression relative to Python2 in undocumented pydoc ‘allmethods’; it was missing unbound methods on the class.
- **Issue #17474**: Remove the deprecated methods of Request class.
• **Issue #16709**: unittest discover order is no-longer filesystem specific. Patch by Jeff Ramnani.
• Use the HTTPS PyPI url for upload, overriding any plain HTTP URL in pypirc.
• **Issue #5024**: sndhdr.whichhdr now returns the frame count for WAV files rather than -1.
• **Issue #17460**: Remove the strict argument of HTTPConnection and removing the DeprecationWarning being issued from 3.2 onwards.
• **Issue #16880**: Do not assume _imp.load_dynamic() is defined in the imp module.
• **Issue #16389**: Fixed a performance regression relative to Python 3.1 in the caching of compiled regular expressions.
• Added missing FeedParser and BytesFeedParser to email.parser.__all__.
• **Issue #17431**: Fix missing import of BytesFeedParser in email.parser.
• **Issue #12921**: http.server’s send_error takes an explain argument to send more information in response. Patch contributed by Karl.
• **Issue #17414**: Add timeit, repeat, and default_timer to timeit.__all__.
• **Issue #1285086**: Get rid of the refcounting hack and speed up urllib.parse.unquote() and urllib.parse.unquote_to_bytes().
• **Issue #17099**: Have importlib.find_loader() raise ValueError when __loader__ is not set, harmonizing with what happens when the attribute is set to None.
• Expose the O_PATH constant in the os module if it is available.
• **Issue #17368**: Fix an off-by-one error in the Python JSON decoder that caused a failure while decoding empty object literals when object_pairs_hook was specified.
• **Issue #17385**: Fix quadratic behavior in threading.Condition. The FIFO queue now uses a deque instead of a list.
• **Issue #15806**: Add contextlib.ignore(). This creates a context manager to ignore specified exceptions, replacing the “except
SomeException: pass" idiom.

- **Issue #14645**: The email generator classes now produce output using the specified linesep throughout. Previously if the prolog, epilog, or body were stored with a different linesep, that linesep was used. This fix corrects an RFC non-compliance issue with smtplib.send_message.

- **Issue #17278**: Fix a crash in heapq.heappush() and heapq.heappop() when the list is being resized concurrently.

- **Issue #16962**: Use getdents64 instead of the obsolete getdents syscall in the subprocess module on Linux.

- **Issue #16935**: unittest now counts the module as skipped if it raises SkipTest, instead of counting it as an error. Patch by Zachary Ware.

- **Issue #17018**: Make Process.join() retry if os.waitpid() fails with EINTR.

- **Issue #17223**: array module: Fix a crasher when converting an array containing invalid characters (outside range \([U+0000; U+10ffff]\)) to Unicode: repr(array), str(array) and array.tounicode(). Patch written by Manuel Jacob.

- **Issue #17197**: profile/cProfile modules refactored so that code of run() and runctx() utility functions is not duplicated in both modules.

- **Issue #14720**: sqlite3: Convert datetime microseconds correctly. Patch by Lowe Thideman.

- **Issue #15132**: Allow a list for the defaultTest argument of unittest.TestProgram. Patch by Jyrki Pulliainen.

- **Issue #17225**: JSON decoder now counts columns in the first line starting with 1, as in other lines.

- **Issue #6623**: Added explicit DeprecationWarning for ftplib.netrc, which has been deprecated and undocumented for a long time.

- **Issue #13700**: Fix byte/string handling in imaplib authentication when an authobject is specified.

- **Issue #13153**: Tkinter functions now raise TclError instead of ValueError when a string argument contains non-BMP character.
- **Issue #9669**: Protect re against infinite loops on zero-width matching in non-greedy repeat. Patch by Matthew Barnett.
- **Issue #13169**: The maximal repetition number in a regular expression has been increased from 65534 to 2147483647 (on 32-bit platform) or 4294967294 (on 64-bit).
- **Issue #17143**: Fix a missing import in the trace module. Initial patch by Berker Peksag.
- **Issue #15220**: email.feedparser's line splitting algorithm is now simpler and faster.
- **Issue #16743**: Fix mmap overflow check on 32 bit Windows.
- **Issue #16996**: webbrowser module now uses shutil.which() to find a web-browser on the executable search path.
- **Issue #16800**: tempfile.gettempdir() no longer left temporary files when the disk is full. Original patch by Amir Szekely.
- **Issue #17192**: Import libffi-3.0.12.
- **Issue #16564**: Fixed regression relative to Python2 in the operation of email.encoders.encode_7or8bit when used with binary data.
- **Issue #17052**: unittest discovery should use self.testLoader.
- **Issue #4591**: Uid and gid values larger than 2**31 are supported now.
- **Issue #17141**: random.vonmisesvariate() no longer hangs for large kappas.
- **Issue #17149**: Fix random.vonmisesvariate to always return results in [0, 2*math.pi].
- **Issue #1470548**: XMLGenerator now works with binary output streams.
- **Issue #6975**: os.path.realpath() now correctly resolves multiple nested symlinks on POSIX platforms.
- **Issue #13773**: sqlite3.connect() gets a new uri parameter to pass the filename as a URI, allowing to pass custom options.
- **Issue #16564**: Fixed regression relative to Python2 in the operation of email.encoders.encode_noop when used with binary data.
- **Issue #10355**: The mode, name, encoding and newlines properties now work on SpooledTemporaryFile objects even when they have not yet rolled over. Obsolete method xreadline (which has never worked in Python 3) has been removed.

- **Issue #16686**: Fixed a lot of bugs in audioop module. Fixed crashes in avgpp(), maxpp() and ratecv(). Fixed an integer overflow in add(), bias(), and ratecv(). reverse(), lin2lin() and ratecv() no more lose precision for 32-bit samples. max() and rms() no more returns a negative result and various other functions now work correctly with 32-bit sample -0x80000000.

- **Issue #17073**: Fix some integer overflows in sqlite3 module.

- **Issue #16723**: httplib.HTTPResponse no longer marked closed when the connection is automatically closed.

- **Issue #15359**: Add CAN_BCM protocol support to the socket module. Patch by Brian Thorne.

- **Issue #16948**: Fix quoted printable body encoding for non-latin1 character sets in the email package.

- **Issue #16811**: Fix folding of headers with no value in the provisional email policies.

- **Issue #17132**: Update symbol for “yield from” grammar changes.

- **Issue #17076**: Make copying of xattrs more tolerant of missing FS support. Patch by Thomas Wouters.

- **Issue #17089**: Expat parser now correctly works with string input when the internal XML encoding is not UTF-8 or US-ASCII. It also now accepts bytes and strings larger than 2 GiB.

- **Issue #6083**: Fix multiple segmentation faults occured when PyArg_ParseTuple parses nested mutating sequence.

- **Issue #5289**: Fix ctypes.util.find_library on Solaris.

- **Issue #17106**: Fix a segmentation fault in io.TextIOWrapper when an underlying stream or a decoder produces data of an unexpected type (i.e. when io.TextIOWrapper initialized with text stream or use bytes-to-bytes codec).

- **Issue #17015**: When it has a spec, a Mock object now inspects its signature when matching calls, so that arguments can be
matched positionally or by name.

- **Issue #15633**: `httplib.HTTPResponse` is now marked closed when the server sends less than the advertised Content-Length.
- **Issue #12268**: The `io` module file object write methods no longer abort early when one of its write system calls is interrupted (EINTR).
- **Issue #6972**: The `zipfile` module no longer overwrites files outside of its destination path when extracting malicious zip files.
- **Issue #4844**: `ZipFile` now raises `BadZipFile` when opens a ZIP file with an incomplete “End of Central Directory” record. Original patch by Guilherme Polo and Alan McIntyre.
- **Issue #17071**: `Signature.bind()` now works when one of the keyword arguments is named `self`.
- **Issue #12004**: Fix an internal error in `PyZipFile` when writing an invalid Python file. Patch by Ben Morgan.
- **Issue #16972**: `site.addpackage()` consider already known paths even when none are explicitly passed in. Bug report and fix by Kirill.
- **Issue #1602133**: on Mac OS X a shared library build (`--enable-shared`) now fills the `os.environ` variable correctly.
- **Issue #15505**: `unittest.installHandler` no longer assumes SIGINT handler is set to a callable object.
- **Issue #13454**: Fix a crash when deleting an iterator created by `itertools.tee()` if all other iterators were very advanced before.
- **Issue #12411**: Fix to `cgi.parse_multipart` to correctly use bytes boundaries and bytes data. Patch by Jonas Wagner.
- **Issue #16957**: `shutil.which()` no longer searches a bare file name in the current directory on Unix and no longer searches a relative file path with a directory part in PATH directories. Patch by
Thomas Kluyver.

- **Issue #1159051**: GzipFile now raises EOFError when reading a corrupted file with truncated header or footer.
- **Issue #16993**: shutil.which() now preserves the case of the path and extension on Windows.
- **Issue #16992**: On Windows in signal.set_wakeup_fd, validate the file descriptor argument.
- **Issue #16422**: For compatibility with the Python version, the C version of decimal now uses strings instead of integers for rounding mode constants.
- **Issue #15861**: tkinter now correctly works with lists and tuples containing strings with whitespaces, backslashes or unbalanced braces.
- **Issue #9720**: zipfile now writes correct local headers for files larger than 4 GiB.
- **Issue #16955**: Fix the poll() method for multiprocessing's socket connections on Windows.
- SSLContext.load_dh_params() now properly closes the input file.
- **Issue #15031**: Refactor some .pyc management code to cut down on code duplication. Thanks to Ronan Lamy for the report and taking an initial stab at the problem.
- **Issue #16398**: Optimize deque.rotate() so that it only moves pointers and doesn't touch the underlying data with increfs and decrefs.
- **Issue #16900**: Issue a ResourceWarning when an ssl socket is left unclosed.
- **Issue #13899**: \A, \Z, and \B now correctly match the A, Z, and B literals when used inside character classes (e.g. ' [\A ] '). Patch by Matthew Barnett.
- **Issue #15545**: Fix regression in sqlite3's iterdump method where it was failing if the connection used a row factory (such as sqlite3.Row) that produced unsortable objects. (Regression was introduced by fix for 9750).
- fcntl: add F_DUPFD_CLOEXEC constant, available on Linux
2.6.24+.

- **Issue #15972**: Fix error messages when os functions expecting a file name or file descriptor receive the incorrect type.
- **Issue #8109**: The ssl module now has support for server-side SNI, thanks to a `SSLContext.set_servername_callback()` method. Patch by Daniel Black.
- **Issue #16860**: In tempfile, use O_CLOEXEC when available to set the close-on-exec flag atomically.
- **Issue #16674**: `random.getrandbits()` is now 20-40% faster for small integers.
- **Issue #16009**: JSON error messages now provide more information.
- **Issue #16828**: Fix error incorrectly raised by `bz2.compress(b'')` and `bz2.BZ2Compressor.compress(b'')`. Initial patch by Martin Packman.
- **Issue #16833**: In `http.client.HTTPConnection`, do not concatenate the request headers and body when the payload exceeds 16 KB, since it can consume more memory for no benefit. Patch by Benno Leslie.
- **Issue #16541**: `tk_setPalette()` now works with keyword arguments.
- **Issue #16820**: In `configparser`, `parser.popitem()` no longer raises `ValueError`. This makes `parser.clean()` work correctly.
- **Issue #16820**: In `configparser`, `parser['section'] = {}` now preserves section order within the parser. This makes `parser.update()` preserve section order as well.
- **Issue #16820**: In `configparser`, `parser['DEFAULT'] = {}` now correctly clears previous values stored in the default section. Same goes for `parser.update({'DEFAULT': {}})`.
- **Issue #9586**: Redefine `SEM_FAILED` on MacOSX to keep compiler happy.
- **Issue #16787**: Increase asyncore and asynchat default output buffers size, to decrease CPU usage and increase throughput.
- **Issue #10527**: make multiprocessing use `poll()` instead of `select()`
if available.

- **Issue #16688**: Now regexes contained backreferences correctly work with non-ASCII strings. Patch by Matthew Barnett.
- **Issue #16486**: Make aifc files act as context managers.
- **Issue #16485**: Now file descriptors are closed if file header patching failed on closing an aifc file.
- **Issue #16640**: Run less code under a lock in sched module.
- **Issue #16165**: sched.scheduler.run() no longer blocks a scheduler for other threads.
- **Issue #16641**: Default values of sched.scheduler.enter() are no longer modifiable.
- **Issue #16618**: Make glob.glob match consistently across strings and bytes regarding leading dots. Patch by Serhiy Storchaka.
- **Issue #16788**: Add samestat to Lib/ntpath.py
- **Issue #16713**: Parsing of ‘tel’ urls using urlparse separates params from path.
- **Issue #16443**: Add docstrings to regular expression match objects. Patch by Anton Kasyanov.
- **Issue #15701**: Fix HTTPError info method call to return the headers information.
- **Issue #16752**: Add a missing import to modulefinder. Patch by Berker Peksag.
- **Issue #16646**: ftplib.FTP.makeport() might lose socket error details. (patch by Serhiy Storchaka)
- **Issue #16626**: Fix infinite recursion in glob.glob() on Windows when the pattern contains a wildcard in the drive or UNC path. Patch by Serhiy Storchaka.
- **Issue #15783**: Except for the number methods, the C version of decimal now supports all None default values present in decimal.py. These values were largely undocumented.
- **Issue #11175**: argparse.FileType now accepts encoding and errors arguments. Patch by Lucas Maystre.
- **Issue #16488**: epoll() objects now support the with statement. Patch by Serhiy Storchaka.
- **Issue #16298**: In HTTPResponse.read(), close the socket when there is no Content-Length and the incoming stream is finished. Patch by Eran Rundstein.
- **Issue #16049**: Add abc.ABC class to enable the use of inheritance to create ABCs, rather than the more cumbersome metaclass=ABCMeta. Patch by Bruno Dupuis.
- Expose the TCP_FASTOPEN and MSG_FASTOPEN flags in socket when they’re available.
  - **Issue #15701**: Add a .headers attribute to urllib.error.HTTPError. Patch contributed by Berker Peksag.
- **Issue #15872**: Fix 3.3 regression introduced by the new fd-based shutil.rmtree that caused it to not ignore certain errors when ignore_errors was set. Patch by Alessandro Moura and Serhiy Storchaka.
- **Issue #16248**: Disable code execution from the user’s home directory by tkinter when the -E flag is passed to Python. Patch by Zachary Ware.
- **Issue #13390**: New function `sys.getallocatedblocks()` returns the number of memory blocks currently allocated.
- **Issue #16628**: Fix a memory leak in ctypes.resize().
- **Issue #13614**: Fix setup.py register failure with invalid rst in description. Patch by Julien Courteau and Pierre Paul Lefebvre.
- **Issue #13512**: Create ~/.pypirc securely (CVE-2011-4944). Initial patch by Philip Jenvey, tested by Mageia and Debian.
- **Issue #7719**: Make distutils ignore .nfs* files instead of choking later on. Initial patch by SilentGhost and Jeff Ramnani.
- **Issue #13120**: Allow to call pdb.set_trace() from thread. Patch by Ilya Sandler.
- **Issue #16585**: Make CJK encoders support error handlers that return bytes per PEP 383.
- **Issue #10182**: The re module doesn’t truncate indices to 32 bits anymore. Patch by Serhiy Storchaka.
- **Issue #16333**: use (",", ": " ) as default separator in json when indent is specified, to avoid trailing whitespace. Patch by Serhiy
- **Issue #16573**: In 2to3, treat `enumerate()` like a consuming call, so superfluous `list()` calls aren't added to `filter()`, `map()`, and `zip()` which are directly passed `enumerate()`.
- **Issue #16464**: Reset the Content-Length header when a `urllib` Request is reused with new data.
- **Issue #12848**: The pure Python pickle implementation now treats object lengths as unsigned 32-bit integers, like the C implementation does. Patch by Serhiy Storchaka.
- **Issue #16423**: `urllib.request` now has support for data: URLs. Patch by Mathias Panzenböck.
- **Issue #4473**: Add a `POP3.stls()` to switch a clear-text POP3 session into an encrypted POP3 session, on supported servers. Patch by Lorenzo Catucci.
- **Issue #4473**: Add a `POP3.capa()` method to query the capabilities advertised by the POP3 server. Patch by Lorenzo Catucci.
- **Issue #4473**: Ensure the socket is shutdown cleanly in `POP3.close()`. Patch by Lorenzo Catucci.
- **Issue #16522**: added FAIL_FAST flag to doctest.
- **Issue #15627**: Add the `importlib.abc.InspectLoader.source_to_code()` method.
- **Issue #16408**: Fix file descriptors not being closed in error conditions in the zipfile module. Patch by Serhiy Storchaka.
- **Issue #14631**: Add a new `weakref.WeakMethod` to simulate weak references to bound methods.
- **Issue #16469**: Fix exceptions from float -> Fraction and Decimal -> Fraction conversions for special values to be consistent with those for float -> int and Decimal -> int. Patch by Alexey Kachayev.
- **Issue #16481**: multiprocessing no longer leaks process handles on Windows.
- **Issue #12428**: Add a pure Python implementation of `functools.partial()`. Patch by Brian Thorne.
- **Issue #16140**: The subprocess module no longer double closes
its child subprocess.PIPE parent file descriptors on child error prior to exec().

- Remove a bare print to stdout from the subprocess module that could have happened if the child process wrote garbage to its pre-exec error pipe.

- The subprocess module now raises its own SubprocessError instead of a RuntimeError in various error situations which should not normally happen.

- **Issue #16327**: The subprocess module no longer leaks file descriptors used for stdin/stdout/STDERR pipes to the child when fork() fails.

- **Issue #14396**: Handle the odd rare case of waitpid returning 0 when not expected in subprocess.Popen.wait().

- **Issue #16411**: Fix a bug where zlib.decompressobj().flush() might try to access previously-freed memory. Patch by Serhiy Storchaka.

- **Issue #16357**: Fix calling accept() on a SSLSocket created through SSLContext.wrap_socket(). Original patch by Jeff McNeil.

- **Issue #16409**: The reporthook callback made by the legacy urllib.request.urlretrieve API now properly supplies a constant non-zero block_size as it did in Python 3.2 and 2.7. This matches the behavior of urllib.request.URLopener.retrieve.

- **Issue #16431**: Use the type information when constructing a Decimal subtype from a Decimal argument.

- **Issue #15641**: Clean up deprecated classes from importlib. Patch by Taras Lyapun.

- **Issue #16350**: zlib.decompressobj().decompress() now accumulates data from successive calls after EOF in unused_data, instead of only saving the argument to the last call. decompressobj().flush() now correctly sets unused_data and unconsumed_tail. A bug in the handling of MemoryError when setting the unconsumed_tail attribute has also been fixed. Patch by Serhiy Storchaka.

- **Issue #12759**: sre_parse now raises a proper error when the
name of the group is missing. Initial patch by Serhiy Storchaka.

- **Issue #16152**: fix tokenize to ignore whitespace at the end of the code when no newline is found. Patch by Ned Batchelder.
- **Issue #16284**: Prevent keeping unnecessary references to worker functions in concurrent.futures ThreadPoolExecutor.
- **Issue #16230**: Fix a crash in select.select() when one the lists changes size while it is being encoded. Patch by Serhiy Storchaka.
- **Issue #16228**: Fix a crash in the json module where a list changes size while it is being encoded. Patch by Serhiy Storchaka.
- **Issue #16351**: New function gc.get_stats() returns per-generation collection statistics.
- **Issue #14897**: Enhance error messages of struct.pack and struct.pack_into. Patch by Matti Mäki.
- **Issue #16316**: mimetypes now recognizes the .xz and .txz (.tar.xz) extensions. Patch by Serhiy Storchaka.
- **Issue #12890**: cgitb no longer prints spurious <p> tags in text mode when the logdir option is specified.
- **Issue #16307**: Fix multiprocessing.Pool.map_async not calling its callbacks. Patch by Janne Karila.
- **Issue #16305**: Fix a segmentation fault occurring when interrupting math.factorial.
- **Issue #16116**: Fix include and library paths to be correct when building C extensions in venvs.
- **Issue #16245**: Fix the value of a few entities in html.entities.html5.
- **Issue #16301**: Fix the localhost verification in urllib/request.py for file:// urls.
- **Issue #16250**: Fix the invocations of URLError which had misplaced filename attribute for exception.
- **Issue #10836**: Fix exception raised when file not found in urllretrive Initial patch by Ezio Melotti.
- **Issue #14398**: Fix size truncation and overflow bugs in the bz2 module.
- **Issue #12692**: Fix resource leak in urllib.request when talking to an HTTP server that does not include a Connection: close
header in its responses.

- **Issue #12034**: Fix bogus caching of result in check_GetFinalPathNameByHandle. Patch by Atsuo Ishimoto.
- Improve performance of `lzma.LZMAFile` (see also issue #16034).
- **Issue #16220**: wsgiref now always calls close() on an iterable response. Patch by Brent Tubbs.
- **Issue #16270**: urllib may hang when used for retrieving files via FTP by using a context manager. Patch by Giampaolo Rodola.
- **Issue #16461**: Wave library should be able to deal with 4GB wav files, and sample rate of 44100 Hz.
- **Issue #16176**: Properly identify Windows 8 via `platform.platform()`.
- **Issue #16088**: BaseHTTPRequestHandler’s send_error method includes a Content-Length header in its response now. Patch by Antoine Pitrou.
- **Issue #16114**: The subprocess module no longer provides a misleading error message stating that args[0] did not exist when either the cwd or executable keyword arguments specified a path that did not exist.
- **Issue #16169**: Fix ctypes.WinError()’s confusion between errno and winerror.
- **Issue #16110**: logging.fileConfig now accepts a pre-initialised ConfigParser instance.
- **Issue #1492704**: shutil.copyfile() raises a distinct SameFileError now if source and destination are the same file. Patch by Atsuo Ishimoto.
- **Issue #13896**: Make shelf instances work with ‘with’ as context managers. Original patch by Filip Gruszczynski.
- **Issue #15417**: Add support for csh and fish in venv activation scripts.
- **Issue #14377**: ElementTree.write and some of the module-level functions have a new parameter - `short_empty_elements`. It controls how elements with no contents are emitted.
- **Issue #16089**: Allow ElementTree.TreeBuilder to work again with
a non-Element element_factory (fixes a regression in SimpleTAL).

- **Issue #9650**: List commonly used format codes in time.strftime and time.strptime docsttings. Original patch by Mike Hoy.
- **Issue #15452**: logging configuration socket listener now has a verify option that allows an application to apply a verification function to the received configuration data before it is acted upon.
- **Issue #16034**: Fix performance regressions in the new `bz2.BZ2File` implementation. Initial patch by Serhiy Storchaka.
- `pty.spawn()` now returns the child process status returned by `os.waitpid()`.
- **Issue #15756**: `subprocess.poll()` now properly handles `errno.ECHILD` to return a returncode of 0 when the child has already exited or cannot be waited on.
- **Issue #15323**: Improve failure message of `Mock.assert_called_once_with()`.
- **Issue #16064**: `unittest -m` claims executable is “python”, not “python3”.
- **Issue #12376**: Pass on parameters in `TextTestResult.__init__() super call.`
- **Issue #15222**: Insert blank line after each message in mbox mailboxes.
- **Issue #16013**: Fix csv.Reader parsing issue with ending quote characters. Patch by Serhiy Storchaka.
- **Issue #15421**: Fix an OverflowError in `Calendar.itermonthdates()` after `datetime.MAXYEAR`. Patch by Cédric Krier.
- **Issue #16112**: `platform.architecture` does not correctly escape argument to `/usr/bin/file`. Patch by David Benjamin.
- **Issue #15970**: `xml.etree.ElementTree` now serializes correctly the empty HTML elements 'meta' and 'param'.
- **Issue #15842**: The `SocketIO.{readable,writable,seekable}` methods now raise `ValueError` when the file-like object is closed. Patch by Alessandro
Moura.

- **Issue #15876**: Fix a refleak in the `curses` module: `window.encoding`.
- **Issue #15881**: Fix `atexit` hook in `multiprocessing`. Original patch by Chris McDonough.
- **Issue #15841**: The `readable()`, `writable()` and `seekable()` methods of `io.BytesIO` and `io.StringIO` objects now raise `ValueError` when the object has been closed. Patch by Alessandro Moura.
- **Issue #15447**: Use `subprocess.DEVNULL` in `webbrowser`, instead of opening `os.devnull` explicitly and leaving it open.
- **Issue #15509**: `webbrowser.UnixBrowser` no longer passes empty arguments to `Popen` when `%action` substitutions produce empty strings.
- **Issue #12776, issue #11839**: Call `argparse` type function (specified by `add_argument`) only once. Before, the type function was called twice in the case where the default was specified and the argument was given as well. This was especially problematic for the `FileType` type, as a default file would always be opened, even if a file argument was specified on the command line.
- **Issue #15906**: Fix a regression in `argparse` caused by the preceding change, when `action='append'`, `type='str'` and `default=[]`.
- **Issue #16113**: Added sha3 module based on the Keccak reference implementation 3.2. The `hashlib` module has four additional hash algorithms: `sha3_224`, `sha3_256`, `sha3_384` and `sha3_512`. As part of the patch some common code was moved from `_hashopenssl.c` to `hashlib.h`.
- `ctypes.call_commethod` was removed, since its only usage was in the defunct samples directory.
- **Issue #16692**: Added TLSv1.1 and TLSv1.2 support for the ssl modules.
- **Issue #16832**: add `abc.get_cache_token()` to expose cache validity checking support in ABCMeta.
IDLE

- **Issue #18429**: Format / Format Paragraph, now works when comment blocks are selected. As with text blocks, this works best when the selection only includes complete lines.
- **Issue #18226**: Add docstrings and unittests for FormatParagraph.py. Original patches by Todd Rovito and Phil Webster.
- **Issue #18279**: Format - Strip trailing whitespace no longer marks a file as changed when it has not been changed. This fix followed the addition of a test file originally written by Phil Webster (the issue's main goal).
- **Issue #7136**: In the Idle File menu, “New Window” is renamed “New File”. Patch by Tal Einat, Roget Serwy, and Todd Rovito.
- Remove dead imports of imp.
- **Issue #18196**: Avoid displaying spurious SystemExit tracebacks.
- **Issue #5492**: Avoid traceback when exiting IDLE caused by a race condition.
- **Issue #17511**: Keep IDLE find dialog open after clicking “Find Next”. Original patch by Sarah K.
- **Issue #18055**: Move IDLE off of imp and on to importlib.
- **Issue #15392**: Create a unittest framework for IDLE. Initial patch by Rajagopalasarma Jayakrishnan. See Lib/idlelib/idle_test/README.txt for how to run Idle tests.
- **Issue #14146**: Highlight source line while debugging on Windows.
- **Issue #17838**: Allow sys.stdin to be reassigned.
- **Issue #13495**: Avoid loading the color delegator twice in IDLE.
- **Issue #17798**: Allow IDLE to edit new files when specified on command line.
- **Issue #14735**: Update IDLE docs to omit “Control-z on Windows”.
- **Issue #17532**: Always include Options menu for IDLE on OS X. Patch by Guilherme Simões.
- **Issue #17585**: Fixed IDLE regression. Now closes when using
exit() or quit().

- **Issue #17657**: Show full Tk version in IDLE's about dialog. Patch by Todd Rovito.
- **Issue #17613**: Prevent traceback when removing syntax colorizer in IDLE.
- **Issue #1207589**: Backwards-compatibility patch for right-click menu in IDLE.
- **Issue #16887**: IDLE now accepts Cancel in tabify/untabify dialog box.
- **Issue #17625**: In IDLE, close the replace dialog after it is used.
- **Issue #14254**: IDLE now handles readline correctly across shell restarts.
- **Issue #17614**: IDLE no longer raises exception when quickly closing a file.
- **Issue #6698**: IDLE now opens just an editor window when configured to do so.
- **Issue #8900**: Using keyboard shortcuts in IDLE to open a file no longer raises an exception.
- **Issue #6649**: Fixed missing exit status in IDLE. Patch by Guilherme Polo.
- **Issue #17114**: IDLE now uses non-strict config parser.
- **Issue #9290**: In IDLE the sys.std* streams now implement io.TextIOBase interface and support all mandatory methods and properties.
- **Issue #5066**: Update IDLE docs. Patch by Todd Rovito.
- **Issue #16829**: IDLE printing no longer fails if there are spaces or other special characters in the file path.
- **Issue #16491**: IDLE now prints chained exception tracebacks.
- **Issue #16819**: IDLE method completion now correctly works for bytes literals.
- **Issue #16504**: IDLE now catches SyntaxErrors raised by tokenizer. Patch by Roger Serwy.
- **Issue #16511**: Use default IDLE width and height if config param is not valid. Patch Serhiy Storchaka.
• **Issue #1207589**: Add Cut/Copy/Paste items to IDLE right click Context Menu. Patch by Todd Rovito.

• **Issue #16123**: IDLE - deprecate running without a subprocess. Patch by Roger Serwy.

Tests

• **Issue #1666318**: Add a test that shutil.copytree() retains directory permissions. Patch by Catherine Devlin.

• **Issue #18273**: move the tests in Lib/test/json_tests to Lib/test/test_json and make them discoverable by unittest. Patch by Zachary Ware.

• Fix a fcntl test case on KFreeBSD, Debian #708653 (Petr Salinger).

• **Issue #18396**: Fix spurious test failure in test_signal on Windows when faulthandler is enabled (Patch by Jeremy Kloth)

• **Issue #17046**: Fix broken test_executable_without_cwd in test_subprocess.

• **Issue #15415**: Add new temp_dir() and change_cwd() context managers to test.support, and refactor temp_cwd() to use them. Patch by Chris Jerdonek.

• **Issue #15494**: test.support is now a package rather than a module (Initial patch by Indra Talip)

• **Issue #17944**: test_zipfile now discoverable and uses subclassing to generate tests for different compression types. Fixed a bug with skipping some tests due to use of exhausted iterators.

• **Issue #18266**: test_largefile now works with unittest test discovery and supports running only selected tests. Patch by Zachary Ware.

• **Issue #17767**: test_locale now works with unittest test discovery. Original patch by Zachary Ware.

• **Issue #18375**: Assume –randomize when –randseed is used for running the testsuite.

• **Issue #11185**: Fix test_wait4 under AIX. Patch by Sébastien Sablé.
• **Issue #18207**: Fix test_ssl for some versions of OpenSSL that ignore seconds in ASN1_TIME fields.

• **Issue #18094**: test_uuid no longer reports skipped tests as passed.

• **Issue #17992**: Add timeouts to asyncore and asynchat tests so that they won’t accidentally hang.

• **Issue #17833**: Fix test_gdb failures seen on machines where debug symbols for glibc are available (seen on PPC64 Linux).

• **Issue #7855**: Add tests for ctypes/winreg for issues found in IronPython. Initial patch by Dino Viehland.

• **Issue #11078**: test___all__ now checks for duplicates in __all__. Initial patch by R. David Murray.

• **Issue #17712**: Fix test_gdb failures on Ubuntu 13.04.

• **Issue #17835**: Fix test_io when the default OS pipe buffer size is larger than one million bytes.

• **Issue #17065**: Use process-unique key for winreg tests to avoid failures if test is run multiple times in parallel (eg: on a buildbot host).

• **Issue #12820**: add tests for the xml.dom.minicompapt module. Patch by John Chandler and Phil Connell.

• **Issue #17691**: test_univnewlines now works with unittest test discovery. Patch by Zachary Ware.

• **Issue #17790**: test_set now works with unittest test discovery. Patch by Zachary Ware.

• **Issue #17789**: test_random now works with unittest test discovery. Patch by Zachary Ware.

• **Issue #17779**: test_osx_env now works with unittest test discovery. Patch by Zachary Ware.

• **Issue #17766**: test_iterlen now works with unittest test discovery. Patch by Zachary Ware.

• **Issue #17690**: test_time now works with unittest test discovery. Patch by Zachary Ware.

• **Issue #17692**: test_sqlite now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #11995**: test_pydoc doesn’t import all sys.path modules anymore.
• **Issue #17448**: test_sax now skips if there are no xml parsers available instead of raising an ImportError.
• **Issue #11420**: make test suite pass with -B/DONTWRITEBYTECODE set. Initial patch by Thomas Wouters.
• **Issue #10652**: make tcl/tk tests run after __all__ test, patch by Zachary Ware.
• **Issue #11963**: remove human verification from test_parser and test_subprocess.
• **Issue #11732**: add a new suppress_crash_popup() context manager to test.support that disables crash popups on Windows and use it in test_faulthandler and test_capi.
• **Issue #13898**: test_ssl no longer prints a spurious stack trace on Ubuntu.
• **Issue #17283**: Share code between __main__.py and regrtest.py in Lib/test.
• **Issue #17249**: convert a test in test_capi to use unittest and reap threads.
• **Issue #17107**: Test client-side SNI support in urllib.request thanks to the new server-side SNI support in the ssl module. Initial patch by Daniel Black.
• **Issue #17041**: Fix testing when Python is configured with the –without-doc-strings.
• **Issue #16923**: Fix ResourceWarnings in test_ssl.
• **Issue #15539**: Added regression tests for Tools/scripts/pindent.py.
• **Issue #17479**: test_io now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #17066**: test_robotparser now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #17334**: test_index now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #17333**: test_imaplib now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #17082**: test_dbm* now work with unittest test discovery. Patch by Zachary Ware.
• **Issue #17079**: test_ctypes now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #17304**: test_hash now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #17303**: test_future* now work with unittest test discovery. Patch by Zachary Ware.
• **Issue #17163**: test_file now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #16925**: test_configparser now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #16918**: test_codecs now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #16919**: test_crypt now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #16910**: test_bytes, test_unicode, and test_userstring now work with unittest test discovery. Patch by Zachary Ware.
• **Issue #16905**: test_warnings now works with unittest test discovery. Initial patch by Berker Peksag.
• **Issue #16898**: test_bufio now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #16888**: test_array now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #16896**: test_asyncore now works with unittest test discovery. Patch by Zachary Ware.
• **Issue #16897**: test_bisect now works with unittest test discovery. Initial patch by Zachary Ware.
• **Issue #16852**: test_genericpath, test_posixpath, test_ntpath, and test_macpath now work with unittest test discovery. Patch by Zachary Ware.
• **Issue #16748**: test_heapq now works with unittest test discovery.
• **Issue #10646**: Tests rearranged for os.samefile/samestat to check for not just symlinks but also hard links.
• **Issue #15302**: Switch regrttest from using getopt to using argparse.

• **Issue #15324**: Fix regrttest parsing of –fromfile, –match, and – randomize options.

• **Issue #16702**: test_urlib2_localnet tests now correctly ignores proxies for localhost tests.

• **Issue #16664**: Add regression tests for glob’s behaviour concerning entries starting with a ”.”. Patch by Sebastian Kreft.

• **Issue #13390**: The -R option to regrttest now also checks for memory allocation leaks, using `sys.getallocatedblocks()`.

• **Issue #16559**: Add more tests for the json module, including some from the official test suite at json.org. Patch by Serhiy Storchaka.

• **Issue #16661**: Fix the `os.getgrouplist()` test by not assuming that it gives the same output as `id -G`.

• **Issue #16115**: Add some tests for the executable argument to subprocess.Popen(). Initial patch by Kushal Das.

• **Issue #16126**: PyErr_Format format mismatch in _testcapimodule.c. Patch by Serhiy Storchaka.

• **Issue #15304**: Fix warning message when `os.chdir()` fails inside `test.support.temp_cwd()`. Patch by Chris Jerdonek.

• **Issue #15802**: Fix test logic in `TestMaildir.test_create_tmp()`. Patch by Serhiy Storchaka.

• **Issue #15557**: Added a test suite for the webbrowser module, thanks to Anton Barkovsky.

• **Issue #16698**: Skip posix test_getgroups when built with OS X deployment target prior to 10.6.

**Build**

• **Issue #16067**: Add description into MSI file to replace installer’s temporary name.

• **Issue #18257**: Fix readlink usage in python-config. Install the
python version again on Darwin.

- **Issue #18481**: Add C coverage reporting with gcov and lcov. A new make target “coverage-report” creates an instrumented Python build, runs unit tests and creates a HTML. The report can be updated with “make coverage-lcov”.

- **Issue #17845**: Clarified the message printed when some module are not built.

- **Issue #18256**: Compilation fix for recent AIX releases. Patch by David Edelsohn.

- **Issue #17547**: In configure, explicitly pass -Wformat for the benefit for GCC 4.8.

- **Issue #15172**: Document NASM 2.10+ as requirement for building OpenSSL 1.0.1 on Windows.

- **Issue #17591**: Use lowercase filenames when including Windows header files. Patch by Roumen Petrov.

- **Issue #17550**: Fix the –enable-profiling configure switch.

- **Issue #17425**: Build with openssl 1.0.1d on Windows.

- **Issue #16754**: Fix the incorrect shared library extension on linux. Introduce two makefile macros SHLIB_SUFFIX and EXT_SUFFIX. SO now has the value of SHLIB_SUFFIX again (as in 2.x and 3.1). The SO macro is removed in 3.4.

- **Issue #5033**: Fix building of the sqlite3 extension module when the SQLite library version has “beta” in it. Patch by Andreas Pelme.

- **Issue #17228**: Fix building without pymalloc.

- **Issue #3718**: Use AC_ARG_VAR to set MACHDEP in configure.ac.

- **Issue #16235**: Implement python-config as a shell script.

- **Issue #16769**: Remove outdated Visual Studio projects.

- **Issue #17031**: Fix running regen in cross builds.

- **Issue #3754**: fix typo in pthread AC_CACHE_VAL.

- **Issue #15484**: Fix _PYTHON_PROJECT_BASE for srcdir != builddir builds; use _PYTHON_PROJECT_BASE in distutils/sysconfig.py.
- Drop support for Windows 2000 (changeset e52df05b496a).
- Issue #17029: Let h2py search the multiarch system include directory.
- Issue #16953: Fix socket module compilation on platforms with HAVE_BROKEN_POLL. Patch by Jeffrey Armstrong.
- Issue #16320: Remove redundant Makefile dependencies for strings and bytes.
- Cross compiling needs host and build settings. configure no longer creates a broken PYTHON_FOR_BUILD variable when –build is missing.
- Fix cross compiling issue in setup.py, ensure that lib_dirs and inc_dirs are defined in cross compiling mode, too.
- Issue #16836: Enable IPv6 support even if IPv6 is disabled on the build host.
- Issue #16593: Have BSD ‘make -s’ do the right thing, thanks to Daniel Shahaf
- Issue #16262: fix out-of-src-tree builds, if mercurial is not installed.
- Issue #15298: ensure _sysconfigdata is generated in build directory, not source directory.
- Issue #15833: Fix a regression in 3.3 that resulted in exceptions being raised if importlib failed to write byte-compiled files. This affected attempts to build Python out-of-tree from a read-only source directory.
- Issue #15923: Fix a mistake in asdl_c.py that resulted in a TypeError after 2801bf875a24 (see #15801).
- Issue #16135: Remove OS/2 support.
- Issue #15819: Make sure we can build Python out-of-tree from a read-only source directory. (Somewhat related to issue #9860.)
- Issue #15587: Enable Tk high-resolution text rendering on Macs with Retina displays. Applies to Tkinter apps, such as IDLE, on OS X framework builds linked with Cocoa Tk 8.5.
- Issue #17161: make install now also installs a python3 man page.
C-API

- **Issue #18351**: Fix various issues in a function in importlib provided to help `PyImport_ExecCodeModuleWithPathnames()` (and thus by extension `PyImport_ExecCodeModule()` and `PyImport_ExecCodeModuleEx()`).
- **Issue #9369**: The types of `char*` arguments of `PyObject_CallFunction()` and `PyObject_CallMethod()` now changed to `const char*`. Based on patches by Jörg Müller and Lars Buitinck.
- **Issue #17206**: `Py_CLEAR()`, `Py_DECREF()`, `Py_INCREF()` and `Py_XDECREF()` now expand their arguments once instead of multiple times. Patch written by Illia Polosukhin.
- **Issue #17522**: Add the `PyGILState_Check()` API.
- **Issue #17327**: Add `PyDict_SetDefault`.
- **Issue #16881**: Fix `Py_ARRAY_LENGTH` macro for GCC < 3.1.
- **Issue #16505**: Remove unused `Py_TPFLAGS_INT_SUBCLASS`.
- **Issue #16086**: `PyTypeObject.tp_flags` and `PyType_Spec.flags` are now unsigned (unsigned long and unsigned int) to avoid an undefined behaviour with `Py_TPFLAGS_TYPE_SUBCLASS` ((1 << 31). `PyType_GetFlags()` result type is now unsigned too (unsigned long, instead of long).
- **Issue #16166**: Add `PY_LITTLE_ENDIAN` and `PY_BIG_ENDIAN` macros and unified endianness detection and handling.

**Documentation**

- **Issue #23006**: Improve the documentation and indexing of `dict.__missing__`. Add an entry in the language datamodel special methods section. Revise and index its discussion in the stdtypes mapping/dict section.
- **Issue #17701**: Improving `strftime` documentation.
- **Issue #18440**: Clarify that `hash()` can truncate the value
returned from an object’s custom `__hash__()` method.

- **Issue #17844**: Add links to encoders and decoders for bytes-to-bytes codecs.
- **Issue #14097**: improve the “introduction” page of the tutorial.
- **Issue #17977**: The documentation for the `cadefault` argument’s default value in `urllib.request.urlopen()` is fixed to match the code.
- **Issue #6696**: add documentation for the Profile objects, and improve profile/cProfile docs. Patch by Tom Pinckney.
- **Issue #15940**: Specify effect of locale on time functions.
- **Issue #17538**: Document XML vulnerabilities
- **Issue #16642**: sched.scheduler timefunc initial default is `time.monotonic`. Patch by Ramchandra Apte
- **Issue #17047**: remove doubled words in docs and docstrings reported by Serhiy Storchaka and Matthew Barnett.
- **Issue #15465**: Document the versioning macros in the C API docs rather than the standard library docs. Patch by Kushal Das.
- **Issue #16406**: Combine the pages for uploading and registering to PyPI.
- **Issue #16403**: Document how distutils uses the maintainer field in `PKG-INFO`. Patch by Jyrki Pulliainen.
- **Issue #16695**: Document how `glob` handles filenames starting with a dot. Initial patch by Jyrki Pulliainen.
- **Issue #8890**: Stop advertising an insecure practice by replacing uses of the `/tmp` directory with better alternatives in the documentation. Patch by Geoff Wilson.
- **Issue #17203**: add long option names to unittest discovery docs.
- **Issue #13094**: add “Why do lambdas defined in a loop with different values all return the same result?” programming FAQ.
- **Issue #14901**: Update portions of the Windows FAQ. Patch by Ashish Nitin Patil.
- **Issue #16267**: Better document the 3.3+ approach to combining `@abstractmethod` with `@staticmethod`, `@classmethod` and `@property`
- **Issue #15209**: Clarify exception chaining description in exceptions
module documentation

- **Issue #15990**: Improve argument/parameter documentation.
- **Issue #16209**: Move the documentation for the str built-in function to a new str class entry in the “Text Sequence Type” section.
- **Issue #13538**: Improve str() and object.__str__() documentation.
- **Issue #16489**: Make it clearer that importlib.find_loader() needs parent packages to be explicitly imported.
- **Issue #16400**: Update the description of which versions of a given package PyPI displays.
- **Issue #15677**: Document that zlib and gzip accept a compression level of 0 to mean ‘no compression’. Patch by Brian Brazil.
- **Issue #16197**: Update winreg docstrings and documentation to match code. Patch by Zachary Ware.
- **Issue #8040**: added a version switcher to the documentation. Patch by Yury Selivanov.
- **Issue #16241**: Document -X faulthandler command line option. Patch by Marek Šuppa.
- Additional comments and some style changes in the concurrent.futures URL retrieval example
- **Issue #16115**: Improve subprocess.Popen() documentation around args, shell, and executable arguments.
- **Issue #13498**: Clarify docs of os.makedirs()'s exist_ok argument. Done with great native-speaker help from R. David Murray.
- **Issue #15533**: Clarify docs and add tests for subprocess.Popen()'s cwd argument.
- **Issue #15979**: Improve timeit documentation.
- **Issue #16036**: Improve documentation of built-in int()'s signature and arguments.
- **Issue #15935**: Clarification of argparse docs, re: add_argument() type and default arguments. Patch contributed by Chris Jerdonek.
- **Issue #11964**: Document a change in v3.2 to the behavior of the indent parameter of json encoding operations.
- **Issue #15116**: Remove references to appscript as it is no longer
being supported.

Tools/Demos

- **Issue #18817**: Fix a resource warning in Lib/aifc.py demo. Patch by Vajrasky Kok.
- **Issue #18439**: Make patchcheck work on Windows for ACKS, NEWS.
- **Issue #18448**: Fix a typo in Tools/demo/eiffel.py.
- **Issue #18457**: Fixed saving of formulas and complex numbers in Tools/demo/ss1.py.
- **Issue #18449**: Make Tools/demo/ss1.py work again on Python 3. Patch by Févry Thibault.
- **Issue #12990**: The “Python Launcher” on OSX could not launch python scripts that have paths that include wide characters.
- **Issue #15239**: Make mkstringprep.py work again on Python 3.
- **Issue #17028**: Allowed Python arguments to be supplied to the Windows launcher.
- **Issue #17156**: pygettext.py now detects the encoding of source files and correctly writes and escapes non-ascii characters.
- **Issue #15539**: Fix a number of bugs in Tools/scripts/pindent.py. Now pindent.py works with a “with” statement. pindent.py no longer produces improper indentation. pindent.py now works with continued lines broken after “class” or “def” keywords and with continuations at the start of line.
- **Issue #11797**: Add a 2to3 fixer that maps reload() to imp.reload().
- **Issue #10966**: Remove the concept of unexpected skipped tests.
- **Issue #9893**: Removed the Misc/Vim directory.
- Removed the Misc/TextMate directory.
- **Issue #16245**: Add the Tools/scripts/parse_html5_entities.py script to parse the list of HTML5 entities and update the html.entities.html5 dictionary.
- **Issue #15378**: Fix Tools/unicode/comparecodecs.py. Patch by Serhiy Storchaka.
• **Issue #16549**: Make json.tool work again on Python 3 and add tests. Initial patch by Berker Peksag and Serhiy Storchaka.

• **Issue #13301**: use ast.literal_eval() instead of eval() in Tools/i18n/msgfmt.py. Patch by Serhiy Storchaka.

**Windows**

• **Issue #18569**: The installer now adds .py to the PATHEXT variable when extensions are registered. Patch by Paul Moore.

(For information about older versions, consult the HISTORY file.)
1. Whetting Your Appetite

If you do much work on computers, eventually you find that there’s some task you’d like to automate. For example, you may wish to perform a search-and-replace over a large number of text files, or rename and rearrange a bunch of photo files in a complicated way. Perhaps you’d like to write a small custom database, or a specialized GUI application, or a simple game.

If you’re a professional software developer, you may have to work with several C/C++/Java libraries but find the usual write/compile/test/re-compile cycle is too slow. Perhaps you’re writing a test suite for such a library and find writing the testing code a tedious task. Or maybe you’ve written a program that could use an extension language, and you don’t want to design and implement a whole new language for your application.

Python is just the language for you.

You could write a Unix shell script or Windows batch files for some of these tasks, but shell scripts are best at moving around files and changing text data, not well-suited for GUI applications or games. You could write a C/C++/Java program, but it can take a lot of development time to get even a first-draft program. Python is simpler to use, available on Windows, Mac OS X, and Unix operating systems, and will help you get the job done more quickly.

Python is simple to use, but it is a real programming language, offering much more structure and support for large programs than shell scripts or batch files can offer. On the other hand, Python also offers much more error checking than C, and, being a very-high-level language, it has high-level data types built in, such as flexible arrays and
dictionaries. Because of its more general data types Python is applicable to a much larger problem domain than Awk or even Perl, yet many things are at least as easy in Python as in those languages.

Python allows you to split your program into modules that can be reused in other Python programs. It comes with a large collection of standard modules that you can use as the basis of your programs — or as examples to start learning to program in Python. Some of these modules provide things like file I/O, system calls, sockets, and even interfaces to graphical user interface toolkits like Tk.

Python is an interpreted language, which can save you considerable time during program development because no compilation and linking is necessary. The interpreter can be used interactively, which makes it easy to experiment with features of the language, to write throw-away programs, or to test functions during bottom-up program development. It is also a handy desk calculator.

Python enables programs to be written compactly and readably. Programs written in Python are typically much shorter than equivalent C, C++, or Java programs, for several reasons:

- the high-level data types allow you to express complex operations in a single statement;
- statement grouping is done by indentation instead of beginning and ending brackets;
- no variable or argument declarations are necessary.

Python is extensible: if you know how to program in C it is easy to add a new built-in function or module to the interpreter, either to perform critical operations at maximum speed, or to link Python programs to libraries that may only be available in binary form (such as a vendor-specific graphics library). Once you are really hooked, you can link the
Python interpreter into an application written in C and use it as an extension or command language for that application.

By the way, the language is named after the BBC show “Monty Python’s Flying Circus” and has nothing to do with reptiles. Making references to Monty Python skits in documentation is not only allowed, it is encouraged!

Now that you are all excited about Python, you’ll want to examine it in some more detail. Since the best way to learn a language is to use it, the tutorial invites you to play with the Python interpreter as you read.

In the next chapter, the mechanics of using the interpreter are explained. This is rather mundane information, but essential for trying out the examples shown later.

The rest of the tutorial introduces various features of the Python language and system through examples, beginning with simple expressions, statements and data types, through functions and modules, and finally touching upon advanced concepts like exceptions and user-defined classes.
2. Using the Python Interpreter
2.1. Invoking the Interpreter

The Python interpreter is usually installed as /usr/local/bin/python3.5 on those machines where it is available; putting /usr/local/bin in your Unix shell's search path makes it possible to start it by typing the command:

```
python3.5
```

to the shell. [1] Since the choice of the directory where the interpreter lives is an installation option, other places are possible; check with your local Python guru or system administrator. (E.g., /usr/local/python is a popular alternative location.)

On Windows machines, the Python installation is usually placed in C:\Python35, though you can change this when you’re running the installer. To add this directory to your path, you can type the following command into the command prompt in a DOS box:

```
set path=%path%;C:\python35
```

Typing an end-of-file character (Control-D on Unix, Control-Z on Windows) at the primary prompt causes the interpreter to exit with a zero exit status. If that doesn’t work, you can exit the interpreter by typing the following command: `quit()`.

The interpreter’s line-editing features include interactive editing, history substitution and code completion on systems that support readline. Perhaps the quickest check to see whether command line editing is supported is typing Control-P to the first Python prompt you get. If it beeps, you have command line editing; see Appendix Interactive Input.
Editing and History Substitution for an introduction to the keys. If nothing appears to happen, or if \^P is echoed, command line editing isn’t available; you’ll only be able to use backspace to remove characters from the current line.

The interpreter operates somewhat like the Unix shell: when called with standard input connected to a tty device, it reads and executes commands interactively; when called with a file name argument or with a file as standard input, it reads and executes a script from that file.

A second way of starting the interpreter is python -c command [arg] ..., which executes the statement(s) in command, analogous to the shell’s -c option. Since Python statements often contain spaces or other characters that are special to the shell, it is usually advised to quote command in its entirety with single quotes.

Some Python modules are also useful as scripts. These can be invoked using python -m module [arg] ..., which executes the source file for module as if you had spelled out its full name on the command line.

When a script file is used, it is sometimes useful to be able to run the script and enter interactive mode afterwards. This can be done by passing -i before the script.

All command line options are described in Command line and environment.

2.1.1. Argument Passing

When known to the interpreter, the script name and additional arguments thereafter are turned into a list of strings and assigned to
the argv variable in the sys module. You can access this list by executing `import sys`. The length of the list is at least one; when no script and no arguments are given, `sys.argv[0]` is an empty string. When the script name is given as `-` (meaning standard input), `sys.argv[0]` is set to `'-'. When `-c command` is used, `sys.argv[0]` is set to `-c`. When `-m module` is used, `sys.argv[0]` is set to the full name of the located module. Options found after `-c command` or `-m module` are not consumed by the Python interpreter's option processing but left in `sys.argv` for the command or module to handle.

## 2.1.2. Interactive Mode

When commands are read from a tty, the interpreter is said to be in *interactive mode*. In this mode it prompts for the next command with the *primary prompt*, usually three greater-than signs (>>>); for continuation lines it prompts with the *secondary prompt*, by default three dots (...). The interpreter prints a welcome message stating its version number and a copyright notice before printing the first prompt:

```
$ python3.5
Python 3.5 (default, Sep 16 2015, 09:25:04)
[GCC 4.8.2] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> 
```

Continuation lines are needed when entering a multi-line construct. As an example, take a look at this `if` statement:

```
>>> the_world_is_flat = True
>>> if the_world_is_flat:
```
... print("Be careful not to fall off!")
...
Be careful not to fall off!

For more on interactive mode, see Interactive Mode.
2.2. The Interpreter and Its Environment

2.2.1. Source Code Encoding

By default, Python source files are treated as encoded in UTF-8. In that encoding, characters of most languages in the world can be used simultaneously in string literals, identifiers and comments — although the standard library only uses ASCII characters for identifiers, a convention that any portable code should follow. To display all these characters properly, your editor must recognize that the file is UTF-8, and it must use a font that supports all the characters in the file.

It is also possible to specify a different encoding for source files. In order to do this, put one more special comment line right after the #! line to define the source file encoding:

```
# -*- coding: encoding -*-
```

With that declaration, everything in the source file will be treated as having the encoding `encoding` instead of UTF-8. The list of possible encodings can be found in the Python Library Reference, in the section on `codecs`.

For example, if your editor of choice does not support UTF-8 encoded files and insists on using some other encoding, say Windows-1252, you can write:

```
# -*- coding: cp-1252 -*-
```

and still use all characters in the Windows-1252 character set in the source files. The special encoding comment must be in the first or second line within the file.
On Unix, the Python 3.x interpreter is by default not installed with the executable named python, so that it does not conflict with a simultaneously installed Python 2.x executable.
3. An Informal Introduction to Python

In the following examples, input and output are distinguished by the presence or absence of prompts (>>> and ...): to repeat the example, you must type everything after the prompt, when the prompt appears; lines that do not begin with a prompt are output from the interpreter. Note that a secondary prompt on a line by itself in an example means you must type a blank line; this is used to end a multi-line command.

Many of the examples in this manual, even those entered at the interactive prompt, include comments. Comments in Python start with the hash character, #, and extend to the end of the physical line. A comment may appear at the start of a line or following whitespace or code, but not within a string literal. A hash character within a string literal is just a hash character. Since comments are to clarify code and are not interpreted by Python, they may be omitted when typing in examples.

Some examples:

```python
# this is the first comment
spam = 1  # and this is the second comment
# ... and now a third!
text = "# This is not a comment because it's inside"
```
3.1. Using Python as a Calculator

Let's try some simple Python commands. Start the interpreter and wait for the primary prompt, >>>. (It shouldn't take long.)

3.1.1. Numbers

The interpreter acts as a simple calculator: you can type an expression at it and it will write the value. Expression syntax is straightforward: the operators +, -, *, and / work just like in most other languages (for example, Pascal or C); parentheses (()) can be used for grouping. For example:

```
>>> 2 + 2
4
>>> 50 - 5*6
20
>>> (50 - 5*6) / 4
5.0
>>> 8 / 5  # division always returns a floating point number
1.6
```

The integer numbers (e.g. 2, 4, 20) have type `int`, the ones with a fractional part (e.g. 5.0, 1.6) have type `float`. We will see more about numeric types later in the tutorial.

Division (/) always returns a float. To do floor division and get an integer result (discarding any fractional result) you can use the // operator; to calculate the remainder you can use %:

```python
>>> 17 / 3  # classic division returns a float
5
>>> 17 // 3  # floor division returns an integer
5
>>> 17 % 3  # remainder
2
```
5.666666666666667
>>> 17 // 3  # floor division discards the fractional part
data type
5
>>> 17 % 3  # the % operator returns the remainder of the division
2
>>> 5 * 3 + 2  # result * divisor + remainder
17

With Python, it is possible to use the ** operator to calculate powers [1]:

```plaintext
>>> 5 ** 2  # 5 squared
25
>>> 2 ** 7  # 2 to the power of 7
128
```

The equal sign (=) is used to assign a value to a variable. Afterwards, no result is displayed before the next interactive prompt:

```plaintext
>>> width = 20
>>> height = 5 * 9
>>> width * height
900
```

If a variable is not “defined” (assigned a value), trying to use it will give you an error:

```plaintext
>>> n  # try to access an undefined variable
NameError: name 'n' is not defined
```

There is full support for floating point; operators with mixed type
operands convert the integer operand to floating point:

```python
>>> 3 * 3.75 / 1.5
7.5
>>> 7.0 / 2
3.5
```

In interactive mode, the last printed expression is assigned to the variable `_`. This means that when you are using Python as a desk calculator, it is somewhat easier to continue calculations, for example:

```python
>>> tax = 12.5 / 100
>>> price = 100.50
>>> price * tax
12.5625
>>> price + _
113.0625
>>> round(_, 2)
113.06
```

This variable should be treated as read-only by the user. Don’t explicitly assign a value to it — you would create an independent local variable with the same name masking the built-in variable with its magic behavior.

In addition to `int` and `float`, Python supports other types of numbers, such as `Decimal` and `Fraction`. Python also has built-in support for complex numbers, and uses the j or J suffix to indicate the imaginary part (e.g. 3+5j).

### 3.1.2. Strings

Besides numbers, Python can also manipulate strings, which can be
expressed in several ways. They can be enclosed in single quotes ('...') or double quotes ("...") with the same result [2]. \ can be used to escape quotes:

```python
>>> 'spam eggs' # single quotes
'spam eggs'
>>> 'doesn\'t' # use \' to escape the single quote.
"doesn't"
>>> "doesn't" # ...or use double quotes instead
"doesn't"
>>> '"Yes," he said.'
"Yes," he said.'
>>> '"Yes," he said.'
"Yes," he said.'
>>> '"Isn\'t," she said.'
"Isn't," she said.'
```

In the interactive interpreter, the output string is enclosed in quotes and special characters are escaped with backslashes. While this might sometimes look different from the input (the enclosing quotes could change), the two strings are equivalent. The string is enclosed in double quotes if the string contains a single quote and no double quotes, otherwise it is enclosed in single quotes. The `print()` function produces a more readable output, by omitting the enclosing quotes and by printing escaped quotes and special characters:

```python
>>> '"Isn\'t," she said.'
"Isn't," she said.'
>>> print('"Isn\'t," she said.')
"Isn't," she said.
>>> s = 'First line.\nSecond line.' # \n means newline
>>> s # without print(), \n is included in the output
'First line.\nSecond line.'
>>> print(s) # with print(), \n produces a new line
"First line.\nSecond line."```
If you don't want characters prefaced by \ to be interpreted as special characters, you can use raw strings by adding an r before the first quote:

```python
>>> print('C:\some\name')  # here \n means newline!
C:\some
ame
>>> print(r'C:\some\name')  # note the r before the quote
C:\some\name
```

String literals can span multiple lines. One way is using triple-quotes: """..."""" or '''...'''. End of lines are automatically included in the string, but it's possible to prevent this by adding a \ at the end of the line. The following example:

```python
print("\
Usage: thingy [OPTIONS]
   -h                        Display this usage message
   -H hostname              Hostname to connect t
"
)
```

produces the following output (note that the initial newline is not included):

```plaintext
Usage: thingy [OPTIONS]
   -h                        Display this usage message
   -H hostname              Hostname to connect t
```

Strings can be concatenated (glued together) with the + operator, and
repeated with *:

```python
>>> # 3 times 'un', followed by 'ium'
>>> 3 * 'un' + 'ium'
'unununium'
```

Two or more string literals (i.e. the ones enclosed between quotes) next to each other are automatically concatenated.

```python
>>> 'Py' 'thon'
'Python'
```

This only works with two literals though, not with variables or expressions:

```python
>>> prefix = 'Py'
>>> prefix + 'thon'  # can't concatenate a variable and a string literal
... SyntaxError: invalid syntax
>>> ('un' * 3) + 'ium'
... SyntaxError: invalid syntax
```

If you want to concatenate variables or a variable and a literal, use +:

```python
>>> prefix + 'thon'
'Python'
```

This feature is particularly useful when you want to break long strings:

```python
>>> text = ('Put several strings within parentheses to have them joined together. '
>>> text
'Put several strings within parentheses to have them joined together.'
```
Strings can be *indexed* (subscripted), with the first character having index 0. There is no separate character type; a character is simply a string of size one:

```python
>>> word = 'Python'
>>> word[0]    # character in position 0
'P'
>>> word[5]    # character in position 5
'n'
```

Indices may also be negative numbers, to start counting from the right:

```python
>>> word[-1]   # last character
'n'
>>> word[-2]   # second-last character
'o'
>>> word[-6]
'P'
```

Note that since -0 is the same as 0, negative indices start from -1.

In addition to indexing, *slicing* is also supported. While indexing is used to obtain individual characters, *slicing* allows you to obtain substring:

```python
>>> word[0:2]   # characters from position 0 (include)
'Py'
>>> word[2:5]   # characters from position 2 (include)
'tho'
```

Note how the start is always included, and the end always excluded. This makes sure that `s[:i] + s[i:]` is always equal to `s`:
Slice indices have useful defaults; an omitted first index defaults to zero, an omitted second index defaults to the size of the string being sliced.

```python
>>> word[:2] + word[2:]
'Python'
>>> word[:4] + word[4:]
'Python'
```

One way to remember how slices work is to think of the indices as pointing between characters, with the left edge of the first character numbered 0. Then the right edge of the last character of a string of $n$ characters has index $n$, for example:

```
+---+---+---+---+---+---+
| P | y | t | h | o | n |
+---+---+---+---+---+---+
0 1 2 3 4 5 6
-6 -5 -4 -3 -2 -1
```

The first row of numbers gives the position of the indices 0...6 in the string; the second row gives the corresponding negative indices. The slice from $i$ to $j$ consists of all characters between the edges labeled $i$ and $j$, respectively.

For non-negative indices, the length of a slice is the difference of the indices, if both are within bounds. For example, the length of
word[1:3] is 2.

Attempting to use an index that is too large will result in an error:

```python
>>> word[42]  # the word only has 6 characters
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: string index out of range
```

However, out of range slice indexes are handled gracefully when used for slicing:

```python
>>> word[4:42]
'on'
>>> word[42:]
''
```

Python strings cannot be changed — they are immutable. Therefore, assigning to an indexed position in the string results in an error:

```python
>>> word[0] = 'J'
...  
TypeError: 'str' object does not support item assignment
>>> word[2:] = 'py'
...  
TypeError: 'str' object does not support item assignment
```

If you need a different string, you should create a new one:

```python
>>> 'J' + word[1:]  
'Jython'
>>> word[:2] + 'py'
'Pypy'
```
The built-in function \texttt{len()} returns the length of a string:

\begin{verbatim}
>>> s = 'supercalifragilisticexpialidocious'
>>> len(s)
34
\end{verbatim}

See also:

**Text Sequence Type — str**
Strings are examples of \textit{sequence types}, and support the common operations supported by such types.

**String Methods**
Strings support a large number of methods for basic transformations and searching.

**String Formatting**
Information about string formatting with \texttt{str.format()} is described here.

**printf-style String Formatting**
The old formatting operations invoked when strings and Unicode strings are the left operand of the \texttt{%} operator are described in more detail here.

### 3.1.3. Lists

Python knows a number of \textit{compound} data types, used to group together other values. The most versatile is the \textit{list}, which can be written as a list of comma-separated values (items) between square brackets. Lists might contain items of different types, but usually the items all have the same type.

\begin{verbatim}
>>> squares = [1, 4, 9, 16, 25]
>>> squares
\end{verbatim}
Like strings (and all other built-in `sequence` type), lists can be indexed and sliced:

```
>>> squares[0]  # indexing returns the item
1
>>> squares[-1]
25
>>> squares[-3:]: # slicing returns a new list
[9, 16, 25]
```

All slice operations return a new list containing the requested elements. This means that the following slice returns a new (shallow) copy of the list:

```
>>> squares[:]
[1, 4, 9, 16, 25]
```

Lists also support operations like concatenation:

```
>>> squares + [36, 49, 64, 81, 100]
[1, 4, 9, 16, 25, 36, 49, 64, 81, 100]
```

Unlike strings, which are **immutable**, lists are a **mutable** type, i.e. it is possible to change their content:

```
>>> cubes = [1, 8, 27, 65, 125]  # something's wrong
>>> 4 ** 3  # the cube of 4 is 64, not 65!
64
>>> cubes[3] = 64  # replace the wrong value
>>> cubes
[1, 8, 27, 64, 125]
```
You can also add new items at the end of the list, by using the `append()` method (we will see more about methods later):

```python
>>> cubes.append(216)  # add the cube of 6
>>> cubes.append(7 ** 3)  # and the cube of 7
>>> cubes
[1, 8, 27, 64, 125, 216, 343]
```

Assignment to slices is also possible, and this can even change the size of the list or clear it entirely:

```python
>>> letters = ['a', 'b', 'c', 'd', 'e', 'f', 'g']
>>> letters
['a', 'b', 'c', 'd', 'e', 'f', 'g']
>>> # replace some values
>>> letters
['a', 'b', 'C', 'D', 'E', 'f', 'g']
>>> # now remove them
>>> letters[2:5] = []
>>> letters
['a', 'b', 'f', 'g']
>>> # clear the list by replacing all the elements with an empty list
>>> letters[:]=[]
>>> letters
[]
```

The built-in function `len()` also applies to lists:

```python
>>> letters = ['a', 'b', 'c', 'd']
>>> len(letters)
4
```

It is possible to nest lists (create lists containing other lists), for example:
>>> a = ['a', 'b', 'c']
>>> n = [1, 2, 3]
>>> x = [a, n]
>>> x
[['a', 'b', 'c'], [1, 2, 3]]
>>> x[0]
['a', 'b', 'c']
>>> x[0][1]
'b'
3.2. First Steps Towards Programming

Of course, we can use Python for more complicated tasks than adding two and two together. For instance, we can write an initial sub-sequence of the *Fibonacci* series as follows:

```python
>>> # Fibonacci series:
... # the sum of two elements defines the next
... a, b = 0, 1
>>> while b < 10:
...     print(b)
...     a, b = b, a+b
... 1
 1
 2
 3
 5
 8
```

This example introduces several new features.

- The first line contains a *multiple assignment*: the variables `a` and `b` simultaneously get the new values 0 and 1. On the last line this is used again, demonstrating that the expressions on the right-hand side are all evaluated first before any of the assignments take place. The right-hand side expressions are evaluated from the left to the right.

- The *while* loop executes as long as the condition (here: `b < 10`) remains true. In Python, like in C, any non-zero integer value is true; zero is false. The condition may also be a string or list value, in fact any sequence; anything with a non-zero length is
true, empty sequences are false. The test used in the example is a simple comparison. The standard comparison operators are written the same as in C: < (less than), > (greater than), == (equal to), <= (less than or equal to), >= (greater than or equal to) and != (not equal to).

- The body of the loop is *indented*: indentation is Python's way of grouping statements. At the interactive prompt, you have to type a tab or space(s) for each indented line. In practice you will prepare more complicated input for Python with a text editor; all decent text editors have an auto-indent facility. When a compound statement is entered interactively, it must be followed by a blank line to indicate completion (since the parser cannot guess when you have typed the last line). Note that each line within a basic block must be indented by the same amount.

- The `print()` function writes the value of the argument(s) it is given. It differs from just writing the expression you want to write (as we did earlier in the calculator examples) in the way it handles multiple arguments, floating point quantities, and strings. Strings are printed without quotes, and a space is inserted between items, so you can format things nicely, like this:

```python
>>> i = 256*256
>>> print('The value of i is', i)
The value of i is 65536
```

The keyword argument *end* can be used to avoid the newline after the output, or end the output with a different string:

```python
>>> a, b = 0, 1
>>> while b < 1000:
...     print(b, end=','
```
\[ \ldots \quad a, \ b = b, \ a+b \]
\[ \ldots \]
1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, \]

**Footnotes**

Since \(^*\) has higher precedence than -, \(-3^*2\) will be interpreted as \(-(3^*2)\) and thus result in -9. To avoid this and get 9, you can use \((-3)^*2\).

Unlike other languages, special characters such as \(\backslash n\) have the same meaning with both single (' . . ') and double ('" . . ") quotes. The only difference between the two is that within single quotes you don’t need to escape " (but you have to escape \' ) and vice versa.
4. More Control Flow Tools

Besides the `while` statement just introduced, Python knows the usual control flow statements known from other languages, with some twists.
4.1. **if** Statements

Perhaps the most well-known statement type is the **if** statement. For example:

```python
>>> x = int(input("Please enter an integer: "))
Please enter an integer: 42
>>> if x < 0:
...     x = 0
...     print('Negative changed to zero')
... elif x == 0:
...     print('Zero')
... elif x == 1:
...     print('Single')
... else:
...     print('More')
More
```

There can be zero or more **elif** parts, and the **else** part is optional. The keyword ‘**elif**’ is short for ‘else if’, and is useful to avoid excessive indentation. An **if** ... **elif** ... **elif** ... **else** sequence is a substitute for the switch or case statements found in other languages.
4.2. for Statements

The for statement in Python differs a bit from what you may be used to in C or Pascal. Rather than always iterating over an arithmetic progression of numbers (like in Pascal), or giving the user the ability to define both the iteration step and halting condition (as C), Python’s for statement iterates over the items of any sequence (a list or a string), in the order that they appear in the sequence. For example (no pun intended):

```python
>>> # Measure some strings:
... words = ['cat', 'window', 'defenestrate']
>>> for w in words:
...     print(w, len(w))
...      
cat 3
window 6
defenestrate 12
```

If you need to modify the sequence you are iterating over while inside the loop (for example to duplicate selected items), it is recommended that you first make a copy. Iterating over a sequence does not implicitly make a copy. The slice notation makes this especially convenient:

```python
>>> for w in words[:]: # Loop over a slice copy of
...     if len(w) > 6:
...         words.insert(0, w)
...        
>>> words
['defenestrate', 'cat', 'window', 'defenestrate']
```
4.3. The `range()` Function

If you do need to iterate over a sequence of numbers, the built-in function `range()` comes in handy. It generates arithmetic progressions:

```python
>>> for i in range(5):
...     print(i)
... 0
 1
 2
 3
 4
```

The given end point is never part of the generated sequence; `range(10)` generates 10 values, the legal indices for items of a sequence of length 10. It is possible to let the range start at another number, or to specify a different increment (even negative; sometimes this is called the 'step'):

```python
range(5, 10)  
  5 through 9
range(0, 10, 3)  
  0, 3, 6, 9
range(-10, -100, -30)  
  -10, -40, -70
```

To iterate over the indices of a sequence, you can combine `range()` and `len()` as follows:
>>> a = ['Mary', 'had', 'a', 'little', 'lamb']
>>> for i in range(len(a)):
...    print(i, a[i])
...
0  Mary
1  had
2  a
3  little
4  lamb

In most such cases, however, it is convenient to use the `enumerate()` function, see Looping Techniques.

A strange thing happens if you just print a range:

```python
>>> print(range(10))
range(0, 10)
```

In many ways the object returned by `range()` behaves as if it is a list, but in fact it isn’t. It is an object which returns the successive items of the desired sequence when you iterate over it, but it doesn’t really make the list, thus saving space.

We say such an object is iterable, that is, suitable as a target for functions and constructs that expect something from which they can obtain successive items until the supply is exhausted. We have seen that the `for` statement is such an iterator. The function `list()` is another; it creates lists from iterables:

```python
>>> list(range(5))
[0, 1, 2, 3, 4]
```

Later we will see more functions that return iterables and take iterables as argument.
4.4. `break` and `continue` Statements, and `else` Clauses on Loops

The `break` statement, like in C, breaks out of the smallest enclosing `for` or `while` loop.

Loop statements may have an else clause; it is executed when the loop terminates through exhaustion of the list (with `for`) or when the condition becomes false (with `while`), but not when the loop is terminated by a `break` statement. This is exemplified by the following loop, which searches for prime numbers:

```python
>>> for n in range(2, 10):
...    for x in range(2, n):
...        if n % x == 0:
...            print(n, 'equals', x, '*', n//x)
...        else:
...            # loop fell through without finding a factor
...            print(n, 'is a prime number')
...
2 is a prime number
3 is a prime number
4 equals 2 * 2
5 is a prime number
6 equals 2 * 3
7 is a prime number
8 equals 2 * 4
9 equals 3 * 3
```

(Yes, this is the correct code. Look closely: the else clause belongs to the `for` loop, not the `if` statement.)
When used with a loop, the else clause has more in common with the else clause of a `try` statement than it does that of `if` statements: a `try` statement's else clause runs when no exception occurs, and a loop's else clause runs when no break occurs. For more on the `try` statement and exceptions, see Handling Exceptions.

The `continue` statement, also borrowed from C, continues with the next iteration of the loop:

```python
>>> for num in range(2, 10):
...    if num % 2 == 0:
...        print("Found an even number", num)
...        continue
...    print("Found a number", num)
Found an even number 2
Found a number 3
Found an even number 4
Found a number 5
Found an even number 6
Found a number 7
Found an even number 8
Found a number 9
```
4.5. **pass** Statements

The `pass` statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

```python
>>> while True:
...   pass  # Busy-wait for keyboard interrupt (Ctrl+C)
...
```

This is commonly used for creating minimal classes:

```python
>>> class MyEmptyClass:
...   pass
...
```

Another place `pass` can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The `pass` is silently ignored:

```python
>>> def initlog(*args):
...   pass  # Remember to implement this!
...
```
4.6. Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

```python
>>> def fib(n):  # write Fibonacci series up to n
...    """Print a Fibonacci series up to n."""
...    a, b = 0, 1
...    while a < n:
...        print(a, end=' ')
...        a, b = b, a+b
...    print()
...    # Now call the function we just defined:
...    fib(2000)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597
```

The keyword `def` introduces a function definition. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function’s documentation string, or docstring. (More about docstrings can be found in the section Documentation Strings.) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it’s good practice to include docstrings in code that you write, so make a habit of it.

The execution of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments
in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a `global` statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using *call by value* (where the *value* is always an object *reference*, not the value of the object). [1] When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

```python
>>> fib
<function fib at 10042ed0>
>>> f = fib
>>> f(100)
0 1 1 2 3 5 8 13 21 34 55 89
```

Coming from other languages, you might object that `fib` is not a function but a procedure since it doesn’t return a value. In fact, even functions without a `return` statement do return a value, albeit a rather boring one. This value is called None (it’s a built-in name). Writing the value None is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using `print()`:

```python
>>> fib(0)
```
It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

```python
>>> def fib2(n): # return Fibonacci series up to n
...     """Return a list containing the Fibonacci series up to n."""
...     result = []
...     a, b = 0, 1
...     while a < n:
...         result.append(a) # see below
...         a, b = b, a+b
...     return result

>>> f100 = fib2(100)  # call it
>>> f100               # write the result
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
```

This example, as usual, demonstrates some new Python features:

- The `return` statement returns with a value from a function. `return` without an expression argument returns None. Falling off the end of a function also returns None.

- The statement `result.append(a)` calls a method of the list object `result`. A method is a function that 'belongs' to an object and is named `obj.methodname`, where `obj` is some object (this may be an expression), and `methodname` is the name of a method that is defined by the object's type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using classes, see Classes) The method `append()` shown in the example is defined for list objects; it adds a new element at the end of the list. In this
example it is equivalent to \( \text{result} = \text{result} + [a] \), but more efficient.
4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

```python
def ask_ok(prompt, retries=4, complaint='Yes or no, please!'):
    while True:
        ok = input(prompt)
        if ok in ('y', 'ye', 'yes'):
            return True
        if ok in ('n', 'no', 'nop', 'nope'):
            return False
        retries = retries - 1
        if retries < 0:
            raise OSError('uncooperative user')
    print(complaint)
```

This function can be called in several ways:

- giving only the mandatory argument: `ask_ok('Do you really want to quit?)`
- giving one of the optional arguments: `ask_ok('OK to overwrite the file?', 2)`
- or even giving all arguments: `ask_ok('OK to overwrite the file?', 2, 'Come on, only yes or no!')`
This example also introduces the `in` keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the `defining` scope, so that

```python
i = 5

def f(arg=i):
    print(arg)

i = 6
f()
```

will print 5.

**Important warning**: The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

```python
def f(a, L=[]):
    L.append(a)
    return L

print(f(1))
print(f(2))
print(f(3))
```

This will print

```python
[1]
[1, 2]
[1, 2, 3]
```
If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

```python
def f(a, L=None):
    if L is None:
        L = []
    L.append(a)
    return L
```

4.7.2. Keyword Arguments

Functions can also be called using keyword arguments of the form `kwarg=value`. For instance, the following function:

```python
def parrot(voltage, state='a stiff', action='voom',
            print("-- This parrot wouldn't", action, end='"
print("if you put", voltage, "volts through it."
print("-- Lovely plumage, the", state)
print("-- It's", state, "!")
```

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

```python
parrot(1000)
parrot(voltage=1000)
parrot(voltage=1000000, action='VOOOOOOM')
parrot(action='VOOOOOOM', voltage=1000000)
parrot('a million', 'bereft of life', 'jump')
parrot('a thousand', state='pushing up the daisies')
```

but all the following calls would be invalid:
In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here's an example that fails due to this restriction:

```python
>>> def function(a):
...     pass
...     ...

>>> function(0, a=0)
Traceback (most recent call last):
  File "<stdin>", line 1, in 
TypeError: function() got multiple values for keyword argument 'a'
```

When a final formal parameter of the form **name is present, it receives a dictionary (see Mapping Types — dict) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form *name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (*name must occur before **name.) For example, if we define a function like this:

```python
def cheeseshop(kind, *arguments, **keywords):
```
print("-- Do you have any", kind, "?")
print("-- I'm sorry, we're all out of", kind)
for arg in arguments:
    print(arg)
print("-") * 40
keys = sorted(keywords.keys())
for kw in keys:
    print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",
           "It's really very, VERY runny, sir.",
           shopkeeper="Michael Palin",
           client="John Cleese",
           sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?
-- I'm sorry, we're all out of Limburger
It's very runny, sir.
It's really very, VERY runny, sir.
----------------------------------------
client : John Cleese
shopkeeper : Michael Palin
sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary's keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

4.7.3. Arbitrary Argument Lists
Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see Tuples and Sequences). Before the variable number of arguments, zero or more normal arguments may occur.

```python
def write_multiple_items(file, separator, *args):
    file.write(separator.join(args))
```

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the *args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

```python
>>> def concat(*args, sep="/"):
...     return sep.join(args)
... >>> concat("earth", "mars", "venus")
'earth/mars/venus'
>>> concat("earth", "mars", "venus", sep=".")
'earth.mars.venus'
```

### 4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in `range()` function expects separate `start` and `stop` arguments. If they are not available separately, write the function call with the *-operator to unpack the arguments out of a list or tuple:

```python
>>> list(range(3, 6))  # normal call with
```

In the same fashion, dictionaries can deliver keyword arguments with the **-operator:

```python
>>> d = {
    "voltage": "four million",
    "state": "bleedin' demised"
}
>>> parrot(**d)
-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised!
```

### 4.7.5. Lambda Expressions

Small anonymous functions can be created with the `lambda` keyword. This function returns the sum of its two arguments: `lambda a, b: a+b`. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

```python
>>> def make_incrementor(n):
...     return lambda x: x + n
... >>> f = make_incrementor(42)
... >>> f(0)
42
```
The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

```
>>> pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]
>>> pairs.sort(key=lambda pair: pair[1])
>>> pairs
[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]
```

4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object's purpose. For brevity, it should not explicitly state the object's name or type, since these are available by other means (except if the name happens to be a verb describing a function's operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object's calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line after the first line of the string determines the amount of indentation for the entire documentation string. (We can't use the first line since it is generally adjacent to the string's opening
quotes so its indentation is not apparent in the string literal.)
Whitespace “equivalent” to this indentation is then stripped from the
start of all lines of the string. Lines that are indented less should not
occur, but if they occur all their leading whitespace should be stripped.
Equivalence of whitespace should be tested after expansion of tabs (to
8 spaces, normally).

Here is an example of a multi-line docstring:

```python
>>> def my_function():
    ...    '''Do nothing, but document it.
    ...    No, really, it doesn't do anything.
    ...    pass
    ...
>>> print(my_function.__doc__)
Do nothing, but document it.
    No, really, it doesn't do anything.
```

4.7.7. Function Annotations

Function annotations are completely optional metadata information
about the types used by user-defined functions (see PEP 484 for more
information).

Annotations are stored in the __annotations__ attribute of the
function as a dictionary and have no effect on any other part of the
function. Parameter annotations are defined by a colon after the
parameter name, followed by an expression evaluating to the value of
the annotation. Return annotations are defined by a literal ->, followed
by an expression, between the parameter list and the colon denoting
the end of the `def` statement. The following example has a positional argument, a keyword argument, and the return value annotated:

```python
>>> def f(ham: str, eggs: str = 'eggs') -> str:
...     print("Annotations:", f.__annotations__)
...     print("Arguments:", ham, eggs)
...     return ham + ' and ' + eggs

>>> f('spam')
Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}
Arguments: spam eggs
'spam and eggs'
```
4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk about coding style. Most languages can be written (or more concise, formatted) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, PEP 8 has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

- Use 4-space indentation, and no tabs.

  4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

- Wrap lines so that they don’t exceed 79 characters.

  This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

- Use blank lines to separate functions and classes, and larger blocks of code inside functions.

- When possible, put comments on a line of their own.

- Use docstrings.

- Use spaces around operators and after commas, but not directly
inside bracketing constructs: \( a = f(1, 2) + g(3, 4) \).

- Name your classes and functions consistently; the convention is to use **CamelCase** for classes and **lower_case_with_underscores** for functions and methods. Always use `self` as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html) for more on classes and methods).

- Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.

- Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

### Footnotes

[1] Actually, *call by object reference* would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list).
5. Data Structures

This chapter describes some things you’ve learned about already in more detail, and adds some new things as well.
5.1. More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

list.\texttt{append}(x)

Add an item to the end of the list. Equivalent to \texttt{a[len(a):] = [x]}.

list.\texttt{extend}(L)

Extend the list by appending all the items in the given list. Equivalent to \texttt{a[len(a):] = L}.

list.\texttt{insert}(i, x)

Insert an item at a given position. The first argument is the index of the element before which to insert, so \texttt{a.insert(0, x)} inserts at the front of the list, and \texttt{a.insert(len(a), x)} is equivalent to \texttt{a.append(x)}.

list.\texttt{remove}(x)

Remove the first item from the list whose value is \texttt{x}. It is an error if there is no such item.

list.\texttt{pop}(i)

Remove the item at the given position in the list, and return it. If no index is specified, \texttt{a.pop()} removes and returns the last item in the list. (The square brackets around the \texttt{i} in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)
**list.clear()**
Remove all items from the list. Equivalent to `del a[:]`.

**list.index(x)**
Return the index in the list of the first item whose value is `x`. It is an error if there is no such item.

**list.count(x)**
Return the number of times `x` appears in the list.

**list.sort(key=None, reverse=False)**
Sort the items of the list in place (the arguments can be used for sort customization, see `sorted()` for their explanation).

**list.reverse()**
Reverse the elements of the list in place.

**list.copy()**
Return a shallow copy of the list. Equivalent to `a[:]`.

An example that uses most of the list methods:

```python
given text
```
You might have noticed that methods like insert, remove or sort that only modify the list have no return value printed – they return the default None. [1] This is a design principle for all mutable data structures in Python.

5.1.1. Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use append(). To retrieve an item from the top of the stack, use pop() without an explicit index. For example:

```python
>>> stack = [3, 4, 5]
>>> stack.append(6)
>>> stack.append(7)
>>> stack
[3, 4, 5, 6, 7]
>>> stack.pop()
7
>>> stack
[3, 4, 5, 6]
>>> stack.pop()
```
5.1.2. Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use `collections.deque` which was designed to have fast appends and pops from both ends. For example:

```python
>>> from collections import deque
>>> queue = deque(["Eric", "John", "Michael"])
>>> queue.append("Terry")          # Terry arrives
'Eric'
>>> queue.append("Graham")         # Graham arrives
>>> queue.popleft()                # The first to arrive now leaves
'Eric'
>>> queue.popleft()                # The second to arrive now leaves
'John'
>>> queue                      # Remaining queue
deque(["Michael", "Terry", "Graham"])
```

5.1.3. List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of
some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

```python
>>> squares = []
>>> for x in range(10):
...     squares.append(x**2)
...
>>> squares
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

Note that this creates (or overwrites) a variable named x that still exists after the loop completes. We can calculate the list of squares without any side effects using:

```python
squares = list(map(lambda x: x**2, range(10)))
```

or, equivalently:

```python
squares = [x**2 for x in range(10)]
```

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a for clause, then zero or more for or if clauses. The result will be a new list resulting from evaluating the expression in the context of the for and if clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

```python
>>> [(x, y) for x in [1, 2, 3] for y in [3, 1, 4] if x != y]
[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 2)]
```
and it's equivalent to:

```python
>>> combs = []
>>> for x in [1, 2, 3]:
...    for y in [3, 1, 4]:
...        if x != y:
...            combs.append((x, y))
...
>>> combs
[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]
```

Note how the order of the `for` and `if` statements is the same in both these snippets.

If the expression is a tuple (e.g. the `(x, y)` in the previous example), it must be parenthesized.

```python
>>> vec = [-4, -2, 0, 2, 4]
>>> # create a new list with the values doubled
>>> [x*2 for x in vec]
[-8, -4, 0, 4, 8]
>>> # filter the list to exclude negative numbers
>>> [x for x in vec if x >= 0]
[0, 2, 4]
>>> # apply a function to all the elements
>>> [abs(x) for x in vec]
[4, 2, 0, 2, 4]
>>> # call a method on each element
>>> freshfruit = ['banana', 'loganberry', 'passion fruit']
>>> [weapon.strip() for weapon in freshfruit]
['banana', 'loganberry', 'passion fruit']
>>> # create a list of 2-tuples like (number, square)
>>> [(x, x**2) for x in range(6)]
[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]
>>> # the tuple must be parenthesized, otherwise an
```
>>> [x, x**2 for x in range(6)]
  File "<stdin>", line 1, in ?
  [x, x**2 for x in range(6)]
^  
SyntaxError: invalid syntax
>>> # flatten a list using a listcomp with two 'for'
>>> vec = [[1,2,3], [4,5,6], [7,8,9]]
>>> [num for elem in vec for num in elem]
[1, 2, 3, 4, 5, 6, 7, 8, 9]

List comprehensions can contain complex expressions and nested functions:

>>> from math import pi
>>> [str(round(pi, i)) for i in range(1, 6)]
['3.1', '3.14', '3.142', '3.1416', '3.14159']

5.1.4. Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

>>> matrix = [
...   [1, 2, 3, 4],
...   [5, 6, 7, 8],
...   [9, 10, 11, 12],
...]

The following list comprehension will transpose rows and columns:

>>> [[row[i] for row in matrix] for i in range(4)]
As we saw in the previous section, the nested listcomp is evaluated in the context of the `for` that follows it, so this example is equivalent to:

```python
global transposed
transposed = []
for i in range(4):
    transposed.append([row[i] for row in matrix])
```

which, in turn, is the same as:

```python
global transposed
transposed = []
for i in range(4):
    # the following 3 lines implement the nested for
    transposed_row = []
    for row in matrix:
        transposed_row.append(row[i])
    transposed.append(transposed_row)
```

In the real world, you should prefer built-in functions to complex flow statements. The `zip()` function would do a great job for this use case:

```python
list(zip(*matrix))
```

See [Unpacking Argument Lists](#) for details on the asterisk in this line.
5.2. The **del** statement

There is a way to remove an item from a list given its index instead of its value: the **del** statement. This differs from the **pop()** method which returns a value. The **del** statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

```python
>>> a = [-1, 1, 66.25, 333, 333, 1234.5]
>>> del a[0]
>>> a
[1, 66.25, 333, 333, 1234.5]
>>> del a[2:4]
>>> a
[1, 66.25, 1234.5]
>>> del a[:]
>>> a
[]
```

**del** can also be used to delete entire variables:

```python
>>> del a
```

Referencing the name `a` hereafter is an error (at least until another value is assigned to it). We'll find other uses for **del** later.
5.3. Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of sequence data types (see Sequence Types — list, tuple, range). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the tuple.

A tuple consists of a number of values separated by commas, for instance:

```python
>>> t = 12345, 54321, 'hello!
```
necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are immutable, and usually contain an heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of namedtuples). Lists are mutable, and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

```python
>>> empty = ()
>>> singleton = 'hello',     # <-- note trailing comma
>>> len(empty)
0
>>> len(singleton)
1
>>> singleton
('hello',)
```

The statement `t = 12345, 54321, 'hello!'` is an example of tuple packing: the values `12345`, `54321` and `'hello!'` are packed together in a tuple. The reverse operation is also possible:

```python
>>> x, y, z = t
```
This is called, appropriately enough, *sequence unpacking* and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.
5.4. Sets

Python also includes a data type for sets. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the `set()` function can be used to create sets. Note: to create an empty set you have to use `set()`, not `{}`; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

```python
>>> basket = {'apple', 'orange', 'apple', 'pear', 'cherry', 'orange'}
>>> print(basket) # show that duplicates have been removed
{'banana', 'orange', 'pear', 'apple'}
>>> 'orange' in basket # fast membership test
True
>>> 'crabgrass' in basket
False

>>> # Demonstrate set operations on unique letters from two words...
... >>> a = set('abracadabra')
... >>> b = set('alacazam')
... >>> a
{'a', 'r', 'b', 'c', 'd'}
... >>> a - b # letters in a but not in b
{'r', 'd', 'b'}
... >>> a | b # letters in either a or b
{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}
... >>> a & b # letters in both a and b
{'}
Similarly to list comprehensions, set comprehensions are also supported:

```python
>>> a = {x for x in 'abracadabra' if x not in 'abc'}
>>> a
{'r', 'd'}
```
5.5. Dictionaries

Another useful data type built into Python is the dictionary (see Mapping Types — dict). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: `{}`. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [2] To check whether a single key is in the dictionary, use the in keyword.
Here is a small example using a dictionary:

```python
>>> tel = {'jack': 4098, 'sape': 4139}
>>> tel['guido'] = 4127
>>> tel
{'sape': 4139, 'guido': 4127, 'jack': 4098}
>>> tel['jack']
4098
>>> del tel['sape']
>>> tel['irv'] = 4127
>>> tel
{'guido': 4127, 'irv': 4127, 'jack': 4098}
>>> list(tel.keys())
['irv', 'guido', 'jack']
>>> sorted(tel.keys())
['guido', 'irv', 'jack']
>>> 'guido' in tel
True
>>> 'jack' not in tel
False
```

The `dict()` constructor builds dictionaries directly from sequences of key-value pairs:

```python
>>> dict([(sape, 4139), (guido, 4127), (jack, {'sape': 4139, 'jack': 4098, 'guido': 4127})
```

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

```python
>>> {x: x**2 for x in (2, 4, 6)}
{2: 4, 4: 16, 6: 36}
```

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:
```python
>>> dict(sape=4139, guido=4127, jack=4098)
{'sape': 4139, 'jack': 4098, 'guido': 4127}
```
5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the `items()` method.

```python
>>> knights = {'gallahad': 'the pure', 'robin': 'the brave
>>> for k, v in knights.items():
...     print(k, v)
...        gallahad the pure
robin the brave
```

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the `enumerate()` function.

```python
>>> for i, v in enumerate(['tic', 'tac', 'toe']):
...     print(i, v)
...        0 tic
1 tac
2 toe
```

To loop over two or more sequences at the same time, the entries can be paired with the `zip()` function.

```python
>>> questions = ['name', 'quest', 'favorite color']
>>> answers = ['lancelot', 'the holy grail', 'blue']
>>> for q, a in zip(questions, answers):
...     print('What is your {0}? It is {1}.').format(q, a)
...        What is your name? It is lancelot.
What is your quest? It is the holy grail.
```
What is your favorite color?  It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the `reversed()` function.

```python
def _for_ i in reversed(range(1, 10, 2)):
  print(i)
... 9
... 7
... 5
... 3
... 1
```

To loop over a sequence in sorted order, use the `sorted()` function which returns a new sorted list while leaving the source unaltered.

```python
def _for f in sorted(set(basket)):
  print(f)
... apple
... banana
... orange
... pear
```

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

```python
def _import_ math
>>> raw_data = [56.2, float('NaN'), 51.7, 55.3, 52.5]
>>> filtered_data = []
>>> _for_ value in raw_data:
  ...  if not math.isnan(value):
  ...   filtered_data.append(value)
>>> print(filtered_data)
[56.2, 51.7, 55.3, 52.5]
```
... filtered_data.append(value)
...

>>> filtered_data
[56.2, 51.7, 55.3, 52.5, 47.8]
5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, \( a < b == c \) tests whether \( a \) is less than \( b \) and moreover \( b \) equals \( c \).

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that \( A \) and not \( B \) or \( C \) is equivalent to \( (A \text{ and } (\text{not } B)) \text{ or } C \). As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if \( A \) and \( C \) are true but \( B \) is false, \( A \text{ and } B \text{ and } C \) does not evaluate the expression \( C \). When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean
expression to a variable. For example,

```python
>>> string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'
>>> non_null = string1 or string2 or string3
>>> non_null
'Trondheim'
```

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.
5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

```
(1, 2, 3) < (1, 2, 4)
[1, 2, 3] < [1, 2, 4]
'ABC' < 'C' < 'Pascal' < 'Python'
(1, 2, 3, 4) < (1, 2, 4)
(1, 2) < (1, 2, -1)
(1, 2, 3) == (1.0, 2.0, 3.0)
(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)
```

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a **TypeError** exception.
Footnotes

[1] Other languages may return the mutated object, which allows method chaining, such as `d->insert("a")- >remove("b")->sort();`.

[2] Calling `d.keys()` will return a dictionary view object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only a view.
If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a script. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you've written in several programs without copying its definition into each program.

To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a module; definitions from a module can be imported into other modules or into the main module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).

A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module’s name (as a string) is available as the value of the global variable __name__. For instance, use your favorite text editor to create a file called fibo.py in the current directory with the following contents:

```
# Fibonacci numbers module

def fib(n):  # write Fibonacci series up to n
    a, b = 0, 1
    while b < n:
        print(b, end=' ')
```
```python
a, b = b, a+b
print()

def fib2(n): # return Fibonacci series up to n
    result = []
    a, b = 0, 1
    while b < n:
        result.append(b)
        a, b = b, a+b
    return result

Now enter the Python interpreter and import this module with the following command:

```
6.1. More on Modules

A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the first time the module name is encountered in an import statement. [1] (They are also run if the file is executed as a script.)

Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user’s global variables. On the other hand, if you know what you are doing you can touch a module's global variables with the same notation used to refer to its functions, modname.itemname.

Modules can import other modules. It is customary but not required to place all import statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module’s global symbol table.

There is a variant of the import statement that imports names from a module directly into the importing module’s symbol table. For example:

```python
>>> from fibo import fib, fib2
>>> fib(500)
1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, fibo is not defined).
There is even a variant to import all names that a module defines:

```
>>> from fibo import *
>>> fib(500)
1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

This imports all names except those beginning with an underscore (_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.

Note that in general the practice of importing * from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.

**Note:** For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it’s just one module you want to test interactively, use `imp.reload()` e.g. `import imp; imp.reload(modulename)`.

### 6.1.1. Executing modules as scripts

When you run a Python module with

```
python fibo.py <arguments>
```

the code in the module will be executed, just as if you imported it, but with the `__name__` set to `"__main__"`. That means that by adding this code at the end of your module:

```
if __name__ == "__main__":
    import sys
```
fib(int(sys.argv[1]))

you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:

```
$ python fibo.py 50
1 1 2 3 5 8 13 21 34
```

If the module is imported, the code is not run:

```
>>> import fibo
>>> 
```

This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite).

### 6.1.2. The Module Search Path

When a module named spam is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named spam.py in a list of directories given by the variable `sys.path`. `sys.path` is initialized from these locations:

- The directory containing the input script (or the current directory when no file is specified).
- `PYTHONPATH` (a list of directory names, with the same syntax as the shell variable PATH).
- The installation-dependent default.

**Note:** On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed.
In other words the directory containing the symlink is **not** added to the module search path.

After initialization, Python programs can modify `sys.path`. The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section **Standard Modules** for more information.

### 6.1.3. “Compiled” Python files

To speed up loading modules, Python caches the compiled version of each module in the `__pycache__` directory under the name `module.version.pyc`, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as `__pycache__/spam.cpython-33.pyc`. This naming convention allows compiled modules from different releases and different versions of Python to coexist.

Python checks the modification date of the source against the compiled version to see if it's out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.

Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that's loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and
there must not be a source module.

Some tips for experts:

- You can use the -0 or -00 switches on the Python command to reduce the size of a compiled module. The -0 switch removes assert statements, the -00 switch removes both assert statements and __doc__ strings. Since some programs may rely on having these available, you should only use this option if you know what you’re doing. “Optimized” modules have an opt- tag and are usually smaller. Future releases may change the effects of optimization.
- A program doesn’t run any faster when it is read from a .pyc file than when it is read from a .py file; the only thing that’s faster about .pyc files is the speed with which they are loaded.
- The module compileall can create .pyc files for all modules in a directory.
- There is more detail on this process, including a flow chart of the decisions, in PEP 3147.
6.2. Standard Modules

Python comes with a library of standard modules, described in a separate document, the Python Library Reference (“Library Reference” hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the winreg module is only provided on Windows systems. One particular module deserves some attention: sys, which is built into every Python interpreter. The variables sys.ps1 and sys.ps2 define the strings used as primary and secondary prompts:

```python
>>> import sys
>>> sys.ps1
'>>>
>>> sys.ps2
'...
>>> sys.ps1 = 'C> '
C> print('Yuck!')
Yuck!
C>
```

These two variables are only defined if the interpreter is in interactive mode.

The variable sys.path is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable PYTHONPATH, or from a built-in default if PYTHONPATH is not set. You can modify it using standard list
operations:

```python
>>> import sys
>>> sys.path.append('/ufs/guido/lib/python')
```
6.3. The `dir()` Function

The built-in function `dir()` is used to find out which names a module defines. It returns a sorted list of strings:

```
>>> import fibo, sys
>>> dir(fibo)
['__name__', 'fib', 'fib2']
>>> dir(sys)
```

Without arguments, `dir()` lists the names you have defined currently:

```
>>> a = [1, 2, 3, 4, 5]
>>> import fibo
>>> fib = fibo.fib
>>> dir()
['__builtins__', '__name__', 'a', 'fib', 'fibo', 'sys'
```
Note that it lists all types of names: variables, modules, functions, etc.

`dir()` does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module `builtins`:

```python
>>> import builtins
>>> dir(builtins)
```
6.4. Packages

Packages are a way of structuring Python’s module namespace by using “dotted module names”. For example, the module name A.B designates a submodule named B in a package named A. Just like the use of modules saves the authors of different modules from having to worry about each other’s global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other’s module names.

Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: .wav, .aiff, .au), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here’s a possible structure for your package (expressed in terms of a hierarchical filesystem):

```
sound/
  __init__.py
  formats/
    __init__.py
    wavread.py
    wavwrite.py
    aiffread.py
    aiffwrite.py
    auread.py
```

Top-level package
Initialize the sound
Subpackage for file
When importing the package, Python searches through the directories on `sys.path` looking for the package subdirectory.

The `__init__.py` files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as `string`, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, `__init__.py` can just be an empty file, but it can also execute initialization code for the package or set the `__all__` variable, described later.

Users of the package can import individual modules from the package, for example:

```python
import sound.effects.echo
```

This loads the submodule `sound.effects.echo`. It must be referenced with its full name.
An alternative way of importing the submodule is:

```python
from sound.effects import echo
```

This also loads the submodule echo, and makes it available without its package prefix, so it can be used as follows:

```python
echo.echofilter(input, output, delay=0.7, atten=4)
```

Yet another variation is to import the desired function or variable directly:

```python
from sound.effects.echo import echofilter
```

Again, this loads the submodule echo, but this makes its function `echofilter()` directly available:

```python
echofilter(input, output, delay=0.7, atten=4)
```

Note that when using `from package import item`, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The import statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an `ImportError` exception is raised.

Contrarily, when using syntax like `import item.subitem.subsubitem`, each item except for the last must be a package; the last item can be a module or a package but can't be a class or function or variable defined in the previous item.
6.4.1. Importing * From a Package

Now what happens when the user writes `from sound.effects import *`? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing submodules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.

The only solution is for the package author to provide an explicit index of the package. The `import` statement uses the following convention: if a package's `__init__.py` code defines a list named `__all__`, it is taken to be the list of module names that should be imported when `from package import *` is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don't see a use for importing * from their package. For example, the file `sound/effects/__init__.py` could contain the following code:

```
__all__ = ["echo", "surround", "reverse"]
```

This would mean that `from sound.effects import *` would import the three named submodules of the sound package.

If `__all__` is not defined, the statement `from sound.effects import *` does not import all submodules from the package `sound.effects` into the current namespace; it only ensures that the package `sound.effects` has been imported (possibly running any initialisation code in `__init__.py`) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by `__init__.py`. It also includes any
submodules of the package that were explicitly loaded by previous
import statements. Consider this code:

```python
import sound.effects.echo
import sound.effects.surround
from sound.effects import *
```

In this example, the echo and surround modules are imported in the
current namespace because they are defined in the sound.effects
package when the from...import statement is executed. (This also
works when __all__ is defined.)

Although certain modules are designed to export only names that
follow certain patterns when you use import *, it is still considered
bad practise in production code.

Remember, there is nothing wrong with using from Package
import specific_submodule! In fact, this is the recommended
notation unless the importing module needs to use submodules with
the same name from different packages.

### 6.4.2. Intra-package References

When packages are structured into subpackages (as with the sound
package in the example), you can use absolute imports to refer to
submodules of siblings packages. For example, if the module
sound.filters.vocoder needs to use the echo module in the
sound.effects package, it can use from sound.effects
import echo.

You can also write relative imports, with the from module import
name form of import statement. These imports use leading dots to
indicate the current and parent packages involved in the relative import. From the `surround` module for example, you might use:

```python
from . import echo
from .. import formats
from ..filters import equalizer
```

Note that relative imports are based on the name of the current module. Since the name of the main module is always "__main__", modules intended for use as the main module of a Python application must always use absolute imports.

### 6.4.3. Packages in Multiple Directories

Packages support one more special attribute, `__path__`. This is initialized to be a list containing the name of the directory holding the package's `__init__.py` before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.

While this feature is not often needed, it can be used to extend the set of modules found in a package.

#### Footnotes

[1] In fact function definitions are also 'statements' that are 'executed'; the execution of a module-level function definition enters the function name in the module's global symbol table.
7. Input and Output

There are several ways to present the output of a program; data can be printed in a human-readable form, or written to a file for future use. This chapter will discuss some of the possibilities.
7.1. Fancier Output Formatting

So far we've encountered two ways of writing values: expression statements and the `print()` function. (A third way is using the `write()` method of file objects; the standard output file can be referenced as `sys.stdout`. See the Library Reference for more information on this.)

Often you'll want more control over the formatting of your output than simply printing space-separated values. There are two ways to format your output; the first way is to do all the string handling yourself; using string slicing and concatenation operations you can create any layout you can imagine. The string type has some methods that perform useful operations for padding strings to a given column width; these will be discussed shortly. The second way is to use the `str.format()` method.

The `string` module contains a `Template` class which offers yet another way to substitute values into strings.

One question remains, of course: how do you convert values to strings? Luckily, Python has ways to convert any value to a string: pass it to the `repr()` or `str()` functions.

The `str()` function is meant to return representations of values which are fairly human-readable, while `repr()` is meant to generate representations which can be read by the interpreter (or will force a `SyntaxError` if there is no equivalent syntax). For objects which don't have a particular representation for human consumption, `str()` will return the same value as `repr()`. Many values, such as numbers or structures like lists and dictionaries, have the same representation
using either function. Strings, in particular, have two distinct representations.

Some examples:

```python
>>> s = 'Hello, world.'
>>> str(s)
'Hello, world.'
>>> repr(s)
'"Hello, world."'
>>> str(1/7)
'0.14285714285714285'
>>> x = 10 * 3.25
>>> y = 200 * 200
>>> s = 'The value of x is ' + repr(x) + ', and y is ' + repr(y)
>>> print(s)
The value of x is 32.5, and y is 40000...
>>> # The repr() of a string adds string quotes and backslashes:
... hello = 'hello, world\n'
>>> hellos = repr(hello)
>>> print(hellos)
'hello, world\n'
>>> # The argument to repr() may be any Python object:
... repr((x, y, ('spam', 'eggs')))
'(32.5, 40000, ('spam', 'eggs'))'
```

Here are two ways to write a table of squares and cubes:

```python
>>> for x in range(1, 11):
...     print(repr(x).rjust(2), repr(x*x).rjust(3),
...     # Note use of 'end' on previous line
...     repr(x*x*x).rjust(4))
... 1 1 1
 2 4  8
 3 9 27
```
4  16   64  
5  25   125 
6  36   216 
7  49   343 
8  64   512 
9  81   729 
10 100  1000

>>> for x in range(1, 11):
...     print('{0:2d} {1:3d} {2:4d}'.format(x, x*x, ...)
1  1   1  
2  4   8  
3  9  27  
4 16  64  
5 25  125 
6 36  216 
7 49  343 
8 64  512 
9 81  729 
10 100 1000

(Note that in the first example, one space between each column was added by the way print() works: it always adds spaces between its arguments.)

This example demonstrates the str.rjust() method of string objects, which right-justifies a string in a field of a given width by padding it with spaces on the left. There are similar methods str.ljust() and str.center(). These methods do not write anything, they just return a new string. If the input string is too long, they don’t truncate it, but return it unchanged; this will mess up your column lay-out but that’s usually better than the alternative, which would be lying about a value. (If you really want truncation you can
always add a slice operation, as in \texttt{x.ljust(n)[:n].}

There is another method, \texttt{str.zfill()}, which pads a numeric string on the left with zeros. It understands about plus and minus signs:

\begin{verbatim}
>>> '12'.zfill(5)
'00012'
>>> '-3.14'.zfill(7)
'-003.14'
>>> '3.14159265359'.zfill(5)
'3.14159265359'
\end{verbatim}

Basic usage of the \texttt{str.format()} method looks like this:

\begin{verbatim}
>>> print('We are the {} who say "{}!"'.format('knights'))
We are the knights who say "Ni!"
>>> print('{0} and {1}'.format('spam', 'eggs'))
spam and eggs
>>> print('{1} and {0}'.format('spam', 'eggs'))
eggs and spam
\end{verbatim}

If keyword arguments are used in the \texttt{str.format()} method, their values are referred to by using the name of the argument.
Positional and keyword arguments can be arbitrarily combined:

```python
>>> print('The story of {0}, {1}, and {other}.').format(0, 1, other='Georg'))
The story of Bill, Manfred, and Georg.
```

'!a' (apply `ascii()`), '!s' (apply `str()`) and '!r' (apply `repr()`) can be used to convert the value before it is formatted:

```python
>>> import math
>>> print('The value of PI is approximately {}.'.format(math.pi))
The value of PI is approximately 3.14159265359.
>>> print('The value of PI is approximately {!r}.').format(math.pi)
The value of PI is approximately 3.141592653589793.
```

An optional ':' and format specifier can follow the field name. This allows greater control over how the value is formatted. The following example rounds Pi to three places after the decimal.

```python
>>> import math
>>> print('The value of PI is approximately {0:.3f}.'.format(math.pi))
The value of PI is approximately 3.142.
```

Passing an integer after the ':' will cause that field to be a minimum number of characters wide. This is useful for making tables pretty.

```python
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 7678}
>>> for name, phone in table.items():
...     print('{0:10} => {1:10d}'.format(name, phone))
...     
... Jack  =>  4098
Dcab  =>  7678
Sjoerd =>  4127
```
If you have a really long format string that you don’t want to split up, it would be nice if you could reference the variables to be formatted by name instead of by position. This can be done by simply passing the dict and using square brackets ‘[]’ to access the keys

```python
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}
>>> print('Jack: {0[Jack]:d}; Sjoerd: {0[Sjoerd]:d};
... Dcab: {0[Dcab]:d}'.format(table))
Jack: 4098; Sjoerd: 4127; Dcab: 8637678
```

This could also be done by passing the table as keyword arguments with the ‘**’ notation.

```python
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}
Jack: 4098; Sjoerd: 4127; Dcab: 8637678
```

This is particularly useful in combination with the built-in function `vars()`, which returns a dictionary containing all local variables.

For a complete overview of string formatting with `str.format()`, see `Format String Syntax`.

### 7.1.1. Old string formatting

The `%` operator can also be used for string formatting. It interprets the left argument much like a `printf()`-style format string to be applied to the right argument, and returns the string resulting from this formatting operation. For example:

```python
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}
>>> print('Jack: %d; Sjoerd: %d; Dcab: %d' % (table['Jack'], table['Sjoerd'], table['Dcab']))
Jack: 4098; Sjoerd: 4127; Dcab: 8637678
```
```python
>>> import math
>>> print('The value of PI is approximately %5.3f.'
      'The value of PI is approximately 3.142.
```

More information can be found in the **printf-style String Formatting** section.
7.2. Reading and Writing Files

`open()` returns a file object, and is most commonly used with two arguments: `open(filename, mode).

```python
>>> f = open('workfile', 'w')
```

The first argument is a string containing the filename. The second argument is another string containing a few characters describing the way in which the file will be used. mode can be 'r' when the file will only be read, 'w' for only writing (an existing file with the same name will be erased), and 'a' opens the file for appending; any data written to the file is automatically added to the end. 'r+' opens the file for both reading and writing. The mode argument is optional; 'r' will be assumed if it's omitted.

Normally, files are opened in text mode, that means, you read and write strings from and to the file, which are encoded in a specific encoding. If encoding is not specified, the default is platform dependent (see open()). 'b' appended to the mode opens the file in binary mode: now the data is read and written in the form of bytes objects. This mode should be used for all files that don't contain text.

In text mode, the default when reading is to convert platform-specific line endings (\n on Unix, \r\n on Windows) to just \n. When writing in text mode, the default is to convert occurrences of \n back to platform-specific line endings. This behind-the-scenes modification to file data is fine for text files, but will corrupt binary data like that in JPEG or EXE files. Be very careful to use binary mode when reading and writing such files.
7.2.1. Methods of File Objects

The rest of the examples in this section will assume that a file object called \texttt{f} has already been created.

To read a file's contents, call \texttt{f.read(size)}, which reads some quantity of data and returns it as a string or bytes object. \texttt{size} is an optional numeric argument. When \texttt{size} is omitted or negative, the entire contents of the file will be read and returned; it's your problem if the file is twice as large as your machine's memory. Otherwise, at most \texttt{size} bytes are read and returned. If the end of the file has been reached, \texttt{f.read()} will return an empty string ("'').

\begin{verbatim}
>>> f.read()
'This is the entire file.\n'
>>> f.read()
''
\end{verbatim}

\texttt{f.readline()} reads a single line from the file; a newline character (\texttt{\textbackslash n}) is left at the end of the string, and is only omitted on the last line of the file if the file doesn't end in a newline. This makes the return value unambiguous; if \texttt{f.readline()} returns an empty string, the end of the file has been reached, while a blank line is represented by '\texttt{\textbackslash n}', a string containing only a single newline.

\begin{verbatim}
>>> f.readline()
'This is the first line of the file.\n'
>>> f.readline()
'Second line of the file\n'
>>> f.readline()
''
\end{verbatim}

For reading lines from a file, you can loop over the file object. This is
memory efficient, fast, and leads to simple code:

```python
>>> for line in f:
...     print(line, end='')
...
This is the first line of the file.
Second line of the file
```

If you want to read all the lines of a file in a list you can also use `list(f)` or `f.readlines()`.

`f.write(string)` writes the contents of `string` to the file, returning the number of characters written.

```python
>>> f.write('This is a test\n')
15
```

To write something other than a string, it needs to be converted to a string first:

```python
>>> value = ('the answer', 42)
>>> s = str(value)
>>> f.write(s)
18
```

`f.tell()` returns an integer giving the file object's current position in the file represented as number of bytes from the beginning of the file when in binary mode and an opaque number when in text mode.

To change the file object's position, use `f.seek(offset, from_what)`. The position is computed from adding `offset` to a reference point; the reference point is selected by the `from_what` argument. A `from_what` value of 0 measures from the beginning of the file, 1 uses the current file position, and 2 uses the end of the file as
the reference point. \textit{from\_what} can be omitted and defaults to 0, using the beginning of the file as the reference point.

```python
>>> f = open('workfile', 'rb+')
>>> f.write(b'0123456789abcdef')
16
>>> f.seek(5)  # Go to the 6th byte in the file
5
>>> f.read(1)
b'5'
>>> f.seek(-3, 2)  # Go to the 3rd byte before the end
13
>>> f.read(1)
b'd'
```

In text files (those opened without a \texttt{b} in the mode string), only seeks relative to the beginning of the file are allowed (the exception being seeking to the very file end with \texttt{seek(0, 2)}) and the only valid \textit{offset} values are those returned from the \texttt{f.tell()}, or zero. Any other \textit{offset} value produces undefined behaviour.

When you're done with a file, call \texttt{f.close()} to close it and free up any system resources taken up by the open file. After calling \texttt{f.close()}, attempts to use the file object will automatically fail.

```python
>>> f.close()
>>> f.read()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: I/O operation on closed file
```

It is good practice to use the \texttt{with} keyword when dealing with file objects. This has the advantage that the file is properly closed after its suite finishes, even if an exception is raised on the way. It is also much
shorter than writing equivalent `try-finally` blocks:

```python
>>> with open('workfile', 'r') as f:
    ...       read_data = f.read()
>>> f.closed
True
```

File objects have some additional methods, such as `isatty()` and `truncate()` which are less frequently used; consult the Library Reference for a complete guide to file objects.

### 7.2.2. Saving structured data with `json`

Strings can easily be written to and read from a file. Numbers take a bit more effort, since the `read()` method only returns strings, which will have to be passed to a function like `int()`, which takes a string like '123' and returns its numeric value 123. When you want to save more complex data types like nested lists and dictionaries, parsing and serializing by hand becomes complicated.

Rather than having users constantly writing and debugging code to save complicated data types to files, Python allows you to use the popular data interchange format called **JSON (JavaScript Object Notation)**. The standard module called `json` can take Python data hierarchies, and convert them to string representations; this process is called **serializing**. Reconstructing the data from the string representation is called **deserializing**. Between serializing and deserializing, the string representing the object may have been stored in a file or data, or sent over a network connection to some distant machine.

**Note:** The JSON format is commonly used by modern applications...
to allow for data exchange. Many programmers are already familiar with it, which makes it a good choice for interoperability.

If you have an object \( x \), you can view its JSON string representation with a simple line of code:

\[
>>> \text{json.dumps([1, 'simple', 'list'])}
\]

'\[1, "simple", "list"]''

Another variant of the \texttt{dumps()} function, called \texttt{dump()}, simply serializes the object to a text file. So if \( f \) is a text file object opened for writing, we can do this:

\[
\text{json.dump}(x, f)
\]

To decode the object again, if \( f \) is a text file object which has been opened for reading:

\[
x = \text{json.load}(f)
\]

This simple serialization technique can handle lists and dictionaries, but serializing arbitrary class instances in JSON requires a bit of extra effort. The reference for the \texttt{json} module contains an explanation of this.

**See also:** \texttt{pickle} - the pickle module

Contrary to \texttt{JSON}, \texttt{pickle} is a protocol which allows the serialization of arbitrarily complex Python objects. As such, it is specific to Python and cannot be used to communicate with applications written in other languages. It is also insecure by default: deserializing pickle data coming from an untrusted source can execute arbitrary code, if the data was crafted by a skilled attacker.
8. Errors and Exceptions

Until now error messages haven’t been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: syntax errors and exceptions.
8.1. Syntax Errors

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

```python
>>> while True print('Hello world')
     File "<stdin>", line 1, in ?
      while True print('Hello world')
   ^
SyntaxError: invalid syntax
```

The parser repeats the offending line and displays a little ‘arrow’ pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token preceding the arrow: in the example, the error is detected at the function `print()`, since a colon (`:`) is missing before it. File name and line number are printed so you know where to look in case the input came from a script.
8.2. Exceptions

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called exceptions and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

```
>>> 10 * (1/0)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ZeroDivisionError: division by zero
>>> 4 + spam*3
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
NameError: name 'spam' is not defined
>>> '2' + 2
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: Can't convert 'int' object to str implicitly
```

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are ZeroDivisionError, NameError and TypeError. The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and
what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

Built-in Exceptions lists the built-in exceptions and their meanings.
8.3. Handling Exceptions

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using Control-C or whatever the operating system supports); note that a user-generated interruption is signalled by raising the `KeyboardInterrupt` exception.

```python
>>> while True:
...     try:
...         x = int(input("Please enter a number: "))
...         break
...     except ValueError:
...         print("Oops! That was no valid number. Try again...")
...```

The `try` statement works as follows.

- First, the `try clause` (the statement(s) between the `try` and `except` keywords) is executed.
- If no exception occurs, the `except clause` is skipped and execution of the `try` statement is finished.
- If an exception occurs during execution of the `try` clause, the rest of the clause is skipped. Then if its type matches the exception named after the `except` keyword, the `except` clause is executed, and then execution continues after the `try` statement.
- If an exception occurs which does not match the exception named in the `except` clause, it is passed on to outer `try` statements; if no handler is found, it is an `unhandled exception` and execution stops with a message as shown above.
A `try` statement may have more than one except clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding try clause, not in other handlers of the same `try` statement. An except clause may name multiple exceptions as a parenthesized tuple, for example:

```python
... except (RuntimeError, TypeError, NameError):
    pass
```

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

```python
import sys

try:
    f = open('myfile.txt')
    s = f.readline()
    i = int(s.strip())
except OSError as err:
    print("OS error: \{0\}".format(err))
except ValueError:
    print("Could not convert data to an integer.")
except:
    print("Unexpected error:", sys.exc_info()[0])
    raise
```

The `try ... except` statement has an optional `else` clause, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:
for arg in sys.argv[1:]:
    try:
        f = open(arg, 'r')
    except IOError:
        print('cannot open', arg)
    else:
        print(arg, 'has', len(f.readlines()), 'lines')
        f.close()

The use of the else clause is better than adding additional code to the try clause because it avoids accidentally catching an exception that wasn't raised by the code being protected by the try ... except statement.

When an exception occurs, it may have an associated value, also known as the exception's argument. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name. The variable is bound to an exception instance with the arguments stored in instance.args. For convenience, the exception instance defines __str__() so the arguments can be printed directly without having to reference .args. One may also instantiate an exception first before raising it and add any attributes to it as desired.

>>> try:
...     raise Exception('spam', 'eggs')
... except Exception as inst:
...     print(type(inst))  # the exception instance
...     print(inst.args)   # arguments stored in .args
...     print(inst)        # __str__ allows arguments to
...     x, y = inst.args   # but may be overridden
...     print('x =', x)    # unpack args
...
If an exception has arguments, they are printed as the last part ('detail') of the message for unhandled exceptions.

Exception handlers don’t just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

```python
>>> def this_fails():
...     x = 1/0
... >>> try:
...     this_fails()
...     except ZeroDivisionError as err:
...         print('Handling run-time error:', err)
Handling run-time error: int division or modulo by zero
```
8.4. Raising Exceptions

The `raise` statement allows the programmer to force a specified exception to occur. For example:

```python
>>> raise NameError('HiThere')
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
NameError: HiThere
```

The sole argument to `raise` indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from `Exception`).

If you need to determine whether an exception was raised but don’t intend to handle it, a simpler form of the `raise` statement allows you to re-raise the exception:

```python
>>> try:
    ...     raise NameError('HiThere')
    ... except NameError:
    ...     print('An exception flew by!')
    ...    raise

An exception flew by!
```

```python
Traceback (most recent call last):
  File "<stdin>", line 2, in ?
NameError: HiThere
```
8.5. User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see Classes for more about Python classes). Exceptions should typically be derived from the Exception class, either directly or indirectly. For example:

```python
>>> class MyError(Exception):
...     def __init__(self, value):
...         self.value = value
...     def __str__(self):
...         return repr(self.value)
...
>>> try:
...     raise MyError(2*2)
... except MyError as e:
...     print('My exception occurred, value:', e.value)

My exception occurred, value: 4

>>> raise MyError('oops!')
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
__main__.MyError: 'oops!'
```

In this example, the default __init__() of Exception has been overridden. The new behavior simply creates the value attribute. This replaces the default behavior of creating the args attribute.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for
exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

```python
class Error(Exception):
    """Base class for exceptions in this module.""
    pass

class InputError(Error):
    """Exception raised for errors in the input.

    Attributes:
    expression -- input expression in which the error occurred
    message -- explanation of the error
    ""

def __init__(self, expression, message):
    self.expression = expression
    self.message = message

class TransitionError(Error):
    """Raised when an operation attempts a state transition
    that's not allowed.

    Attributes:
    previous -- state at beginning of transition
    next -- attempted new state
    message -- explanation of why the specific transition is not allowed
    ""

def __init__(self, previous, next, message):
    self.previous = previous
    self.next = next
    self.message = message
```

Most exceptions are defined with names that end in “Error,” similar to the naming of the standard exceptions.
Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter Classes.
8.6. Defining Clean-up Actions

The `try` statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

```python
>>> try:
...     raise KeyboardInterrupt
... finally:
...     print('Goodbye, world!')
...
Goodbye, world!
KeyboardInterrupt
Traceback (most recent call last):
  File "<stdin>", line 2, in ?
```

A `finally` clause is always executed before leaving the `try` statement, whether an exception has occurred or not. When an exception has occurred in the `try` clause and has not been handled by an `except` clause (or it has occurred in an `except` or `else` clause), it is re-raised after the `finally` clause has been executed. The `finally` clause is also executed "on the way out" when any other clause of the `try` statement is left via a `break`, `continue` or `return` statement. A more complicated example:

```python
>>> def divide(x, y):
...     try:
...         result = x / y
...     except ZeroDivisionError:
...         print("division by zero!")
...     else:
...         print("result is", result)
... finally:
```
As you can see, the `finally` clause is executed in any event. The `TypeError` raised by dividing two strings is not handled by the `except` clause and therefore re-raised after the `finally` clause has been executed.

In real world applications, the `finally` clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.
8.7. Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

```python
for line in open("myfile.txt"):  
    print(line, end="")
```

The problem with this code is that it leaves the file open for an indeterminate amount of time after this part of the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The `with` statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

```python
with open("myfile.txt") as f:  
    for line in f:  
        print(line, end="")
```

After the statement is executed, the file `f` is always closed, even if a problem was encountered while processing the lines. Objects which, like files, provide predefined clean-up actions will indicate this in their documentation.
9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below Private Variables), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subcripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)
9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.
9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A *namespace* is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as `abs()` and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function `maximize` without confusion — users of the modules must prefix it with the module name.

By the way, I use the word *attribute* for any name following a dot — for example, in the expression `z.real`, `real` is an attribute of the object `z`. Strictly speaking, references to names in modules are attribute references: in the expression `modname.funcname`, `modname` is a module object and `funcname` is an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [1]
Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write `modname.the_answer = 42`. Writable attributes may also be deleted with the `del` statement. For example, `del modname.the_answer` will remove the attribute `the_answer` from the object named by `modname`.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called `__main__`, so they have their own global namespace. (The built-in names actually also live in a module; this is called `builtins`.)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:
• the innermost scope, which is searched first, contains the local names
• the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
• the next-to-last scope contains the current module’s global names
• the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module's global names. To rebind variables found outside of the innermost scope, the nonlocal statement can be used; if not declared nonlocal, those variable are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module's namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module's namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no global statement is in effect – assignments to names always go into the innermost scope.
Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement \texttt{del x} removes the binding of \texttt{x} from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, \texttt{import} statements and function definitions bind the module or function name in the local scope.

The \texttt{global} statement can be used to indicate that particular variables live in the global scope and should be rebound there; the \texttt{nonlocal} statement indicates that particular variables live in an enclosing scope and should be rebound there.

9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how \texttt{global } and \texttt{nonlocal} affect variable binding:

```python
def scope_test():
    def do_local():
        spam = "local spam"
    def do_nonlocal():
        nonlocal spam
        spam = "nonlocal spam"
    def do_global():
        global spam
        spam = "global spam"
    spam = "test spam"
    do_local()
    print("After local assignment:", spam)
    do_nonlocal()
    print("After nonlocal assignment:", spam)
    do_global()
    print("After global assignment:", spam)
```
```python
scope_test()
print("In global scope:", spam)
```

The output of the example code is:

```
After local assignment: test spam
After nonlocal assignment: nonlocal spam
After global assignment: nonlocal spam
In global scope: global spam
```

Note how the `local` assignment (which is default) didn't change `scope_test`'s binding of `spam`. The `nonlocal` assignment changed `scope_test`'s binding of `spam`, and the `global` assignment changed the module-level binding.

You can also see that there was no previous binding for `spam` before the `global` assignment.
9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

```python
class ClassName:
    <statement-1>
    ...
    <statement-N>
```

Class definitions, like function definitions (def statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an if statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is
created. This is basically a wrapper around the contents of the namespace created by the class definition; we'll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: `obj.name`. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

```python
class MyClass:
    """A simple example class""
    i = 12345
def f(self):
    return 'hello world'
```

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value of MyClass.i by assignment. `__doc__` is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the
class. For example (assuming the above class):

```python
x = MyClass()
```

creates a new instance of the class and assigns this object to the local variable `x`.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named `__init__()`, like this:

```python
def __init__(self):
    self.data = []
```

When a class defines an `__init__()` method, class instantiation automatically invokes `__init__()` for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

```python
x = MyClass()
```

Of course, the `__init__()` method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to `__init__()`. For example,

```python
>>> class Complex:
...     def __init__(self, realpart, imagpart):
...         self.r = realpart
...         self.i = imagpart
...
>>> x = Complex(3.0, -4.5)
>>> x.r, x.i
(3.0, -4.5)
```
9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

*data attributes* correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if `x` is the instance of `MyClass` created above, the following piece of code will print the value 16, without leaving a trace:

```python
x.counter = 1
while x.counter < 10:
    x.counter = x.counter * 2
print(x.counter)
del x.counter
```

The other kind of instance attribute reference is a *method*. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, `x.f` is a valid method reference, since `MyClass.f` is a function, but `x.i` is not, since `MyClass.i` is not. But `x.f` is not the same thing as
MyClass.f — it is a method object, not a function object.

9.3.4. Method Objects

Usually, a method is called right after it is bound:

```python
x.f()
```

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: `x.f` is a method object, and can be stored away and called at a later time. For example:

```python
xf = x.f
while True:
    print(xf())
```

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that `x.f()` was called without an argument above, even though the function definition for `f()` specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call `x.f()` is exactly equivalent to `MyClass.f(x)`. In general, calling a method with a list of $n$ arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before
the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

```python
class Dog:
    kind = 'canine'  # class variable shared by all instances

    def __init__(self, name):
        self.name = name  # instance variable unique to each instance

>>> d = Dog('Fido')
>>> e = Dog('Buddy')
>>> d.kind  # shared by all dogs
'canine'
>>> e.kind  # shared by all dogs
'canine'
>>> d.name  # unique to d
'Fido'
```
As discussed in *A Word About Names and Objects*, shared data can have possibly surprising effects with involving *mutable* objects such as lists and dictionaries. For example, the *tricks* list in the following code should not be used as a class variable because just a single list would be shared by all *Dog* instances:

```python
class Dog:
    
    tricks = []  # mistaken use of a class variable
    
    def __init__(self, name):
        self.name = name

    def add_trick(self, trick):
        self.tricks.append(trick)

>>> d = Dog('Fido')
>>> e = Dog('Buddy')
>>> d.add_trick('roll over')
>>> e.add_trick('play dead')
>>> d.tricks  # unexpectedly shared by all dogs
['roll over', 'play dead']
```

Correct design of the class should use an instance variable instead:

```python
class Dog:

    def __init__(self, name):
        self.name = name
        self.tricks = []  # creates a new empty list for each dog
```
```python
def add_trick(self, trick):
    self.tricks.append(trick)

>>> d = Dog('Fido')
>>> e = Dog('Buddy')
>>> d.add_trick('roll over')
>>> e.add_trick('play dead')
>>> d.tricks
['roll over']
>>> e.tricks
['play dead']
```
9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the name self has absolutely no special
meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

```python
# Function defined outside the class
def f1(self, x, y):
    return min(x, x+y)

class C:
    f = f1
    def g(self):
        return 'hello world'
    h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

```python
class Bag:
    def __init__(self):
        self.data = []
    def add(self, x):
        self.data.append(x)
    def addtwice(self, x):
Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we'll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored as object.__class__.
9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

```python
class DerivedClassName(BaseClassName):
    <statement-1>
    ...
    ...
    <statement-N>
```

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

```python
class DerivedClassName(modname.BaseClassName):
```

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There's nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.
Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just call BaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

- Use `isinstance()` to check an instance’s type: `isinstance(obj, int)` will be True only if `obj.__class__` is `int` or some class derived from `int`.
- Use `issubclass()` to check class inheritance: `issubclass(bool, int)` is True since `bool` is a subclass of `int`. However, `issubclass(float, int)` is False since `float` is not a subclass of `int`.

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

```python
class DerivedClassName(Base1, Base2, Base3):
    <statement-1>
    ...
```
For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for in Base1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to super(). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from object, so any case of multiple inheritance provides more than one path to reach object. To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see https://www.python.org/download/releases/2.3/mro/.
9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. _spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form __spam (at least two leading underscores, at most one trailing underscore) is textually replaced with _classname__spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

```python
class Mapping:
    def __init__(self, iterable):
        self.items_list = []
        self.__update(iterable)

    def update(self, iterable):
        for item in iterable:
            self.items_list.append(item)

    __update = update  # private copy of original update
```
```python
class MappingSubclass(Mapping):

    def update(self, keys, values):
        # provides new signature for update()
        # but does not break __init__()
        for item in zip(keys, values):
            self.items_list.append(item)
```

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(), setattr() and delattr(), as well as when referencing __dict__ directly.
9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

```python
class Employee:
    pass

john = Employee() # Create an empty employee record

# Fill the fields of the record
john.name = 'John Doe'
john.dept = 'computer lab'
john.salary = 1000
```

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods `read()` and `readline()` that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: `m.__self__` is the instance object with the method `m()`, and `m.__func__` is the function object corresponding to the method.
9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the `raise` statement:

```
raise Class
raise Instance
```

In the first form, `Class` must be an instance of `type` or of a class derived from it. The first form is a shorthand for:

```
raise Class()
```

A class in an `except` clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

```
class B(Exception):
    pass
class C(B):
    pass
class D(C):
    pass

for cls in [B, C, D]:
    try:
        raise cls()
    except D:
        print("D")
```
```python
except C:
    print("C")
except B:
    print("B")
```

Note that if the except clauses were reversed (with `except B` first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception's class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function `str()`.
9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a `for` statement:

```python
for element in [1, 2, 3]:
    print(element)
for element in (1, 2, 3):
    print(element)
for key in {'one':1, 'two':2}:
    print(key)
for char in "123":
    print(char)
for line in open("myfile.txt"):
    print(line, end='')
```

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the `for` statement calls `iter()` on the container object. The function returns an iterator object that defines the method `__next__()` which accesses elements in the container one at a time. When there are no more elements, `__next__()` raises a `StopIteration` exception which tells the `for` loop to terminate. You can call the `__next__()` method using the `next()` built-in function; this example shows how it all works:

```python
>>> s = 'abc'
>>> it = iter(s)
>>> it
<iterator object at 0x00A1DB50>
>>> next(it)
'a'
>>> next(it)
```
Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an `__iter__()` method which returns an object with a `__next__()` method. If the class defines `__next__()`, then `__iter__()` can just return `self`:

```python
class Reverse:
    """Iterator for looping over a sequence backwards."""
    def __init__(self, data):
        self.data = data
        self.index = len(data)
    def __iter__(self):
        return self
    def __next__(self):
        if self.index == 0:
            raise StopIteration
        self.index = self.index - 1
        return self.data[self.index]
```

```python
>>> rev = Reverse('spam')
>>> iter(rev)
<__main__.Reverse object at 0x00A1DB50>
>>> for char in rev:
...    print(char)
...    print(char)
...
ma
```
ps
9.10. Generators

Generators are a simple and powerful tool for creating iterators. They are written like regular functions but use the `yield` statement whenever they want to return data. Each time `next()` is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

```python
def reverse(data):
    for index in range(len(data)-1, -1, -1):
        yield data[index]

>>> for char in reverse('golf'):
   ...     print(char)
   ...
f
l
o
g
```

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the `__iter__()` and `__next__()` methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like `self.index` and `self.data`.

In addition to automatic method creation and saving program state,
when generators terminate, they automatically raise StopIteration. In combination, these features make it easy to create iterators with no more effort than writing a regular function.
9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

```python
>>> sum(i*i for i in range(10))  # sum of squares
285

>>> xvec = [10, 20, 30]
>>> yvec = [7, 5, 3]
>>> sum(x*y for x,y in zip(xvec, yvec))  # dot product
260

>>> from math import pi, sin
>>> sine_table = {x: sin(x*pi/180) for x in range(0, 180)}

>>> unique_words = set(word for line in page for word

>>> valedictorian = max((student.gpa, student.name)

>>> data = 'golf'
>>> list(data[i] for i in range(len(data)-1, -1, -1))
['f', 'l', 'o', 'g']
```

Footnotes
Except for one thing. Module objects have a secret read-only attribute called __dict__ which returns the dictionary used to implement the module's namespace; the name __dict__ is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers.
10. Brief Tour of the Standard Library
10.1. Operating System Interface

The `os` module provides dozens of functions for interacting with the operating system:

```python
>>> import os
>>> os.getcwd()   # Return the current working directory
'C:\Python35'
>>> os.chdir('/server/accesslogs')  # Change current directory
>>> os.system('mkdir today')  # Run the command mkdir in the system shell
0
```

Be sure to use the `import os` style instead of `from os import *`. This will keep `os.open()` from shadowing the built-in `open()` function which operates much differently.

The built-in `dir()` and `help()` functions are useful as interactive aids for working with large modules like `os`:

```python
>>> import os
>>> dir(os)
<returns a list of all module functions>
>>> help(os)
<returns an extensive manual page created from the module's docstrings>
```

For daily file and directory management tasks, the `shutil` module provides a higher level interface that is easier to use:

```python
>>> import shutil
>>> shutil.copyfile('data.db', 'archive.db')
'archive.db'
>>> shutil.move('/build/executables', 'installdir')
```
'installdir'
10.2. File Wildcards

The `glob` module provides a function for making file lists from directory wildcard searches:

```python
>>> import glob
>>> glob.glob('*.py')
['primes.py', 'random.py', 'quote.py']
```
10.3. Command Line Arguments

Common utility scripts often need to process command line arguments. These arguments are stored in the `sys` module’s `argv` attribute as a list. For instance the following output results from running `python demo.py one two three` at the command line:

```python
>>> import sys
>>> print(sys.argv)
['demo.py', 'one', 'two', 'three']
```

The `getopt` module processes `sys.argv` using the conventions of the Unix `getopt()` function. More powerful and flexible command line processing is provided by the `argparse` module.
10.4. Error Output Redirection and Program Termination

The `sys` module also has attributes for `stdin`, `stdout`, and `stderr`. The latter is useful for emitting warnings and error messages to make them visible even when `stdout` has been redirected:

```python
>>> sys.stderr.write('Warning, log file not found starting a new one
Warning, log file not found starting a new one
```

The most direct way to terminate a script is to use `sys.exit()`. 
10.5. String Pattern Matching

The `re` module provides regular expression tools for advanced string processing. For complex matching and manipulation, regular expressions offer succinct, optimized solutions:

```python
>>> import re
>>> re.findall(r'\b[a-z]*', 'which foot or hand fell fastest')
['foot', 'fell', 'fastest']
>>> re.sub(r'\b[a-z]+ \1', r'\1', 'cat in the the that')
'cat in the hat'
```

When only simple capabilities are needed, string methods are preferred because they are easier to read and debug:

```python
>>> 'tea for too'.replace('too', 'two')
'tea for two'
```
10.6. Mathematics

The `math` module gives access to the underlying C library functions for floating point math:

```python
>>> import math
>>> math.cos(math.pi / 4)
0.70710678118654757
>>> math.log(1024, 2)
10.0
```

The `random` module provides tools for making random selections:

```python
>>> import random
>>> random.choice(['apple', 'pear', 'banana'])
'apple'
>>> random.sample(range(100), 10)  # sampling without replacement
[30, 83, 16, 4, 8, 81, 41, 50, 18, 33]
>>> random.random()  # random float
0.17970987693706186
>>> random.randrange(6)  # random integer chosen from range(6)
4
```

The `statistics` module calculates basic statistical properties (the mean, median, variance, etc.) of numeric data:

```python
>>> import statistics
>>> data = [2.75, 1.75, 1.25, 0.25, 0.5, 1.25, 3.5]
>>> statistics.mean(data)
1.6071428571428572
>>> statistics.median(data)
1.25
>>> statistics.variance(data)
1.3720238095238095
```
The SciPy project <http://scipy.org> has many other modules for numerical computations.
10.7. Internet Access

There are a number of modules for accessing the internet and processing internet protocols. Two of the simplest are `urllib.request` for retrieving data from URLs and `smtplib` for sending mail:

```python
>>> from urllib.request import urlopen
>>> with urlopen('http://tycho.usno.navy.mil/cgi-bin/timer.pl') as response:
...     for line in response:
...         line = line.decode('utf-8')  # Decoding
...         if 'EST' in line or 'EDT' in line:  # Look for Eastern Time
...             print(line)

Nov. 25, 09:43:32 PM EST

>>> import smtplib
>>> server = smtplib.SMTP('localhost')
>>> server.sendmail('soothsayer@example.org', 'jcaesar@example.org',
...                 'To: jcaesar@example.org
...                 From: soothsayer@example.org
...                 ''Beware the Ides of March.
...                 ''
...                 ')
>>> server.quit()

(Note that the second example needs a mailserver running on localhost.)
10.8. Dates and Times

The `datetime` module supplies classes for manipulating dates and times in both simple and complex ways. While date and time arithmetic is supported, the focus of the implementation is on efficient member extraction for output formatting and manipulation. The module also supports objects that are timezone aware.

```python
>>> # dates are easily constructed and formatted
>>> from datetime import date
>>> now = date.today()
>>> now
datetime.date(2003, 12, 2)
>>> now.strftime('%m-%d-%y. %d %b %Y is a %A on the
'12-02-03. 02 Dec 2003 is a Tuesday on the 02 day of

>>> # dates support calendar arithmetic
>>> birthday = date(1964, 7, 31)
>>> age = now - birthday
>>> age.days
14368
```
10.9. Data Compression

Common data archiving and compression formats are directly supported by modules including: `zlib`, `gzip`, `bz2`, `lzma`, `zipfile` and `tarfile`.

```
>>> import zlib
>>> s = b'witch which has which witches wrist watch'
>>> len(s)
41
>>> t = zlib.compress(s)
>>> len(t)
37
>>> zlib.decompress(t)
b'witch which has which witches wrist watch'
>>> zlib.crc32(s)
226805979
```
10.10. Performance Measurement

Some Python users develop a deep interest in knowing the relative performance of different approaches to the same problem. Python provides a measurement tool that answers those questions immediately.

For example, it may be tempting to use the tuple packing and unpacking feature instead of the traditional approach to swapping arguments. The `timeit` module quickly demonstrates a modest performance advantage:

```python
>>> from timeit import Timer
>>> Timer('t=a; a=b; b=t', 'a=1; b=2').timeit()
0.57535828626024577
>>> Timer('a,b = b,a', 'a=1; b=2').timeit()
0.54962537085770791
```

In contrast to `timeit`'s fine level of granularity, the `profile` and `pstats` modules provide tools for identifying time critical sections in larger blocks of code.
10.11. Quality Control

One approach for developing high quality software is to write tests for each function as it is developed and to run those tests frequently during the development process.

The *doctest* module provides a tool for scanning a module and validating tests embedded in a program’s docstrings. Test construction is as simple as cutting-and-pasting a typical call along with its results into the docstring. This improves the documentation by providing the user with an example and it allows the doctest module to make sure the code remains true to the documentation:

```python
def average(values):
    """Computes the arithmetic mean of a list of numbers."
    >>> print(average([20, 30, 70]))
    40.0
    """
    return sum(values) / len(values)

import doctest
doctest.testmod()  # automatically validate the embedded tests
```

The *unittest* module is not as effortless as the *doctest* module, but it allows a more comprehensive set of tests to be maintained in a separate file:

```python
import unittest
class TestStatisticalFunctions(unittest.TestCase):
    def test_average(self):
```
self.assertEqual(average([20, 30, 70]), 40.0)
self.assertEqual(round(average([1, 5, 7]), 1)

with self.assertRaises(ZeroDivisionError):
    average([])

with self.assertRaises(TypeError):
    average(20, 30, 70)

unittest.main()  # Calling from the command line invokes all tests
10.12. Batteries Included

Python has a “batteries included” philosophy. This is best seen through the sophisticated and robust capabilities of its larger packages. For example:

- The `xmlrpc.client` and `xmlrpc.server` modules make implementing remote procedure calls into an almost trivial task. Despite the modules names, no direct knowledge or handling of XML is needed.
- The `email` package is a library for managing email messages, including MIME and other RFC 2822-based message documents. Unlike `smtplib` and `poplib` which actually send and receive messages, the email package has a complete toolset for building or decoding complex message structures (including attachments) and for implementing internet encoding and header protocols.
- The `json` package provides robust support for parsing this popular data interchange format. The `csv` module supports direct reading and writing of files in Comma-Separated Value format, commonly supported by databases and spreadsheets. XML processing is supported by the `xml.etree.ElementTree`, `xml.dom` and `xml.sax` packages. Together, these modules and packages greatly simplify data interchange between Python applications and other tools.
- The `sqlite3` module is a wrapper for the SQLite database library, providing a persistent database that can be updated and accessed using slightly nonstandard SQL syntax.
- Internationalization is supported by a number of modules including `gettext`, `locale`, and the `codecs` package.
The Python Software Foundation is a non-profit corporation. Please donate.
Last updated on Dec 06, 2015. Found a bug?
Created using Sphinx 1.3.1.
11. Brief Tour of the Standard Library – Part II

This second tour covers more advanced modules that support professional programming needs. These modules rarely occur in small scripts.
11.1. Output Formatting

The `reprlib` module provides a version of `repr()` customized for abbreviated displays of large or deeply nested containers:

```python
>>> import reprlib
>>> reprlib.repr(set('supercalifragilisticexpialidocious')
"{'a', 'c', 'd', 'e', 'f', 'g', ...}"
```

The `pprint` module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the “pretty printer” adds line breaks and indentation to more clearly reveal data structure:

```python
>>> import pprint
>>> t=[[['black', 'cyan'], 'white', ['green', 'red', 'yellow'], 'blue']]
... >>> pprint.pprint(t, width=30)
[[['black', 'cyan'],
  'white',
  ['green', 'red'],
  [['magenta', 'yellow'],
    'blue']]]
```

The `textwrap` module formats paragraphs of text to fit a given screen width:

```python
>>> import textwrap
>>> doc = """The wrap() method is just like fill() except that it returns a list of strings instead of one big string with the wrapped lines."""
```
The `locale` module accesses a database of culture specific data formats. The grouping attribute of locale's format function provides a direct way of formatting numbers with group separators:

```python
>>> import locale

>>> locale.setlocale(locale.LC_ALL, 'English_United States.1252')

>>> conv = locale.localeconv()  # get a mapping

>>> x = 1234567.8

>>> locale.format("%d", x, grouping=True)
'1,234,567'

>>> locale.format_string("%s.*f", (conv['currency_symbol'], conv['frac_digits']), x), grouping=True)
'$1,234,567.80'
```
11.2. Templating

The `string` module includes a versatile `Template` class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by $ with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing $$ creates a single escaped $:

```python
>>> from string import Template
>>> t = Template('${village}folk send $$10 to $cause.
' 'Nottinghamfolk send $10 to the ditch fund.
```

The `substitute()` method raises a `KeyError` when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the `safe_substitute()` method may be more appropriate — it will leave placeholders unchanged if data is missing:

```python
>>> t = Template('Return the $item to $owner.')
>>> d = dict(item='unladen swallow')
>>> t.substitute(d)
Traceback (most recent call last):
  ...
KeyError: 'owner'
>>> t.safe_substitute(d)
'Return the unladen swallow to $owner.'
```
Template subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

```python
>>> import time, os.path
>>> photofiles = ['img_1074.jpg', 'img_1076.jpg', 'img_1077.jpg']
>>> class BatchRename(Template):
...     delimiter = '%'
>>> fmt = input('Enter rename style (%d-date %n-seqnum %f-format): )
Enter rename style (%d-date %n-seqnum %f-format): Ashley_%n%f

>>> t = BatchRename(fmt)
>>> date = time.strftime('%d%b%y')
>>> for i, filename in enumerate(photofiles):
...     base, ext = os.path.splitext(filename)
...     newname = t.substitute(d=date, n=i, f=ext)
...     print('{0} --> {1}'.format(filename, newname))

img_1074.jpg --> Ashley_0.jpg
img_1076.jpg --> Ashley_1.jpg
img_1077.jpg --> Ashley_2.jpg
```

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.
11.3. Working with Binary Data Record Layouts

The \texttt{struct} module provides \texttt{pack()} and \texttt{unpack()} functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the \texttt{zipfile} module. Pack codes "H" and "I" represent two and four byte unsigned numbers respectively. The "<" indicates that they are standard size and in little-endian byte order:

```python
import struct

with open('myfile.zip', 'rb') as f:
    data = f.read()

start = 0
for i in range(3):  # show the first 3 file headers
    start += 14
    fields = struct.unpack('<IIHH', data[start:start+14])
    crc32, comp_size, uncomp_size, filenamesize, extra_size = fields

    start += 16
    filename = data[start:start+filenamesize]
    start += filenamesize
    extra = data[start:start+extra_size]
    print(filename, hex(crc32), comp_size, uncomp_size)
    start += extra_size + comp_size  # skip to the next file
```


11.4. Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level `threading` module can run tasks in background while the main program continues to run:

```python
import threading, zipfile

class AsyncZip(threading.Thread):
    def __init__(self, infile, outfile):
        threading.Thread.__init__(self)
        self.infile = infile
        self.outfile = outfile
    def run(self):
        f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP_DEFLATED)
        f.write(self.infile)
        f.close()
        print('Finished background zip of:', self.infile)

background = AsyncZip('mydata.txt', 'myarchive.zip')
background.start()
print('The main program continues to run in foreground.

background.join()  # Wait for the background task
print('Main program waited until background was done.

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading
module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the `queue` module to feed that thread with requests from other threads. Applications using `Queue` objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.
11.5. Logging

The logging module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to sys.stderr:

```python
import logging
logging.debug('Debugging information')
logging.info('Informational message')
logging.warning('Warning:config file %s not found',
logging.error('Error occurred')
logging.critical('Critical error -- shutting down')
```

This produces the following output:

```
WARNING:root:Warning:config file server.conf not found
ERROR:root:Error occurred
CRITICAL:root:Critical error -- shutting down
```

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: DEBUG, INFO, WARNING, ERROR, and CRITICAL.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.
11.6. Weak References

Python does automatic memory management (reference counting for most objects and garbage collection to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

This approach works fine for most applications but occasionally there is a need to track objects only as long as they are being used by something else. Unfortunately, just tracking them creates a reference that makes them permanent. The weakref module provides tools for tracking objects without creating a reference. When the object is no longer needed, it is automatically removed from a weakref table and a callback is triggered for weakref objects. Typical applications include caching objects that are expensive to create:

```python
>>> import weakref, gc
>>> class A:
...     def __init__(self, value):
...         self.value = value
...     def __repr__(self):
...         return str(self.value)
...
>>> a = A(10)  # create a reference
>>> d = weakref.WeakValueDictionary()
>>> d['primary'] = a  # does not create a reference
>>> d['primary']  # fetch the object if it is still alive
10
>>> del a  # remove the one reference
>>> gc.collect()  # run garbage collection
0
>>> d['primary']  # entry was automatically removed
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
    d['primary']  # entry was automatically removed
```

File "C:/python35/lib/weakref.py", line 46, in __getitem__
    o = self.data[key]()
KeyError: 'primary'
11.7. Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The array module provides an array() object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode "H") rather than the usual 16 bytes per entry for regular lists of Python int objects:

```python
>>> from array import array
>>> a = array('H', [4000, 10, 700, 22222])
>>> sum(a)
26932
>>> a[1:3]
array('H', [10, 700])
```

The collections module provides a deque() object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

```python
>>> from collections import deque
>>> d = deque(['task1', 'task2', 'task3'])
>>> d.append('task4')
>>> print('Handling', d.popleft())
Handling task1
```

```python
unsearched = deque([starting_node])
def breadth_first_search(unsearched):
    node = unsearched.popleft()
```
for m in gen_moves(node):
    if is_goal(m):
        return m
unsearched.append(m)

In addition to alternative list implementations, the library also offers other tools such as the `bisect` module with functions for manipulating sorted lists:

```python
>>> import bisect
>>> scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua')]
>>> bisect.insort(scores, (300, 'ruby'))
>>> scores
[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua')]
```

The `heapq` module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

```python
>>> from heapq import heapify, heappop, heappush
>>> data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]
>>> heapify(data)  # rearrange to heap order
>>> heappush(data, -5)  # add a new entry
>>> [heappop(data) for i in range(3)]  # fetch the three smallest entries
[-5, 0, 1]
```
11.8. Decimal Floating Point Arithmetic

The `decimal` module offers a `Decimal` datatype for decimal floating point arithmetic. Compared to the built-in `float` implementation of binary floating point, the class is especially helpful for

- financial applications and other uses which require exact decimal representation,
- control over precision,
- control over rounding to meet legal or regulatory requirements,
- tracking of significant decimal places, or
- applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

```python
>>> from decimal import *
>>> round(Decimal('0.70') * Decimal('1.05'), 2)
Decimal('0.74')
>>> round(.70 * 1.05, 2)
0.73
```

The `Decimal` result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. Decimal reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the `Decimal` class to perform modulo calculations and equality tests that are unsuitable for binary floating point.
point:

```python
>>> Decimal('1.00') % Decimal('.10')
Decimal('0.00')
>>> 1.00 % 0.10
0.09999999999999995

>>> sum([Decimal('0.1')] * 10) == Decimal('1.0')
True
>>> sum([0.1] * 10) == 1.0
False
```

The `decimal` module provides arithmetic with as much precision as needed:

```python
>>> getcontext().prec = 36
>>> Decimal(1) / Decimal(7)
Decimal('0.142857142857142857142857142857142857')
```
12. Virtual Environments and Packages
12.1. Introduction

Python applications will often use packages and modules that don’t come as part of the standard library. Applications will sometimes need a specific version of a library, because the application may require that a particular bug has been fixed or the application may be written using an obsolete version of the library’s interface.

This means it may not be possible for one Python installation to meet the requirements of every application. If application A needs version 1.0 of a particular module but application B needs version 2.0, then the requirements are in conflict and installing either version 1.0 or 2.0 will leave one application unable to run.

The solution for this problem is to create a virtual environment (often shortened to “virtualenv”), a self-contained directory tree that contains a Python installation for a particular version of Python, plus a number of additional packages.

Different applications can then use different virtual environments. To resolve the earlier example of conflicting requirements, application A can have its own virtual environment with version 1.0 installed while application B has another virtualenv with version 2.0. If application B requires a library be upgraded to version 3.0, this will not affect application A’s environment.
12.2. Creating Virtual Environments

The script used to create and manage virtual environments is called `pyvenv`. `pyvenv` will usually install the most recent version of Python that you have available; the script is also installed with a version number, so if you have multiple versions of Python on your system you can select a specific Python version by running `pyvenv-3.4` or whichever version you want.

To create a virtualenv, decide upon a directory where you want to place it and run `pyvenv` with the directory path:

```bash
pyenv tutorial-env
```

This will create the `tutorial-env` directory if it doesn't exist, and also create directories inside it containing a copy of the Python interpreter, the standard library, and various supporting files.

Once you've created a virtual environment, you need to activate it.

On Windows, run:

```bash
tutorial-env/Scripts/activate
```

On Unix or MacOS, run:

```bash
source tutorial-env/bin/activate
```

(This script is written for the bash shell. If you use the `csh` or `fish` shells, there are alternate `activate.csh` and `activate.fish` scripts you should use instead.)

Activating the virtualenv will change your shell's prompt to show what
virtualenv you’re using, and modify the environment so that running python will get you that particular version and installation of Python. For example:

```
-> source ~/envs/tutorial-env/bin/activate
(tutorial-env) -> python
Python 3.4.3+ (3.4:c7b9645a6f35+, May 22 2015, 09:31...

>>> import sys
>>> sys.path
['', '/usr/local/lib/python34.zip', '...
'~/envs/tutorial-env/lib/python3.4/site-packages']
>>> ```
12.3. Managing Packages with pip

Once you’ve activated a virtual environment, you can install, upgrade, and remove packages using a program called pip. By default pip will install packages from the Python Package Index, <https://pypi.python.org/pypi>. You can browse the Python Package Index by going to it in your web browser, or you can use pip’s limited search feature:

```
(tutorial-env) -> pip search astronomy
skyfield - Elegant astronomy for Python
gary - Galactic astronomy and gravity
novas - The United States Naval Observatory
astroobs - Provides astronomy ephemeris
PyAstronomy - A collection of astronomy related...
```

pip has a number of subcommands: “search”, “install”, “uninstall”, “freeze”, etc. (Consult the Installing Python Modules guide for complete documentation for pip.)

You can install the latest version of a package by specifying a package’s name:

```
-> pip install novas
Collecting novas
  Downloading novas-3.1.1.3.tar.gz (136kB)
Installing collected packages: novas
  Running setup.py install for novas
Successfully installed novas-3.1.1.3
```

You can also install a specific version of a package by giving the
package name followed by == and the version number:

```bash
-> pip install requests==2.6.0
Collecting requests==2.6.0
  Using cached requests-2.6.0-py2.py3-none-any.whl
Installing collected packages: requests
Successfully installed requests-2.6.0
```

If you re-run this command, pip will notice that the requested version is already installed and do nothing. You can supply a different version number to get that version, or you can run `pip install --upgrade` to upgrade the package to the latest version:

```bash
-> pip install --upgrade requests
Collecting requests
Installing collected packages: requests
  Found existing installation: requests 2.6.0
    Uninstalling requests-2.6.0:
      Successfully uninstalled requests-2.6.0
Successfully installed requests-2.7.0
```

`pip uninstall` followed by one or more package names will remove the packages from the virtual environment.

`pip show` will display information about a particular package:

```bash
(tutorial-env) -> pip show requests
---
Metadata-Version: 2.0
Name: requests
Version: 2.7.0
Summary: Python HTTP for Humans.
Home-page: http://python-requests.org
Author: Kenneth Reitz
Author-email: me@kennethreitz.com
```
pip list will display all of the packages installed in the virtual environment:

```
(tutorial-env) -> pip list
novas (3.1.1.3)
numpy (1.9.2)
pip (7.0.3)
requests (2.7.0)
setuptools (16.0)
```

pip freeze will produce a similar list of the installed packages, but the output uses the format that pip install expects. A common convention is to put this list in a requirements.txt file:

```
(tutorial-env) -> pip freeze > requirements.txt
(tutorial-env) -> cat requirements.txt
novas==3.1.1.3
numpy==1.9.2
requests==2.7.0
```

The requirements.txt can then be committed to version control and shipped as part of an application. Users can then install all the necessary packages with install -r:

```
-> pip install -r requirements.txt
Collecting novas==3.1.1.3 (from -r requirements.txt
... Collecting numpy==1.9.2 (from -r requirements.txt (from -r requirements.txt
... Collecting requests==2.7.0 (from -r requirements.txt
```
... Installing collected packages: novas, numpy, request
Running setup.py install for novas
Successfully installed novas-3.1.1.3 numpy-1.9.2 requests-2.5.2

pip has many more options. Consult the Installing Python Modules
guide for complete documentation for pip. When you’ve written a
package and want to make it available on the Python Package Index,
consult the Distributing Python Modules guide.
13. What Now?

Reading this tutorial has probably reinforced your interest in using Python — you should be eager to apply Python to solving your real-world problems. Where should you go to learn more?

This tutorial is part of Python's documentation set. Some other documents in the set are:

- **The Python Standard Library**: You should browse through this manual, which gives complete (though terse) reference material about types, functions, and the modules in the standard library. The standard Python distribution includes a *lot* of additional code. There are modules to read Unix mailboxes, retrieve documents via HTTP, generate random numbers, parse command-line options, write CGI programs, compress data, and many other tasks. Skimming through the Library Reference will give you an idea of what's available.

- **Installing Python Modules** explains how to install additional modules written by other Python users.

- **The Python Language Reference**: A detailed explanation of Python's syntax and semantics. It's heavy reading, but is useful as a complete guide to the language itself.

More Python resources:

- **https://www.python.org**: The major Python Web site. It contains code, documentation, and pointers to Python-related pages around the Web. This Web site is mirrored in various places around the world, such as Europe, Japan, and Australia; a mirror
may be faster than the main site, depending on your geographical location.

- **https://docs.python.org**: Fast access to Python’s documentation.
- **https://pypi.python.org/pypi**: The Python Package Index, previously also nicknamed the Cheese Shop, is an index of user-created Python modules that are available for download. Once you begin releasing code, you can register it here so that others can find it.
- **http://code.activestate.com/recipes/langs/python/**: The Python Cookbook is a sizable collection of code examples, larger modules, and useful scripts. Particularly notable contributions are collected in a book also titled Python Cookbook (O'Reilly & Associates, ISBN 0-596-00797-3.)
- **http://www.pyvideo.org** collects links to Python-related videos from conferences and user-group meetings.
- **http://scipy.org**: The Scientific Python project includes modules for fast array computations and manipulations plus a host of packages for such things as linear algebra, Fourier transforms, non-linear solvers, random number distributions, statistical analysis and the like.

For Python-related questions and problem reports, you can post to the newsgroup *comp.lang.python*, or send them to the mailing list at *python-list@python.org*. The newsgroup and mailing list are gatewayed, so messages posted to one will automatically be forwarded to the other. There are hundreds of postings a day, asking (and answering) questions, suggesting new features, and announcing new modules. Mailing list archives are available at *https://mail.python.org/pipermail/*.

Before posting, be sure to check the list of **Frequently Asked Questions** (also called the FAQ). The FAQ answers many of the questions that come up again and again, and may already contain the solution for your problem.
14. Interactive Input Editing and History Substitution

Some versions of the Python interpreter support editing of the current input line and history substitution, similar to facilities found in the Korn shell and the GNU Bash shell. This is implemented using the GNU Readline library, which supports various styles of editing. This library has its own documentation which we won’t duplicate here.
14.1. Tab Completion and History Editing

Completion of variable and module names is automatically enabled at interpreter startup so that the Tab key invokes the completion function; it looks at Python statement names, the current local variables, and the available module names. For dotted expressions such as `string.a`, it will evaluate the expression up to the final `'.'` and then suggest completions from the attributes of the resulting object. Note that this may execute application-defined code if an object with a `__getattr__()` method is part of the expression. The default configuration also saves your history into a file named `.python_history` in your user directory. The history will be available again during the next interactive interpreter session.
14.2. Alternatives to the Interactive Interpreter

This facility is an enormous step forward compared to earlier versions of the interpreter; however, some wishes are left: It would be nice if the proper indentation were suggested on continuation lines (the parser knows if an indent token is required next). The completion mechanism might use the interpreter's symbol table. A command to check (or even suggest) matching parentheses, quotes, etc., would also be useful.

One alternative enhanced interactive interpreter that has been around for quite some time is IPython, which features tab completion, object exploration and advanced history management. It can also be thoroughly customized and embedded into other applications. Another similar enhanced interactive environment is bpython.
15. Floating Point Arithmetic: Issues and Limitations

Floating-point numbers are represented in computer hardware as base 2 (binary) fractions. For example, the decimal fraction

\[0.125\]

has value \(1/10 + 2/100 + 5/1000\), and in the same way the binary fraction

\[0.001\]

has value \(0/2 + 0/4 + 1/8\). These two fractions have identical values, the only real difference being that the first is written in base 10 fractional notation, and the second in base 2.

Unfortunately, most decimal fractions cannot be represented exactly as binary fractions. A consequence is that, in general, the decimal floating-point numbers you enter are only approximated by the binary floating-point numbers actually stored in the machine.

The problem is easier to understand at first in base 10. Consider the fraction \(1/3\). You can approximate that as a base 10 fraction:

\[0.3\]

or, better,

\[0.33\]
or, better,

0.333

and so on. No matter how many digits you’re willing to write down, the result will never be exactly 1/3, but will be an increasingly better approximation of 1/3.

In the same way, no matter how many base 2 digits you’re willing to use, the decimal value 0.1 cannot be represented exactly as a base 2 fraction. In base 2, 1/10 is the infinitely repeating fraction

0.0001100110011001100110011001100110011001100110011...

Stop at any finite number of bits, and you get an approximation. On most machines today, floats are approximated using a binary fraction with the numerator using the first 53 bits starting with the most significant bit and with the denominator as a power of two. In the case of 1/10, the binary fraction is 3602879701896397 / 2 ** 55 which is close to but not exactly equal to the true value of 1/10.

Many users are not aware of the approximation because of the way values are displayed. Python only prints a decimal approximation to the true decimal value of the binary approximation stored by the machine. On most machines, if Python were to print the true decimal value of the binary approximation stored for 0.1, it would have to display

>>> 0.1
0.100000000000000000000000000000000000000000000000000

That is more digits than most people find useful, so Python keeps the
number of digits manageable by displaying a rounded value instead

```python
>>> 1 / 10
0.1
```

Just remember, even though the printed result looks like the exact value of 1/10, the actual stored value is the nearest representable binary fraction.

Interestingly, there are many different decimal numbers that share the same nearest approximate binary fraction. For example, the numbers 0.1 and 0.10000000000000001 and 0.10000000000000000555111512312578270211815834045410 are all approximated by 3602879701896397 / 2 ** 55. Since all of these decimal values share the same approximation, any one of them could be displayed while still preserving the invariant `eval(repr(x)) == x`.

Historically, the Python prompt and built-in `repr()` function would choose the one with 17 significant digits, 0.10000000000000001. Starting with Python 3.1, Python (on most systems) is now able to choose the shortest of these and simply display 0.1.

Note that this is in the very nature of binary floating-point: this is not a bug in Python, and it is not a bug in your code either. You'll see the same kind of thing in all languages that support your hardware’s floating-point arithmetic (although some languages may not display the difference by default, or in all output modes).

For more pleasant output, you may wish to use string formatting to produce a limited number of significant digits:

```python
>>> format(math.pi, '.12g')  # give 12 significant digits
```
It's important to realize that this is, in a real sense, an illusion: you're simply rounding the display of the true machine value.

One illusion may beget another. For example, since 0.1 is not exactly 1/10, summing three values of 0.1 may not yield exactly 0.3, either:

```python
>>> .1 + .1 + .1 == .3
False
```

Also, since the 0.1 cannot get any closer to the exact value of 1/10 and 0.3 cannot get any closer to the exact value of 3/10, then pre-rounding with `round()` function cannot help:

```python
>>> round(.1, 1) + round(.1, 1) + round(.1, 1) == round(.3, 1)
False
```

Though the numbers cannot be made closer to their intended exact values, the `round()` function can be useful for post-rounding so that results with inexact values become comparable to one another:

```python
>>> round(.1 + .1 + .1, 10) == round(.3, 10)
True
```

Binary floating-point arithmetic holds many surprises like this. The problem with "0.1" is explained in precise detail below, in the
“Representation Error” section. See *The Perils of Floating Point* for a more complete account of other common surprises.

As that says near the end, “there are no easy answers.” Still, don’t be unduly wary of floating-point! The errors in Python float operations are inherited from the floating-point hardware, and on most machines are on the order of no more than 1 part in $2^{53}$ per operation. That’s more than adequate for most tasks, but you do need to keep in mind that it’s not decimal arithmetic and that every float operation can suffer a new rounding error.

While pathological cases do exist, for most casual use of floating-point arithmetic you’ll see the result you expect in the end if you simply round the display of your final results to the number of decimal digits you expect. `str()` usually suffices, and for finer control see the `str.format()` method's format specifiers in *Format String Syntax*.

For use cases which require exact decimal representation, try using the `decimal` module which implements decimal arithmetic suitable for accounting applications and high-precision applications.

Another form of exact arithmetic is supported by the `fractions` module which implements arithmetic based on rational numbers (so the numbers like $1/3$ can be represented exactly).

If you are a heavy user of floating point operations you should take a look at the Numerical Python package and many other packages for mathematical and statistical operations supplied by the SciPy project. See <http://scipy.org>.

Python provides tools that may help on those rare occasions when you really do want to know the exact value of a float. The `float.as_integer_ratio()` method expresses the value of a float
as a fraction:

```python
>>> x = 3.14159
>>> x.as_integer_ratio()
(3537115888337719, 1125899906842624)
```

Since the ratio is exact, it can be used to losslessly recreate the original value:

```python
>>> x == 3537115888337719 / 1125899906842624
True
```

The `float.hex()` method expresses a float in hexadecimal (base 16), again giving the exact value stored by your computer:

```python
>>> x.hex()
'0x1.921f9f01b866ep+1'
```

This precise hexadecimal representation can be used to reconstruct the float value exactly:

```python
>>> x == float.fromhex('0x1.921f9f01b866ep+1')
True
```

Since the representation is exact, it is useful for reliably porting values across different versions of Python (platform independence) and exchanging data with other languages that support the same format (such as Java and C99).

Another helpful tool is the `math.fsum()` function which helps mitigate loss-of-precision during summation. It tracks “lost digits” as values are added onto a running total. That can make a difference in overall accuracy so that the errors do not accumulate to the point where they affect the final total:
```python
>>> sum([0.1] * 10) == 1.0
False
>>> math.fsum([0.1] * 10) == 1.0
True
```
15.1. Representation Error

This section explains the “0.1” example in detail, and shows how you can perform an exact analysis of cases like this yourself. Basic familiarity with binary floating-point representation is assumed.

*Representation error* refers to the fact that some (most, actually) decimal fractions cannot be represented exactly as binary (base 2) fractions. This is the chief reason why Python (or Perl, C, C++, Java, Fortran, and many others) often won’t display the exact decimal number you expect.

Why is that? 1/10 is not exactly representable as a binary fraction. Almost all machines today (November 2000) use IEEE-754 floating point arithmetic, and almost all platforms map Python floats to IEEE-754 “double precision”. 754 doubles contain 53 bits of precision, so on input the computer strives to convert 0.1 to the closest fraction it can of the form \( J/2**N \) where \( J \) is an integer containing exactly 53 bits. Rewriting

\[
\begin{align*}
1 / 10 & \approx J / (2**N) \\
J & \approx 2**N / 10
\end{align*}
\]

and recalling that \( J \) has exactly 53 bits (is \( \geq 2**52 \) but \( < 2**53 \)), the best value for \( N \) is 56:

\[
>>> \ 2**52 \ <= \ 2**56 \ // \ 10 \ < \ 2**53 \\
True
\]
That is, 56 is the only value for $N$ that leaves $J$ with exactly 53 bits. The best possible value for $J$ is then that quotient rounded:

```python
>>> q, r = divmod(2**56, 10)
>>> r
6
```

Since the remainder is more than half of 10, the best approximation is obtained by rounding up:

```python
>>> q+1
7205759403792794
```

Therefore the best possible approximation to 1/10 in 754 double precision is:

```
7205759403792794 / 2 ** 56
```

Dividing both the numerator and denominator by two reduces the fraction to:

```
3602879701896397 / 2 ** 55
```

Note that since we rounded up, this is actually a little bit larger than 1/10; if we had not rounded up, the quotient would have been a little bit smaller than 1/10. But in no case can it be exactly 1/10!

So the computer never “sees” 1/10: what it sees is the exact fraction given above, the best 754 double approximation it can get:

```python
>>> 0.1 * 2 ** 55
3602879701896397.0
```

If we multiply that fraction by 10**55, we can see the value out to 55
decimal digits:

```python
>>> 3602879701896397 * 10 ** 55 // 2 ** 55
100000000000000055511151231257827021181583404541015625
```

meaning that the exact number stored in the computer is equal to the decimal value 0.1000000000000000055511151231257827021181583404541015625. Instead of displaying the full decimal value, many languages (including older versions of Python), round the result to 17 significant digits:

```python
>>> format(0.1, '.17f')
'0.10000000000000001'
```

The `fractions` and `decimal` modules make these calculations easy:

```python
>>> from decimal import Decimal
>>> from fractions import Fraction

>>> Fraction.from_float(0.1)
Fraction(3602879701896397, 36028797018963968)

>>> (0.1).as_integer_ratio()
(3602879701896397, 36028797018963968)

>>> Decimal.from_float(0.1)
Decimal('0.1000000000000000055511151231257827021181583404541015625')

>>> format(Decimal.from_float(0.1), '.17')
'0.10000000000000001'
```
16. Appendix
16.1. Interactive Mode

16.1.1. Error Handling

When an error occurs, the interpreter prints an error message and a stack trace. In interactive mode, it then returns to the primary prompt; when input came from a file, it exits with a nonzero exit status after printing the stack trace. (Exceptions handled by an except clause in a try statement are not errors in this context.) Some errors are unconditionally fatal and cause an exit with a nonzero exit; this applies to internal inconsistencies and some cases of running out of memory. All error messages are written to the standard error stream; normal output from executed commands is written to standard output.

Typing the interrupt character (usually Control-C or Delete) to the primary or secondary prompt cancels the input and returns to the primary prompt. [1] Typing an interrupt while a command is executing raises the KeyboardInterrupt exception, which may be handled by a try statement.

16.1.2. Executable Python Scripts

On BSD’ish Unix systems, Python scripts can be made directly executable, like shell scripts, by putting the line

```
#!/usr/bin/env python3.5
```

(assuming that the interpreter is on the user’s PATH) at the beginning of the script and giving the file an executable mode. The #! must be the first two characters of the file. On some platforms, this first line must end with a Unix-style line ending ("\n"), not a Windows
(\r\n) line ending. Note that the hash, or pound, character, '#', is used to start a comment in Python.

The script can be given an executable mode, or permission, using the **chmod** command.

```
$ chmod +x myscript.py
```

On Windows systems, there is no notion of an “executable mode”. The Python installer automatically associates .py files with python.exe so that a double-click on a Python file will run it as a script. The extension can also be .pyw, in that case, the console window that normally appears is suppressed.

### 16.1.3. The Interactive Startup File

When you use Python interactively, it is frequently handy to have some standard commands executed every time the interpreter is started. You can do this by setting an environment variable named **PYTHONSTARTUP** to the name of a file containing your start-up commands. This is similar to the .profile feature of the Unix shells.

This file is only read in interactive sessions, not when Python reads commands from a script, and not when /dev/tty is given as the explicit source of commands (which otherwise behaves like an interactive session). It is executed in the same namespace where interactive commands are executed, so that objects that it defines or imports can be used without qualification in the interactive session. You can also change the prompts sys.ps1 and sys.ps2 in this file.

If you want to read an additional start-up file from the current directory, you can program this in the global start-up file using code like if
os.path.isfile('.pythonrc.py'):
exec(open('.pythonrc.py').read()). If you want to use the startup file in a script, you must do this explicitly in the script:

```python
import os
filename = os.environ.get('PYTHONSTARTUP')
if filename and os.path.isfile(filename):
    with open(filename) as fobj:
        startup_file = fobj.read()
    exec(startup_file)
```

16.1.4. The Customization Modules

Python provides two hooks to let you customize it: sitecustomize and usercustomize. To see how it works, you need first to find the location of your user site-packages directory. Start Python and run this code:

```python
>>> import site
>>> site.getusersitepackages()
'/home/user/.local/lib/python3.5/site-packages'
```

Now you can create a file named usercustomize.py in that directory and put anything you want in it. It will affect every invocation of Python, unless it is started with the -s option to disable the automatic import.

sitecustomize works in the same way, but is typically created by an administrator of the computer in the global site-packages directory, and is imported before usercustomize. See the documentation of the site module for more details.
Footnotes

[1] A problem with the GNU Readline package may prevent this.
1. Command line and environment

The CPython interpreter scans the command line and the environment for various settings.

**CPython implementation detail:** Other implementations’ command line schemes may differ. See *Alternate Implementations* for further resources.
1.1. Command line

When invoking Python, you may specify any of these options:

```python
python [-bBdEhiIOqsSuvVwX?] [-c command | -m module-name]
```

The most common use case is, of course, a simple invocation of a script:

```bash
python myscript.py
```

### 1.1.1. Interface options

The interpreter interface resembles that of the UNIX shell, but provides some additional methods of invocation:

- When called with standard input connected to a tty device, it prompts for commands and executes them until an EOF (an end-of-file character, you can produce that with Ctrl-D on UNIX or Ctrl-Z, Enter on Windows) is read.
- When called with a file name argument or with a file as standard input, it reads and executes a script from that file.
- When called with a directory name argument, it reads and executes an appropriately named script from that directory.
- When called with `-c command`, it executes the Python statement(s) given as `command`. Here `command` may contain multiple statements separated by newlines. Leading whitespace is significant in Python statements!
- When called with `-m module-name`, the given module is located on the Python module path and executed as a script.

In non-interactive mode, the entire input is parsed before it is
An interface option terminates the list of options consumed by the interpreter, all consecutive arguments will end up in sys.argv – note that the first element, subscript zero (sys.argv[0]), is a string reflecting the program’s source.

-c <command>

Execute the Python code in command. command can be one or more statements separated by newlines, with significant leading whitespace as in normal module code.

If this option is given, the first element of sys.argv will be "-c" and the current directory will be added to the start of sys.path (allowing modules in that directory to be imported as top level modules).

-m <module-name>

Search sys.path for the named module and execute its contents as the __main__ module.

Since the argument is a module name, you must not give a file extension (.py). The module-name should be a valid Python module name, but the implementation may not always enforce this (e.g. it may allow you to use a name that includes a hyphen).

Package names (including namespace packages) are also permitted. When a package name is supplied instead of a normal module, the interpreter will execute <pkg>.__main__ as the main module. This behaviour is deliberately similar to the handling of directories and zipfiles that are passed to the interpreter as the script argument.
**Note:** This option cannot be used with built-in modules and extension modules written in C, since they do not have Python module files. However, it can still be used for precompiled modules, even if the original source file is not available.

If this option is given, the first element of `sys.argv` will be the full path to the module file (while the module file is being located, the first element will be set to "-m"). As with the `-c` option, the current directory will be added to the start of `sys.path`.

Many standard library modules contain code that is invoked on their execution as a script. An example is the `timeit` module:

```
python -mtimeit -s 'setup here' 'benchmarked code
python -mtimeit -h # for details
```

See also:
- `runpy.run_module()`
  
  Equivalent functionality directly available to Python code

**PEP 338** – Executing modules as scripts

*Changed in version 3.1:* Supply the package name to run a `__main__` submodule.

*Changed in version 3.4:* namespace packages are also supported

- Read commands from standard input (`sys.stdin`). If standard input is a terminal, `-i` is implied.

If this option is given, the first element of `sys.argv` will be "-" and the current directory will be added to the start of `sys.path`. 
Execute the Python code contained in `script`, which must be a filesystem path (absolute or relative) referring to either a Python file, a directory containing a `__main__.py` file, or a zipfile containing a `__main__.py` file.

If this option is given, the first element of `sys.argv` will be the script name as given on the command line.

If the script name refers directly to a Python file, the directory containing that file is added to the start of `sys.path`, and the file is executed as the `__main__` module.

If the script name refers to a directory or zipfile, the script name is added to the start of `sys.path` and the `__main__.py` file in that location is executed as the `__main__` module.

See also: `runpy.run_path()`
Equivalent functionality directly available to Python code

If no interface option is given, `-i` is implied, `sys.argv[0]` is an empty string ("""") and the current directory will be added to the start of `sys.path`. Also, tab-completion and history editing is automatically enabled, if available on your platform (see `Readline configuration`).

See also: Invoking the Interpreter

*Changed in version 3.4:* Automatic enabling of tab-completion and history editing.
1.1.2. Generic options

-?
-h
--help

Print a short description of all command line options.

-V
--version

Print the Python version number and exit. Example output could be:

Python 3.0

1.1.3. Miscellaneous options

-b

Issue a warning when comparing bytes or bytearray with str or bytes with int. Issue an error when the option is given twice (-bb).

-B

If given, Python won’t try to write .pyc files on the import of source modules. See also PYTHONDONTWRITEBYTECODE.

-d

Turn on parser debugging output (for wizards only, depending on compilation options). See also PYTHONDEBUG.

-E

Ignore all PYTHON* environment variables, e.g. PYTHONPATH and
**PYTHONHOME**, that might be set.

- **i**
  When a script is passed as first argument or the `-c` option is used, enter interactive mode after executing the script or the command, even when `sys.stdin` does not appear to be a terminal. The `PYTHONSTARTUP` file is not read.
  
  This can be useful to inspect global variables or a stack trace when a script raises an exception. See also **PYTHONINSPECT**.

- **I**
  Run Python in isolated mode. This also implies -E and -s. In isolated mode `sys.path` contains neither the script's directory nor the user's site-packages directory. All `PYTHON*` environment variables are ignored, too. Further restrictions may be imposed to prevent the user from injecting malicious code.

  *New in version 3.4.*

- **O**
  Turn on basic optimizations. This changes the filename extension for compiled (bytecode) files from `.pyc` to `.pyo`. See also **PYTHONOPTIMIZE**.

- **OO**
  Discard docstrings in addition to the -O optimizations.

- **q**
  Don’t display the copyright and version messages even in interactive mode.

  *New in version 3.2.*
**-R**

Kept for compatibility. On Python 3.3 and greater, hash randomization is turned on by default.

On previous versions of Python, this option turns on hash randomization, so that the `__hash__()` values of str, bytes and datetime are “salted” with an unpredictable random value. Although they remain constant within an individual Python process, they are not predictable between repeated invocations of Python.

Hash randomization is intended to provide protection against a denial-of-service caused by carefully-chosen inputs that exploit the worst case performance of a dict construction, $O(n^2)$ complexity. See [http://www.ocert.org/advisories/ocert-2011-003.html](http://www.ocert.org/advisories/ocert-2011-003.html) for details.

**PYTHONHASHSEED** allows you to set a fixed value for the hash seed secret.

*New in version 3.2.3.*

**-s**

Don’t add the `user site-packages directory` to `sys.path`.

**See also:** [PEP 370 – Per user site-packages directory](http://www.python.org/dev/peps/pep-0370/)

**-S**

Disable the import of the module `site` and the site-dependent manipulations of `sys.path` that it entails. Also disable these manipulations if `site` is explicitly imported later (call `site.main()` if you want them to be triggered).

**-u**

Force the binary layer of the stdout and stderr streams (which is
available as their buffer attribute) to be unbuffered. The text I/O layer will still be line-buffered if writing to the console, or block-buffered if redirected to a non-interactive file.

See also PYTHONUNBUFFERED.

-\texttt{v}
Print a message each time a module is initialized, showing the place (filename or built-in module) from which it is loaded. When given twice (\texttt{-vv}), print a message for each file that is checked for when searching for a module. Also provides information on module cleanup at exit. See also PYTHONVERBOSE.

-\texttt{W} arg
Warning control. Python's warning machinery by default prints warning messages to \texttt{sys.stderr}. A typical warning message has the following form:

\begin{quote}
\texttt{file:line: category: message}
\end{quote}

By default, each warning is printed once for each source line where it occurs. This option controls how often warnings are printed.

Multiple \texttt{-W} options may be given; when a warning matches more than one option, the action for the last matching option is performed. Invalid \texttt{-W} options are ignored (though, a warning message is printed about invalid options when the first warning is issued).

Warnings can also be controlled from within a Python program using the \texttt{warnings} module.

The simplest form of argument is one of the following action strings
(or a unique abbreviation):

ignore
   Ignore all warnings.

default
   Explicitly request the default behavior (printing each warning once per source line).

all
   Print a warning each time it occurs (this may generate many messages if a warning is triggered repeatedly for the same source line, such as inside a loop).

module
   Print each warning only the first time it occurs in each module.

once
   Print each warning only the first time it occurs in the program.

error
   Raise an exception instead of printing a warning message.

The full form of argument is:

\[ \text{action: message: category: module: line} \]

Here, \textit{action} is as explained above but only applies to messages that match the remaining fields. Empty fields match all values; trailing empty fields may be omitted. The \textit{message} field matches the start of the warning message printed; this match is case-insensitive. The \textit{category} field matches the warning category. This must be a class name; the match tests whether the actual warning category of the message is a subclass of the specified warning category. The full class name must be given. The \textit{module} field matches the (fully-qualified) module name; this match is case-
sensitive. The *line* field matches the line number, where zero matches all line numbers and is thus equivalent to an omitted line number.

**See also:** *warnings* – the warnings module

**PEP 230** – Warning framework

**PYTHONWARNINGS**

---

**-X**

Skip the first line of the source, allowing use of non-Unix forms of `#!cmd`. This is intended for a DOS specific hack only.

**Note:** The line numbers in error messages will be off by one.

---

**-X**

Reserved for various implementation-specific options. CPython currently defines the following possible values:

- `-X faulthandler` to enable *faulthandler*;
- `-X showrefcount` to enable the output of the total reference count and memory blocks (only works on debug builds);
- `-X tracemalloc` to start tracing Python memory allocations using the *tracemalloc* module. By default, only the most recent frame is stored in a traceback of a trace. Use `-X tracemalloc=NFRAME` to start tracing with a traceback limit of `NFRAME` frames. See the *tracemalloc.start()* for more information.

It also allows to pass arbitrary values and retrieve them through the *sys._xoptions* dictionary.

*Changed in version 3.2:* It is now allowed to pass `-X` with CPython.
New in version 3.3: The -X faulthandler option.

New in version 3.4: The -X showrefcount and -X tracemalloc options.

1.1.4. Options you shouldn’t use

-J
Reserved for use by Jython.
1.2. Environment variables

These environment variables influence Python's behavior, they are processed before the command-line switches other than -E or -l. It is customary that command-line switches override environmental variables where there is a conflict.

**PYTHONHOME**

Change the location of the standard Python libraries. By default, the libraries are searched in `prefix/lib/pythonversion` and `exec_prefix/lib/pythonversion`, where `prefix` and `exec_prefix` are installation-dependent directories, both defaulting to `/usr/local`.

When **PYTHONHOME** is set to a single directory, its value replaces both `prefix` and `exec_prefix`. To specify different values for these, set **PYTHONHOME** to `prefix:exec_prefix`.

**PYTHONPATH**

Augment the default search path for module files. The format is the same as the shell’s PATH: one or more directory pathnames separated by `os.pathsep` (e.g. colons on Unix or semicolons on Windows). Non-existent directories are silently ignored.

In addition to normal directories, individual **PYTHONPATH** entries may refer to zipfiles containing pure Python modules (in either source or compiled form). Extension modules cannot be imported from zipfiles.

The default search path is installation dependent, but generally begins with `prefix/lib/pythonversion` (see **PYTHONHOME**).
above). It is *always* appended to **PYTHONPATH**.

An additional directory will be inserted in the search path in front of **PYTHONPATH** as described above under *Interface options*. The search path can be manipulated from within a Python program as the variable **sys.path**.

**PYTHONSTARTUP**

If this is the name of a readable file, the Python commands in that file are executed before the first prompt is displayed in interactive mode. The file is executed in the same namespace where interactive commands are executed so that objects defined or imported in it can be used without qualification in the interactive session. You can also change the prompts **sys.ps1** and **sys.ps2** and the hook **sys.__interactivehook__** in this file.

**PYTHONOPTIMIZE**

If this is set to a non-empty string it is equivalent to specifying the **-O** option. If set to an integer, it is equivalent to specifying **-O** multiple times.

**PYTHONDEBUG**

If this is set to a non-empty string it is equivalent to specifying the **-d** option. If set to an integer, it is equivalent to specifying **-d** multiple times.

**PYTHONINSPECT**

If this is set to a non-empty string it is equivalent to specifying the **-i** option.

This variable can also be modified by Python code using **os.environ** to force inspect mode on program termination.
**PYTHONUNBUFFERED**

If this is set to a non-empty string it is equivalent to specifying the `-u` option.

**PYTHONVERBOSE**

If this is set to a non-empty string it is equivalent to specifying the `-v` option. If set to an integer, it is equivalent to specifying `-v` multiple times.

**PYTHONCASEOK**

If this is set, Python ignores case in `import` statements. This only works on Windows and OS X.

**PYTHONDONTWRITEBYTECODE**

If this is set to a non-empty string, Python won’t try to write `.pyc` or `.pyo` files on the import of source modules. This is equivalent to specifying the `-B` option.

**PYTHONHASHSEED**

If this variable is not set or set to `random`, a random value is used to seed the hashes of `str`, `bytes` and `datetime` objects.

If `PYTHONHASHSEED` is set to an integer value, it is used as a fixed seed for generating the `hash()` of the types covered by the hash randomization.

Its purpose is to allow repeatable hashing, such as for selftests for the interpreter itself, or to allow a cluster of python processes to share hash values.

The integer must be a decimal number in the range $[0, 4294967295]$. Specifying the value 0 will disable hash randomization.
New in version 3.2.3.

**PYTHONIOENCODING**

If this is set before running the interpreter, it overrides the encoding used for stdin/stdout/stderr, in the syntax `encodingname:errorhandler`. Both the `encodingname` and the `:errorhandler` parts are optional and have the same meaning as in `str.encode()`.

For stderr, the `:errorhandler` part is ignored; the handler will always be 'backslashreplace'.

*Changed in version 3.4:* The `encodingname` part is now optional.

**PYTHONNOUSERSITE**

If this is set, Python won't add the user site-packages directory to `sys.path`.

See also: [PEP 370](https://www.python.org/dev/peps/pep-0370/) – Per user site-packages directory

**PYTHONUSERBASE**

Defines the user base directory, which is used to compute the path of the user site-packages directory and Distutils installation paths for `python setup.py install --user`.

See also: [PEP 370](https://www.python.org/dev/peps/pep-0370/) – Per user site-packages directory

**PYTHONEXECUTABLE**

If this environment variable is set, `sys.argv[0]` will be set to its value instead of the value got through the C runtime. Only works on Mac OS X.
**PYTHONWARNINGS**

This is equivalent to the `-W` option. If set to a comma separated string, it is equivalent to specifying `-W` multiple times.

**PYTHONFAULTHANDLER**

If this environment variable is set to a non-empty string, `faulthandler.enable()` is called at startup: install a handler for SIGSEGV, SIGFPE, SIGABRT, SIGBUS and SIGILL signals to dump the Python traceback. This is equivalent to `-X` faulthandler option.

*New in version 3.3.*

**PYTHONTRACEMALLOC**

If this environment variable is set to a non-empty string, start tracing Python memory allocations using the `tracemalloc` module. The value of the variable is the maximum number of frames stored in a traceback of a trace. For example, `PYTHONTRACEMALLOC=1` stores only the most recent frame. See the `tracemalloc.start()` for more information.

*New in version 3.4.*

**PYTHONASYNCIODEBUG**

If this environment variable is set to a non-empty string, enable the debug mode of the `asyncio` module.

*New in version 3.4.*

### 1.2.1. Debug-mode variables

Setting these variables only has an effect in a debug build of Python,
that is, if Python was configured with the `--with-pydebug` build option.

**PYTHONTHREADDEBUG**

If set, Python will print threading debug info.

**PYTHONDUMPREFS**

If set, Python will dump objects and reference counts still alive after shutting down the interpreter.

**PYTHONMALLOCSTATS**

If set, Python will print memory allocation statistics every time a new object arena is created, and on shutdown.
2. Using Python on Unix platforms
2.1. Getting and installing the latest version of Python

2.1.1. On Linux

Python comes preinstalled on most Linux distributions, and is available as a package on all others. However there are certain features you might want to use that are not available on your distro's package. You can easily compile the latest version of Python from source.

In the event that Python doesn't come preinstalled and isn't in the repositories as well, you can easily make packages for your own distro. Have a look at the following links:

See also:

    for Debian users

http://en.opensuse.org/Portal:Packaging
    for OpenSuse users

    for Fedora users

    for Slackware users

2.1.2. On FreeBSD and OpenBSD

- FreeBSD users, to add the package use:
OpenBSD users use:

```
```

For example i386 users get the 2.5.1 version of Python using:

```
pkg_add ftp://ftp.openbsd.org/pub/OpenBSD/4.2/packages/i386/python-2.5.1p2.tgz
```

### 2.1.3. On OpenSolaris

You can get Python from OpenCSW. Various versions of Python are available and can be installed with e.g. `pkgutil -i python27`. 
2.2. Building Python

If you want to compile CPython yourself, first thing you should do is get the source. You can download either the latest release's source or just grab a fresh clone. (If you want to contribute patches, you will need a clone.)

The build process consists in the usual

```
./configure
make
make install
```

invocations. Configuration options and caveats for specific Unix platforms are extensively documented in the README file in the root of the Python source tree.

**Warning:** make install can overwrite or masquerade the python3 binary. make altinstall is therefore recommended instead of make install since it only installs `exec_prefix/bin/pythonversion`. 
2.3. Python-related paths and files

These are subject to difference depending on local installation conventions; prefix ($\{prefix\}$) and exec_prefix ($\{exec_prefix\}$) are installation-dependent and should be interpreted as for GNU software; they may be the same.

For example, on most Linux systems, the default for both is /usr.

<table>
<thead>
<tr>
<th>File/directory</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>exec_prefix/bin/python3</td>
<td>Recommended location of the interpreter.</td>
</tr>
<tr>
<td>prefix/lib/pythonversion, exec_prefix/lib/pythonversion</td>
<td>Recommended locations of the directories containing the standard modules.</td>
</tr>
<tr>
<td>prefix/include/pythonversion, exec_prefix/include/pythonversion</td>
<td>Recommended locations of the directories containing the include files needed for developing Python extensions and embedding the interpreter.</td>
</tr>
</tbody>
</table>
2.4. Miscellaneous

To easily use Python scripts on Unix, you need to make them executable, e.g. with

```
$ chmod +x script
```

and put an appropriate Shebang line at the top of the script. A good choice is usually

```
#!/usr/bin/env python3
```

which searches for the Python interpreter in the whole PATH. However, some Unices may not have the `env` command, so you may need to hardcode `/usr/bin/python3` as the interpreter path.

To use shell commands in your Python scripts, look at the `subprocess` module.
2.5. Editors

Vim and Emacs are excellent editors which support Python very well. For more information on how to code in Python in these editors, look at:

- http://sourceforge.net/projects/python-mode

Geany is an excellent IDE with support for a lot of languages. For more information, read: http://www.geany.org/

Komodo edit is another extremely good IDE. It also has support for a lot of languages. For more information, read http://komodoide.com/.
3. Using Python on Windows

This document aims to give an overview of Windows-specific behaviour you should know about when using Python on Microsoft Windows.
3.1. Installing Python

Unlike most Unix systems and services, Windows does not include a system supported installation of Python. To make Python available, the CPython team has compiled Windows installers (MSI packages) with every release for many years. These installers are primarily intended to add a per-user installation of Python, with the core interpreter and library being used by a single user. The installer is also able to install for all users of a single machine, and a separate ZIP file is available for application-local distributions.

3.1.1. Installation Steps

Four Python 3.5 installers are available for download - two each for the 32-bit and 64-bit versions of the interpreter. The web installer is a small initial download, and it will automatically download the required components as necessary. The offline installer includes the components necessary for a default installation and only requires an internet connection for optional features. See Installing Without Downloading for other ways to avoid downloading during installation.

After starting the installer, one of two options may be selected:
If you select “Install Now”:

- You will not need to be an administrator (unless a system update for the C Runtime Library is required or you install the Python Launcher for Windows for all users)
- Python will be installed into your user directory
- The Python Launcher for Windows will be installed according to the option at the bottom of the first page
- The standard library, test suite, launcher and pip will be installed
- If selected, the install directory will be added to your PATH
- Shortcuts will only be visible for the current user

Selecting “Customize installation” will allow you to select the features to install, the installation location and other options or post-install actions. To install debugging symbols or binaries, you will need to use this option.

To perform an all-users installation, you should select “Customize installation”. In this case:
• You may be required to provide administrative credentials or approval
• Python will be installed into the Program Files directory
• The Python Launcher for Windows will be installed into the Windows directory
• Optional features may be selected during installation
• The standard library can be pre-compiled to bytecode
• If selected, the install directory will be added to the system PATH
• Shortcuts are available for all users

3.1.2. Installing Without UI

All of the options available in the installer UI can also be specified from the command line, allowing scripted installers to replicate an installation on many machines without user interaction. These options may also be set without suppressing the UI in order to change some of the defaults.

To completely hide the installer UI and install Python silently, pass the /quiet option. To skip past the user interaction but still display progress and errors, pass the /passive option. The /uninstall option may be passed to immediately begin removing Python - no prompt will be displayed.

All other options are passed as name=value, where the value is usually 0 to disable a feature, 1 to enable a feature, or a path. The full list of available options is shown below.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>InstallAllUsers</td>
<td>Perform a system-wide installation.</td>
<td>0</td>
</tr>
<tr>
<td>TargetDir</td>
<td>The installation directory</td>
<td>Selected based on Inst</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>DefaultAllUsersTargetDir</td>
<td>The default installation directory for all-user installs</td>
<td>%ProgramFiles%\Python %ProgramFiles(x86)%\Python</td>
</tr>
<tr>
<td>DefaultJustForMeTargetDir</td>
<td>The default install directory for just-for-me installs</td>
<td>%LocalAppData%\Programs\PythonXY or %LocalAppData%\Programs\PythonXY-32</td>
</tr>
<tr>
<td>DefaultCustomTargetDir</td>
<td>The default custom install directory displayed in the UI</td>
<td>(empty)</td>
</tr>
<tr>
<td>AssociateFiles</td>
<td>Create file associations if the launcher is also installed.</td>
<td>1</td>
</tr>
<tr>
<td>CompileAll</td>
<td>Compile all .py files to .pyc.</td>
<td>0</td>
</tr>
<tr>
<td>PrependPath</td>
<td>Add install and Scripts directories to PATH and .PY to PATHEXT</td>
<td>0</td>
</tr>
<tr>
<td>Shortcuts</td>
<td>Create shortcuts for the interpreter, documentation and IDLE if</td>
<td>1</td>
</tr>
<tr>
<td>Feature</td>
<td>Description</td>
<td>Value</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Include_doc</td>
<td>Install Python manual</td>
<td>1</td>
</tr>
<tr>
<td>Include_debug</td>
<td>Install debug binaries</td>
<td>0</td>
</tr>
<tr>
<td>Include_dev</td>
<td>Install developer headers and libraries</td>
<td>1</td>
</tr>
<tr>
<td>Include_exe</td>
<td>Install python.exe and related files</td>
<td>1</td>
</tr>
<tr>
<td>Include_launcher</td>
<td>Install Python Launcher for Windows.</td>
<td>1</td>
</tr>
<tr>
<td>InstallLauncherAllUsers</td>
<td>Installs Python Launcher for Windows for all users.</td>
<td>1</td>
</tr>
<tr>
<td>Include_lib</td>
<td>Install standard library and extension modules</td>
<td>1</td>
</tr>
<tr>
<td>Include_pip</td>
<td>Install bundled pip and setuptools</td>
<td>1</td>
</tr>
<tr>
<td>Include_symbols</td>
<td>Install debugging symbols (*.pdb)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Install Tcl/Tk</td>
<td></td>
</tr>
<tr>
<td>Include_tcltk</td>
<td>support and IDLE</td>
<td>1</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------</td>
<td>---</td>
</tr>
<tr>
<td>Include_test</td>
<td>Install standard library test suite</td>
<td>1</td>
</tr>
<tr>
<td>Include_tools</td>
<td>Install utility scripts</td>
<td>1</td>
</tr>
<tr>
<td>LauncherOnly</td>
<td>Only installs the launcher. This will override most other options.</td>
<td>0</td>
</tr>
<tr>
<td>SimpleInstall</td>
<td>Disable most install UI</td>
<td>0</td>
</tr>
<tr>
<td>SimpleInstallDescription</td>
<td>A custom message to display when the simplified install UI is used.</td>
<td>(empty)</td>
</tr>
</tbody>
</table>

For example, to silently install a default, system-wide Python installation, you could use the following command (from an elevated command prompt):

```plaintext
python-3.5.0.exe /quiet InstallAllUsers=1 PrependPath=1 Include_test=0
```

To allow users to easily install a personal copy of Python without the test suite, you could provide a shortcut with the following command. This will display a simplified initial page and disallow customization:

```plaintext
python-3.5.0.exe InstallAllUsers=0 Include_launcher=0
```
(Note that omitting the launcher also omits file associations, and is only recommended for per-user installs when there is also a system-wide installation that included the launcher.)

The options listed above can also be provided in a file named unattend.xml alongside the executable. This file specifies a list of options and values. When a value is provided as an attribute, it will be converted to a number if possible. Values provided as element text are always left as strings. This example file sets the same options and the previous example:

```xml
<Options>
    <Option Name="InstallAllUsers" Value="no" />
    <Option Name="Include_launcher" Value="0" />
    <Option Name="Include_test" Value="no" />
    <Option Name="SimpleInstall" Value="yes" />
    <Option Name="SimpleInstallDescription">Just for me, no test suite</Option>
</Options>
```

3.1.3. Installing Without Downloading

As some features of Python are not included in the initial installer download, selecting those features may require an internet connection. To avoid this need, all possible components may be downloaded on-demand to create a complete layout that will no longer require an internet connection regardless of the selected features. Note that this download may be bigger than required, but where a large number of installations are going to be performed it is very useful to have a locally cached copy.
Execute the following command from Command Prompt to download all possible required files. Remember to substitute python-3.5.0.exe for the actual name of your installer, and to create layouts in their own directories to avoid collisions between files with the same name.

```
python-3.5.0.exe /layout [optional target directory]
```

You may also specify the /quiet option to hide the progress display.

3.1.4. Other Platforms

With ongoing development of Python, some platforms that used to be supported earlier are no longer supported (due to the lack of users or developers). Check PEP 11 for details on all unsupported platforms.

- Windows CE is still supported.
- The Cygwin installer offers to install the Python interpreter as well (cf. Cygwin package source, Maintainer releases)

See Python for Windows for detailed information about platforms with pre-compiled installers.

See also:

**Python on XP**

“7 Minutes to “Hello World!”” by Richard Dooling, 2006

**Installing on Windows**


**For Windows users**

3.2. Alternative bundles

Besides the standard CPython distribution, there are modified packages including additional functionality. The following is a list of popular versions and their key features:

**ActivePython**
- Installer with multi-platform compatibility, documentation, PyWin32

**Anaconda**
- Popular scientific modules (such as numpy, scipy and pandas) and the conda package manager.

**Canopy**
- A “comprehensive Python analysis environment” with editors and other development tools.

**WinPython**
- Windows-specific distribution with prebuilt scientific packages and tools for building packages.

Note that these packages may not include the latest versions of Python or other libraries, and are not maintained or supported by the core Python team.
3.3. Configuring Python

To run Python conveniently from a command prompt, you might consider changing some default environment variables in Windows. While the installer provides an option to configure the PATH and PATHEXT variables for you, this is only reliable for a single, system-wide installation. If you regularly use multiple versions of Python, consider using the Python Launcher for Windows.

3.3.1. Excursus: Setting environment variables

Windows allows environment variables to be configured permanently at both the User level and the System level, or temporarily in a command prompt.

To temporarily set environment variables, open Command Prompt and use the `set` command:

```
C:/>set PATH=C:\Program Files\Python 3.5;%PATH%
C:/>set PYTHONPATH=%PYTHONPATH%;C:\My_python_lib
C:/>python
```

These changes will apply to any further commands executed in that console, and will be inherited by any applications started from the console.

Including the variable name within percent signs will expand to the existing value, allowing you to add your new value at either the start or the end. Modifying PATH by adding the directory containing `python.exe` to the start is a common way to ensure the correct version of Python is launched.
To permanently modify the default environment variables, click Start and search for ‘edit environment variables’, or open System properties, Advanced system settings and click the Environment Variables button. In this dialog, you can add or modify User and System variables. To change System variables, you need non-restricted access to your machine (i.e. Administrator rights).

**Note:** Windows will concatenate User variables *after* System variables, which may cause unexpected results when modifying PATH.

The `PYTHONPATH` variable is used by all versions of Python 2 and Python 3, so you should not permanently configure this variable unless it only includes code that is compatible with all of your installed Python versions.

**See also:**

- [http://support.microsoft.com/kb/100843](http://support.microsoft.com/kb/100843)  
  Environment variables in Windows NT
  The SET command, for temporarily modifying environment variables
  The SETX command, for permanently modifying environment variables
- [http://support.microsoft.com/kb/310519](http://support.microsoft.com/kb/310519)  
  How To Manage Environment Variables in Windows XP
- [http://www.chem.gla.ac.uk/~louis/software/faq/q1.html](http://www.chem.gla.ac.uk/~louis/software/faq/q1.html)  
  Setting Environment variables, Louis J. Farrugia
3.3.2. Finding the Python executable

*Changed in version 3.5.*

Besides using the automatically created start menu entry for the Python interpreter, you might want to start Python in the command prompt. The installer for Python 3.5 and later has an option to set that up for you.

On the first page of the installer, an option labelled “Add Python 3.5 to PATH” can be selected to have the installer add the install location into the PATH. The location of the Scripts\ folder is also added. This allows you to type `python` to run the interpreter, and `pip` or `. Thus, you can also execute your scripts with command line options, see Command line documentation.

If you don’t enable this option at install time, you can always re-run the installer, select Modify, and enable it. Alternatively, you can manually modify the PATH using the directions in Excursus: Setting environment variables. You need to set your PATH environment variable to include the directory of your Python installation, delimited by a semicolon from other entries. An example variable could look like this (assuming the first two entries already existed):

```
C:\WINDOWS\system32;C:\WINDOWS;C:\Program Files\Python
```
3.4. Python Launcher for Windows

*New in version 3.3.*

The Python launcher for Windows is a utility which aids in locating and executing of different Python versions. It allows scripts (or the command-line) to indicate a preference for a specific Python version, and will locate and execute that version.

Unlike the PATH variable, the launcher will correctly select the most appropriate version of Python. It will prefer per-user installations over system-wide ones, and orders by language version rather than using the most recently installed version.

3.4.1. Getting started

3.4.1.1. From the command-line

System-wide installations of Python 3.3 and later will put the launcher on your PATH. The launcher is compatible with all available versions of Python, so it does not matter which version is installed. To check that the launcher is available, execute the following command in Command Prompt:

```
py
```

You should find that the latest version of Python 2.x you have installed is started - it can be exited as normal, and any additional command-line arguments specified will be sent directly to Python.

If you have multiple versions of Python 2.x installed (e.g., 2.6 and 2.7) you will have noticed that Python 2.7 was started - to launch Python
2.6, try the command:

```
py -2.6
```

If you have a Python 3.x installed, try the command:

```
py -3
```

You should find the latest version of Python 3.x starts.

If you see the following error, you do not have the launcher installed:

```
'py' is not recognized as an internal or external command operable program or batch file.
```

Per-user installations of Python do not add the launcher to PATH unless the option was selected on installation.

### 3.4.1.2. Virtual environments

*New in version 3.5.*

If the launcher is run with no explicit Python version specification, and a virtual environment (created with the standard library `venv` module or the external `virtualenv` tool) active, the launcher will run the virtual environment's interpreter rather than the global one. To run the global interpreter, either deactivate the virtual environment, or explicitly specify the global Python version.

### 3.4.1.3. From a script

Let's create a test Python script - create a file called `hello.py` with the following contents
```python
#!/ python
import sys
sys.stdout.write("hello from Python %s\n" % (sys.version,))
```

From the directory in which hello.py lives, execute the command:

```
py hello.py
```

You should notice the version number of your latest Python 2.x installation is printed. Now try changing the first line to be:

```
#!/ python3
```

Re-executing the command should now print the latest Python 3.x information. As with the above command-line examples, you can specify a more explicit version qualifier. Assuming you have Python 2.6 installed, try changing the first line to `#!/ python2.6` and you should find the 2.6 version information printed.

### 3.4.1.4. From file associations

The launcher should have been associated with Python files (i.e. `.py`, `.pyw`, `.pyc` files) when it was installed. This means that when you double-click on one of these files from Windows explorer the launcher will be used, and therefore you can use the same facilities described above to have the script specify the version which should be used.

The key benefit of this is that a single launcher can support multiple Python versions at the same time depending on the contents of the first line.

### 3.4.2. Shebang Lines
If the first line of a script file starts with `#!`, it is known as a “shebang” line. Linux and other Unix like operating systems have native support for such lines and are commonly used on such systems to indicate how a script should be executed. This launcher allows the same facilities to be using with Python scripts on Windows and the examples above demonstrate their use.

To allow shebang lines in Python scripts to be portable between Unix and Windows, this launcher supports a number of ‘virtual’ commands to specify which interpreter to use. The supported virtual commands are:

- `/usr/bin/env python`
- `/usr/bin/python`
- `/usr/local/bin/python`
- `python`

For example, if the first line of your script starts with

```
#! /usr/bin/python
```

The default Python will be located and used. As many Python scripts written to work on Unix will already have this line, you should find these scripts can be used by the launcher without modification. If you are writing a new script on Windows which you hope will be useful on Unix, you should use one of the shebang lines starting with `/usr`.

Any of the above virtual commands can be suffixed with an explicit version (either just the major version, or the major and minor version) - for example `/usr/bin/python2.7` - which will cause that specific version to be located and used.

The `/usr/bin/env` form of shebang line has one further special
property. Before looking for installed Python interpreters, this form will search the executable PATH for a Python executable. This corresponds to the behaviour of the Unix env program, which performs a PATH search.

3.4.3. Arguments in shebang lines

The shebang lines can also specify additional options to be passed to the Python interpreter. For example, if you have a shebang line:

```bash
#!/usr/bin/python -v
```

Then Python will be started with the -v option.

3.4.4. Customization

3.4.4.1. Customization via INI files

Two .ini files will be searched by the launcher - py.ini in the current user’s “application data” directory (i.e. the directory returned by calling the Windows function SHGetFolderPath with CSIDL_LOCAL_APPDATA) and py.ini in the same directory as the launcher. The same .ini files are used for both the ‘console’ version of the launcher (i.e. py.exe) and for the ‘windows’ version (i.e. pyw.exe)

Customization specified in the “application directory” will have precedence over the one next to the executable, so a user, who may not have write access to the .ini file next to the launcher, can override commands in that global .ini file.

3.4.4.2. Customizing default Python versions
In some cases, a version qualifier can be included in a command to dictate which version of Python will be used by the command. A version qualifier starts with a major version number and can optionally be followed by a period (‘.’) and a minor version specifier. If the minor qualifier is specified, it may optionally be followed by “-32” to indicate the 32-bit implementation of that version be used.

For example, a shebang line of `#!python` has no version qualifier, while `#!python3` has a version qualifier which specifies only a major version.

If no version qualifiers are found in a command, the environment variable `PY_PYTHON` can be set to specify the default version qualifier - the default value is “2”. Note this value could specify just a major version (e.g. “2”) or a major.minor qualifier (e.g. “2.6”), or even major.minor-32.

If no minor version qualifiers are found, the environment variable `PY_PYTHON{major}` (where `{major}` is the current major version qualifier as determined above) can be set to specify the full version. If no such option is found, the launcher will enumerate the installed Python versions and use the latest minor release found for the major version, which is likely, although not guaranteed, to be the most recently installed version in that family.

On 64-bit Windows with both 32-bit and 64-bit implementations of the same (major.minor) Python version installed, the 64-bit version will always be preferred. This will be true for both 32-bit and 64-bit implementations of the launcher - a 32-bit launcher will prefer to execute a 64-bit Python installation of the specified version if available. This is so the behavior of the launcher can be predicted knowing only what versions are installed on the PC and without regard to the order in which they were installed (i.e., without knowing whether a 32 or 64-
bit version of Python and corresponding launcher was installed last). As noted above, an optional “-32” suffix can be used on a version specifier to change this behaviour.

Examples:

- If no relevant options are set, the commands python and python2 will use the latest Python 2.x version installed and the command python3 will use the latest Python 3.x installed.
- The commands python3.1 and python2.7 will not consult any options at all as the versions are fully specified.
- If PY_PYTHON=3, the commands python and python3 will both use the latest installed Python 3 version.
- If PY_PYTHON=3.1-32, the command python will use the 32-bit implementation of 3.1 whereas the command python3 will use the latest installed Python (PY_PYTHON was not considered at all as a major version was specified.)
- If PY_PYTHON=3 and PY_PYTHON3=3.1, the commands python and python3 will both use specifically 3.1

In addition to environment variables, the same settings can be configured in the .INI file used by the launcher. The section in the INI file is called [defaults] and the key name will be the same as the environment variables without the leading PY_ prefix (and note that the key names in the INI file are case insensitive.) The contents of an environment variable will override things specified in the INI file.

For example:

- Setting PY_PYTHON=3.1 is equivalent to the INI file containing:

  [defaults]
  python=3.1
- Setting `PY_PYTHON=3` and `PY_PYTHON3=3.1` is equivalent to the INI file containing:

```
[defaults]
python=3
python3=3.1
```

### 3.4.5. Diagnostics

If an environment variable `PYLAUNCH_DEBUG` is set (to any value), the launcher will print diagnostic information to stderr (i.e. to the console). While this information manages to be simultaneously verbose \textit{and} terse, it should allow you to see what versions of Python were located, why a particular version was chosen and the exact command-line used to execute the target Python.
3.5. Finding modules

Python usually stores its library (and thereby your site-packages folder) in the installation directory. So, if you had installed Python to C:\Python\, the default library would reside in C:\Python\Lib\ and third-party modules should be stored in C:\Python\Lib\site-packages\.

This is how *sys.path* is populated on Windows:

- An empty entry is added at the start, which corresponds to the current directory.
- If the environment variable *PYTHONPATH* exists, as described in Environment variables, its entries are added next. Note that on Windows, paths in this variable must be separated by semicolons, to distinguish them from the colon used in drive identifiers (C:\ etc.).
- Additional “application paths” can be added in the registry as subkeys of \SOFTWARE\Python\PythonCore\version\PythonPath under both the HKEY_CURRENT_USER and HKEY_LOCAL_MACHINE hives. Subkeys which have semicolon-delimited path strings as their default value will cause each path to be added to *sys.path*. (Note that all known installers only use HKLM, so HKCU is typically empty.)
- If the environment variable *PYTHONHOME* is set, it is assumed as “Python Home”. Otherwise, the path of the main Python executable is used to locate a “landmark file” (Lib\os.py) to deduce the “Python Home”. If a Python home is found, the relevant sub-directories added to *sys.path* (Lib, plat-win, etc) are based on that folder. Otherwise, the core Python path is constructed from the PythonPath stored in the registry.
• If the Python Home cannot be located, no PYTHONPATH is specified in the environment, and no registry entries can be found, a default path with relative entries is used (e.g. .\Lib; .\plat-win, etc).

If a pyenv.cfg file is found alongside the main executable or in the directory one level above the executable, the following variations apply:

• If home is an absolute path and PYTHONHOME is not set, this path is used instead of the path to the main executable when deducing the home location.
• If applocal is set to true, the home property or the main executable is always used as the home path, and all environment variables or registry values affecting the path are ignored. The landmark file is not checked.

The end result of all this is:

• When running python.exe, or any other .exe in the main Python directory (either an installed version, or directly from the PCbuild directory), the core path is deduced, and the core paths in the registry are ignored. Other “application paths” in the registry are always read.
• When Python is hosted in another .exe (different directory, embedded via COM, etc), the “Python Home” will not be deduced, so the core path from the registry is used. Other “application paths” in the registry are always read.
• If Python can’t find its home and there are no registry value (frozen .exe, some very strange installation setup) you get a path with some default, but relative, paths.

For those who want to bundle Python into their application or distribution, the following advice will prevent conflicts with other
installations:

- Include a `pyvenv.cfg` file alongside your executable containing `applocal = true`. This will ensure that your own directory will be used to resolve paths even if you have included the standard library in a ZIP file. It will also ignore user site-packages and other paths listed in the registry.

- If you are loading `python3.dll` or `python35.dll` in your own executable, explicitly call `Py_SetPath()` or (at least) `Py_SetProgramName()` before `Py_Initialize()`.

- Clear and/or overwrite `PYTHONPATH` and set `PYTHONHOME` before launching `python.exe` from your application.

- If you cannot use the previous suggestions (for example, you are a distribution that allows people to run `python.exe` directly), ensure that the landmark file (`Lib\os.py`) exists in your install directory. (Note that it will not be detected inside a ZIP file.)

These will ensure that the files in a system-wide installation will not take precedence over the copy of the standard library bundled with your application. Otherwise, your users may experience problems using your application. Note that the first suggestion is the best, as the other may still be susceptible to non-standard paths in the registry and user site-packages.
3.6. Additional modules

Even though Python aims to be portable among all platforms, there are features that are unique to Windows. A couple of modules, both in the standard library and external, and snippets exist to use these features.

The Windows-specific standard modules are documented in MS Windows Specific Services.

3.6.1. PyWin32

The PyWin32 module by Mark Hammond is a collection of modules for advanced Windows-specific support. This includes utilities for:

- Component Object Model (COM)
- Win32 API calls
- Registry
- Event log
- Microsoft Foundation Classes (MFC) user interfaces

PythonWin is a sample MFC application shipped with PyWin32. It is an embeddable IDE with a built-in debugger.

See also:

Win32 How Do I...?
by Tim Golden

Python and COM
by David and Paul Boddie

3.6.2. cx_Freeze
cx_Freeze is a distutils extension (see Extending Distutils) which wraps Python scripts into executable Windows programs (*.exe files). When you have done this, you can distribute your application without requiring your users to install Python.

3.6.3. WConio

Since Python’s advanced terminal handling layer, curses, is restricted to Unix-like systems, there is a library exclusive to Windows as well: Windows Console I/O for Python.

WConio is a wrapper for Turbo-C’s CONIO.H, used to create text user interfaces.
3.7. Compiling Python on Windows

If you want to compile CPython yourself, first thing you should do is get the source. You can download either the latest release’s source or just grab a fresh checkout.

The source tree contains a build solution and project files for Microsoft Visual Studio 2015, which is the compiler used to build the official Python releases. These files are in the PCbuild directory.

Check PCbuild/readme.txt for general information on the build process.

For extension modules, consult Building C and C++ Extensions on Windows.

See also:

**Python + Windows + distutils + SWIG + gcc MinGW**

or “Creating Python extensions in C/C++ with SWIG and compiling them with MinGW gcc under Windows” or “Installing Python extension with distutils and without Microsoft Visual C++” by Sébastien Sauvage, 2003

**MingW – Python extensions**

by Trent Apted et al, 2007
3.8. Embedded Distribution

New in version 3.5.

The embedded distribution is a ZIP file containing a minimal Python environment. It is intended for acting as part of another application, rather than being directly accessed by end-users.

When extracted, the embedded distribution is (almost) fully isolated from the user’s system, including environment variables, system registry settings, and installed packages. The standard library is included as pre-compiled and optimized .pyc files in a ZIP, and python3.dll, python35.dll, python.exe and pythonw.exe are all provided. Tcl/tk (including all dependants, such as Idle), pip and the Python documentation are not included.

Note: The embedded distribution does not include the Microsoft C Runtime and it is the responsibility of the application installer to provide this. The runtime may have already been installed on a user’s system previously or automatically via Windows Update, and can be detected by finding ucrtbase.dll in the system directory.

Third-party packages should be installed by the application installer alongside the embedded distribution. Using pip to manage dependencies as for a regular Python installation is not supported with this distribution, though with some care it may be possible to include and use pip for automatic updates. In general, third-party packages should be treated as part of the application (“vendoring”) so that the developer can ensure compatibility with newer versions before providing updates to users.
The two recommended use cases for this distribution are described below.

3.8.1. Python Application

An application written in Python does not necessarily require users to be aware of that fact. The embedded distribution may be used in this case to include a private version of Python in an install package. Depending on how transparent it should be (or conversely, how professional it should appear), there are two options.

Using a specialized executable as a launcher requires some coding, but provides the most transparent experience for users. With a customized launcher, there are no obvious indications that the program is running on Python: icons can be customized, company and version information can be specified, and file associations behave properly. In most cases, a custom launcher should simply be able to call Py_Main with a hard-coded command line.

The simpler approach is to provide a batch file or generated shortcut that directly calls the python.exe or pythonw.exe with the required command-line arguments. In this case, the application will appear to be Python and not its actual name, and users may have trouble distinguishing it from other running Python processes or file associations.

With the latter approach, packages should be installed as directories alongside the Python executable to ensure they are available on the path. With the specialized launcher, packages can be located in other locations as there is an opportunity to specify the search path before launching the application.
3.8.2. Embedding Python

Applications written in native code often require some form of scripting language, and the embedded Python distribution can be used for this purpose. In general, the majority of the application is in native code, and some part will either invoke python.exe or directly use python3.dll. For either case, extracting the embedded distribution to a subdirectory of the application installation is sufficient to provide a loadable Python interpreter.

As with the application use, packages can be installed to any location as there is an opportunity to specify search paths before initializing the interpreter. Otherwise, there is no fundamental differences between using the embedded distribution and a regular installation.
3.9. Other resources

See also:

**Python Programming On Win32**

**A Python for Windows Tutorial**
by Amanda Birmingham, 2004

**PEP 397 - Python launcher for Windows**
The proposal for the launcher to be included in the Python distribution.
4. Using Python on a Macintosh

**Author:** Bob Savage <bobsavage@mac.com>

Python on a Macintosh running Mac OS X is in principle very similar to Python on any other Unix platform, but there are a number of additional features such as the IDE and the Package Manager that are worth pointing out.
4.1. Getting and Installing MacPython

Mac OS X 10.8 comes with Python 2.7 pre-installed by Apple. If you wish, you are invited to install the most recent version of Python 3 from the Python website (https://www.python.org). A current “universal binary” build of Python, which runs natively on the Mac’s new Intel and legacy PPC CPU’s, is available there.

What you get after installing is a number of things:

- A MacPython 3.4 folder in your Applications folder. In here you find IDLE, the development environment that is a standard part of official Python distributions; PythonLauncher, which handles double-clicking Python scripts from the Finder; and the “Build Applet” tool, which allows you to package Python scripts as standalone applications on your system.

- A framework /Library/Frameworks/Python.framework, which includes the Python executable and libraries. The installer adds this location to your shell path. To uninstall MacPython, you can simply remove these three things. A symlink to the Python executable is placed in /usr/local/bin/.

The Apple-provided build of Python is installed in /System/Library/Frameworks/Python.framework and /usr/bin/python, respectively. You should never modify or delete these, as they are Apple-controlled and are used by Apple- or third-party software. Remember that if you choose to install a newer Python version from python.org, you will have two different but functional Python installations on your computer, so it will be important that your paths and usages are consistent with what you want to do.

IDLE includes a help menu that allows you to access Python
documentation. If you are completely new to Python you should start reading the tutorial introduction in that document.

If you are familiar with Python on other Unix platforms you should read the section on running Python scripts from the Unix shell.

**4.1.1. How to run a Python script**

Your best way to get started with Python on Mac OS X is through the IDLE integrated development environment, see section *The IDE* and use the Help menu when the IDE is running.

If you want to run Python scripts from the Terminal window command line or from the Finder you first need an editor to create your script. Mac OS X comes with a number of standard Unix command line editors, *vim* and *emacs* among them. If you want a more Mac-like editor, *BBEdit* or *TextWrangler* from Bare Bones Software (see [http://www.barebones.com/products/bbedit/index.html](http://www.barebones.com/products/bbedit/index.html)) are good choices, as is *TextMate* (see [http://macromates.com/](http://macromates.com/)). Other editors include *Gvim* ([http://macvim.org](http://macvim.org)) and *Aquamacs* ([http://aquamacs.org/](http://aquamacs.org/)).

To run your script from the Terminal window you must make sure that `/usr/local/bin` is in your shell search path.

To run your script from the Finder you have two options:

- Drag it to *PythonLauncher*
- Select *PythonLauncher* as the default application to open your script (or any .py script) through the finder Info window and double-click it. *PythonLauncher* has various preferences to control how your script is launched. Option-dragging allows you to change these for one invocation, or use its Preferences menu to
change things globally.

4.1.2. Running scripts with a GUI

With older versions of Python, there is one Mac OS X quirk that you need to be aware of: programs that talk to the Aqua window manager (in other words, anything that has a GUI) need to be run in a special way. Use `pythonw` instead of `python` to start such scripts.

With Python 3.4, you can use either `python` or `pythonw`.

4.1.3. Configuration

Python on OS X honors all standard Unix environment variables such as `PYTHONPATH`, but setting these variables for programs started from the Finder is non-standard as the Finder does not read your `.profile` or `.cshrc` at startup. You need to create a file `~/.MacOSX/environment.plist`. See Apple's Technical Document QA1067 for details.

For more information on installation Python packages in MacPython, see section [Installing Additional Python Packages](#).
4.2. The IDE

MacPython ships with the standard IDLE development environment. A good introduction to using IDLE can be found at https://hkn.eecs.berkeley.edu/~dyoo/python/idle_intro/index.html.
4.3. Installing Additional Python Packages

There are several methods to install additional Python packages:

- Packages can be installed via the standard Python distutils mode (python setup.py install).
- Many packages can also be installed via the setuptools extension or pip wrapper, see https://pip.pypa.io/.
4.4. GUI Programming on the Mac

There are several options for building GUI applications on the Mac with Python.

*PyObjC* is a Python binding to Apple’s Objective-C/Cocoa framework, which is the foundation of most modern Mac development. Information on PyObjC is available from [https://pythonhosted.org/pyobjc/](https://pythonhosted.org/pyobjc/).

The standard Python GUI toolkit is *tkinter*, based on the cross-platform Tk toolkit ([http://www.tcl.tk](http://www.tcl.tk)). An Aqua-native version of Tk is bundled with OS X by Apple, and the latest version can be downloaded and installed from [http://www.activestate.com](http://www.activestate.com); it can also be built from source.

*wxPython* is another popular cross-platform GUI toolkit that runs natively on Mac OS X. Packages and documentation are available from [http://www.wxpython.org](http://www.wxpython.org).

*PyQt* is another popular cross-platform GUI toolkit that runs natively on Mac OS X. More information can be found at [http://www.riverbankcomputing.co.uk/software/pyqt/intro](http://www.riverbankcomputing.co.uk/software/pyqt/intro).
4.5. Distributing Python Applications on the Mac

The “Build Applet” tool that is placed in the MacPython 3.4 folder is fine for packaging small Python scripts on your own machine to run as a standard Mac application. This tool, however, is not robust enough to distribute Python applications to other users.

The standard tool for deploying standalone Python applications on the Mac is py2app. More information on installing and using py2app can be found at http://undefined.org/python/#py2app.
4.6. Other Resources

The MacPython mailing list is an excellent support resource for Python users and developers on the Mac:

https://www.python.org/community/sigs/current/pythonmac-sig/

Another useful resource is the MacPython wiki:

https://wiki.python.org/moin/MacPython
5. Additional Tools and Scripts
5.1. pyvenv - Creating virtual environments

Creation of virtual environments is done by executing the pyvenv script:

```bash
pyvenv /path/to/new/virtual/environment
```

Running this command creates the target directory (creating any parent directories that don’t exist already) and places a pyvenv.cfg file in it with a home key pointing to the Python installation the command was run from. It also creates a bin (or Scripts on Windows) subdirectory containing a copy of the python binary (or binaries, in the case of Windows). It also creates an (initially empty) lib/pythonX.Y/site-packages subdirectory (on Windows, this is Lib\site-packages).

**See also:** Python Packaging User Guide: Creating and using virtual environments

On Windows, you may have to invoke the pyvenv script as follows, if you don’t have the relevant PATH and PATHEXT settings:

```bash
c:\Temp>c:\Python35\python c:\Python35\Tools\Scripts\pyvenv.py myenv
```

or equivalently:

```bash
c:\Temp>c:\Python35\python -m venv myenv
```

The command, if run with -h, will show the available options:

Creates virtual Python environments in one or more target directories.

Positional arguments:
  ENV_DIR               A directory to create the environment in.

Optional arguments:
  -h, --help            show this help message and exit
  --system-site-packages Give access to the global site-packages dir to the virtual environment.
  --symlinks            Try to use symlinks rather than copies, when symlinks are not the default for the platform.
  --copies              Try to use copies rather than symlinks, even when symlinks are the default for the platform.
  --clear               Delete the environment directory if it already exists. If not specified and the directory already exists, an error is raised.
  --upgrade             Upgrade the environment directory to use this version of Python, assuming Python has been upgraded in-place.
  --without-pip         Skips installing or upgrading pip in the virtual environment (pip is bootstrapped by default).

Depending on how the venv functionality has been invoked, the usage message may vary slightly, e.g. referencing pyvenv rather than venv.

* Changed in version 3.4: Installs pip by default, added the --without-pip and --copies options

* Changed in version 3.4: In earlier versions, if the target directory already existed, an error was raised, unless the --clear or --upgrade option was provided. Now, if an existing directory is specified, its contents are removed and the directory is processed as if
it had been newly created.

The created pyvenv.cfg file also includes the include-system-site-packages key, set to true if venv is run with the --system-site-packages option, false otherwise.

Unless the --without-pip option is given, ensurepip will be invoked to bootstrap pip into the virtual environment.

Multiple paths can be given to pyvenv, in which case an identical virtualenv will be created, according to the given options, at each provided path.

Once a venv has been created, it can be “activated” using a script in the venv’s binary directory. The invocation of the script is platform-specific:

<table>
<thead>
<tr>
<th>Platform</th>
<th>Shell</th>
<th>Command to activate virtual environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posix</td>
<td>bash/zsh</td>
<td>$ source &lt;venv&gt;/bin/activate</td>
</tr>
<tr>
<td></td>
<td>fish</td>
<td>$. &lt;venv&gt;/bin/activate.fish</td>
</tr>
<tr>
<td></td>
<td>csh/tcsh</td>
<td>$ source &lt;venv&gt;/bin/activate.csh</td>
</tr>
<tr>
<td>Windows</td>
<td>cmd.exe</td>
<td>C:&gt; &lt;venv&gt;/Scripts/activate.bat</td>
</tr>
<tr>
<td></td>
<td>PowerShell</td>
<td>PS C:&gt; &lt;venv&gt;/Scripts/Activate.ps1</td>
</tr>
</tbody>
</table>

You don’t specifically need to activate an environment; activation just prepends the venv’s binary directory to your path, so that “python” invokes the venv’s Python interpreter and you can run installed scripts without having to use their full path. However, all scripts installed in a venv should be runnable without activating it, and run with the venv’s Python automatically.
You can deactivate a venv by typing “deactivate” in your shell. The exact mechanism is platform-specific: for example, the Bash activation script defines a “deactivate” function, whereas on Windows there are separate scripts called deactivate.bat and Deactivate.ps1 which are installed when the venv is created.

*New in version 3.4: fish and csh activation scripts.*
1. Introduction

This reference manual describes the Python programming language. It is not intended as a tutorial.

While I am trying to be as precise as possible, I chose to use English rather than formal specifications for everything except syntax and lexical analysis. This should make the document more understandable to the average reader, but will leave room for ambiguities. Consequently, if you were coming from Mars and tried to re-implement Python from this document alone, you might have to guess things and in fact you would probably end up implementing quite a different language. On the other hand, if you are using Python and wonder what the precise rules about a particular area of the language are, you should definitely be able to find them here. If you would like to see a more formal definition of the language, maybe you could volunteer your time — or invent a cloning machine :-).

It is dangerous to add too many implementation details to a language reference document — the implementation may change, and other implementations of the same language may work differently. On the other hand, CPython is the one Python implementation in widespread use (although alternate implementations continue to gain support), and its particular quirks are sometimes worth being mentioned, especially where the implementation imposes additional limitations. Therefore, you’ll find short “implementation notes” sprinkled throughout the text.

Every Python implementation comes with a number of built-in and standard modules. These are documented in The Python Standard Library. A few built-in modules are mentioned when they interact in a significant way with the language definition.
1.1. Alternate Implementations

Though there is one Python implementation which is by far the most popular, there are some alternate implementations which are of particular interest to different audiences.

Known implementations include:

CPython
This is the original and most-maintained implementation of Python, written in C. New language features generally appear here first.

Jython
Python implemented in Java. This implementation can be used as a scripting language for Java applications, or can be used to create applications using the Java class libraries. It is also often used to create tests for Java libraries. More information can be found at the Jython website.

Python for .NET
This implementation actually uses the CPython implementation, but is a managed .NET application and makes .NET libraries available. It was created by Brian Lloyd. For more information, see the Python for .NET home page.

IronPython
An alternate Python for .NET. Unlike Python.NET, this is a complete Python implementation that generates IL, and compiles Python code directly to .NET assemblies. It was created by Jim Hugunin, the original creator of Jython. For more information, see the IronPython website.

PyPy
An implementation of Python written completely in Python. It supports several advanced features not found in other implementations like stackless support and a Just in Time compiler.
One of the goals of the project is to encourage experimentation with the language itself by making it easier to modify the interpreter (since it is written in Python). Additional information is available on the PyPy project’s home page.

Each of these implementations varies in some way from the language as documented in this manual, or introduces specific information beyond what’s covered in the standard Python documentation. Please refer to the implementation-specific documentation to determine what else you need to know about the specific implementation you’re using.
1.2. Notation

The descriptions of lexical analysis and syntax use a modified BNF grammar notation. This uses the following style of definition:

```plaintext
name ::= lc_letter (lc_letter | "_")*
lc_letter ::= "a"..."z"
```

The first line says that a name is an `lc_letter` followed by a sequence of zero or more `lc_letter`s and underscores. An `lc_letter` in turn is any of the single characters 'a' through 'z'. (This rule is actually adhered to for the names defined in lexical and grammar rules in this document.)

Each rule begins with a name (which is the name defined by the rule) and ::=.. A vertical bar (|) is used to separate alternatives; it is the least binding operator in this notation. A star (*) means zero or more repetitions of the preceding item; likewise, a plus (+) means one or more repetitions, and a phrase enclosed in square brackets ([ ] ) means zero or one occurrences (in other words, the enclosed phrase is optional). The * and + operators bind as tightly as possible; parentheses are used for grouping. Literal strings are enclosed in quotes. White space is only meaningful to separate tokens. Rules are normally contained on a single line; rules with many alternatives may be formatted alternatively with each line after the first beginning with a vertical bar.

In lexical definitions (as the example above), two more conventions are used: Two literal characters separated by three dots mean a choice of any single character in the given (inclusive) range of ASCII characters. A phrase between angular brackets (<...>) gives an
informal description of the symbol defined; e.g., this could be used to describe the notion of ‘control character’ if needed.

Even though the notation used is almost the same, there is a big difference between the meaning of lexical and syntactic definitions: a lexical definition operates on the individual characters of the input source, while a syntax definition operates on the stream of tokens generated by the lexical analysis. All uses of BNF in the next chapter (“Lexical Analysis”) are lexical definitions; uses in subsequent chapters are syntactic definitions.
2. Lexical analysis

A Python program is read by a parser. Input to the parser is a stream of tokens, generated by the lexical analyzer. This chapter describes how the lexical analyzer breaks a file into tokens.

Python reads program text as Unicode code points; the encoding of a source file can be given by an encoding declaration and defaults to UTF-8, see PEP 3120 for details. If the source file cannot be decoded, a SyntaxError is raised.
2.1. Line structure

A Python program is divided into a number of logical lines.

2.1.1. Logical lines

The end of a logical line is represented by the token NEWLINE. Statements cannot cross logical line boundaries except where NEWLINE is allowed by the syntax (e.g., between statements in compound statements). A logical line is constructed from one or more physical lines by following the explicit or implicit line joining rules.

2.1.2. Physical lines

A physical line is a sequence of characters terminated by an end-of-line sequence. In source files, any of the standard platform line termination sequences can be used - the Unix form using ASCII LF (linefeed), the Windows form using the ASCII sequence CR LF (return followed by linefeed), or the old Macintosh form using the ASCII CR (return) character. All of these forms can be used equally, regardless of platform.

When embedding Python, source code strings should be passed to Python APIs using the standard C conventions for newline characters (the \n character, representing ASCII LF, is the line terminator).

2.1.3. Comments

A comment starts with a hash character (#) that is not part of a string literal, and ends at the end of the physical line. A comment signifies
the end of the logical line unless the implicit line joining rules are invoked. Comments are ignored by the syntax; they are not tokens.

2.1.4. Encoding declarations

If a comment in the first or second line of the Python script matches the regular expression `coding[=:]\s*([-\w.]+)`, this comment is processed as an encoding declaration; the first group of this expression names the encoding of the source code file. The encoding declaration must appear on a line of its own. If it is the second line, the first line must also be a comment-only line. The recommended forms of an encoding expression are

```
# -*- coding: <encoding-name> -*-
```

which is recognized also by GNU Emacs, and

```
# vim:fileencoding=<encoding-name>
```

which is recognized by Bram Moolenaar’s VIM.

If no encoding declaration is found, the default encoding is UTF-8. In addition, if the first bytes of the file are the UTF-8 byte-order mark (`b'\xef\xbb\xbf'`), the declared file encoding is UTF-8 (this is supported, among others, by Microsoft’s notepad).

If an encoding is declared, the encoding name must be recognized by Python. The encoding is used for all lexical analysis, including string literals, comments and identifiers.

2.1.5. Explicit line joining
Two or more physical lines may be joined into logical lines using backslash characters (\), as follows: when a physical line ends in a backslash that is not part of a string literal or comment, it is joined with the following forming a single logical line, deleting the backslash and the following end-of-line character. For example:

```plaintext
if 1900 < year < 2100 and 1 <= month <= 12 \
    and 1 <= day <= 31 and 0 <= hour < 24 \
    and 0 <= minute < 60 and 0 <= second < 60:  # Looks like a valid date
    return 1
```

A line ending in a backslash cannot carry a comment. A backslash does not continue a comment. A backslash does not continue a token except for string literals (i.e., tokens other than string literals cannot be split across physical lines using a backslash). A backslash is illegal elsewhere on a line outside a string literal.

### 2.1.6. Implicit line joining

Expressions in parentheses, square brackets or curly braces can be split over more than one physical line without using backslashes. For example:

```plaintext
month_names = ['Januari', 'Februari', 'Maart', 'April', 'Mei', 'Juni', 'Juli', 'Augustus', 'September', 'Oktober', 'November', 'December']
```

Implicitly continued lines can carry comments. The indentation of the continuation lines is not important. Blank continuation lines are allowed. There is no NEWLINE token between implicit continuation lines. Implicitly continued lines can also occur within triple-quoted
strings (see below); in that case they cannot carry comments.

2.1.7. Blank lines

A logical line that contains only spaces, tabs, formfeeds and possibly a comment, is ignored (i.e., no NEWLINE token is generated). During interactive input of statements, handling of a blank line may differ depending on the implementation of the read-eval-print loop. In the standard interactive interpreter, an entirely blank logical line (i.e. one containing not even whitespace or a comment) terminates a multi-line statement.

2.1.8. Indentation

Leading whitespace (spaces and tabs) at the beginning of a logical line is used to compute the indentation level of the line, which in turn is used to determine the grouping of statements.

Tabs are replaced (from left to right) by one to eight spaces such that the total number of characters up to and including the replacement is a multiple of eight (this is intended to be the same rule as used by Unix). The total number of spaces preceding the first non-blank character then determines the line’s indentation. Indentation cannot be split over multiple physical lines using backslashes; the whitespace up to the first backslash determines the indentation.

Indentation is rejected as inconsistent if a source file mixes tabs and spaces in a way that makes the meaning dependent on the worth of a tab in spaces; a TabError is raised in that case.

**Cross-platform compatibility note:** because of the nature of text editors on non-UNIX platforms, it is unwise to use a mixture of spaces
and tabs for the indentation in a single source file. It should also be noted that different platforms may explicitly limit the maximum indentation level.

A formfeed character may be present at the start of the line; it will be ignored for the indentation calculations above. Formfeed characters occurring elsewhere in the leading whitespace have an undefined effect (for instance, they may reset the space count to zero).

The indentation levels of consecutive lines are used to generate INDENT and DEDENT tokens, using a stack, as follows.

Before the first line of the file is read, a single zero is pushed on the stack; this will never be popped off again. The numbers pushed on the stack will always be strictly increasing from bottom to top. At the beginning of each logical line, the line’s indentation level is compared to the top of the stack. If it is equal, nothing happens. If it is larger, it is pushed on the stack, and one INDENT token is generated. If it is smaller, it must be one of the numbers occurring on the stack; all numbers on the stack that are larger are popped off, and for each number popped off a DEDENT token is generated. At the end of the file, a DEDENT token is generated for each number remaining on the stack that is larger than zero.

Here is an example of a correctly (though confusingly) indented piece of Python code:

```python
def perm(l):
    # Compute the list of all permutations of l
    if len(l) <= 1:
        return [l]
    r = []
    for i in range(len(l)):
        s = l[:i] + l[i+1:]
```
p = perm(s)
for x in p:
    r.append(l[i:i+1] + x)
return r

The following example shows various indentation errors:

def perm(l):
    # error: first line indented
    for i in range(len(l)):
        # error: not indented
        s = l[:i] + l[i+1:]
        p = perm(l[:i] + l[i+1:])
        # error: unexpected indent
        for x in p:
            r.append(l[i:i+1] + x)
    return r  # error: inconsistent dedent

(Actually, the first three errors are detected by the parser; only the last error is found by the lexical analyzer — the indentation of \texttt{return r} does not match a level popped off the stack.)

2.1.9. Whitespace between tokens

Except at the beginning of a logical line or in string literals, the whitespace characters space, tab and formfeed can be used interchangeably to separate tokens. Whitespace is needed between two tokens only if their concatenation could otherwise be interpreted as a different token (e.g., ab is one token, but a b is two tokens).
2.2. Other tokens

Besides NEWLINE, INDENT and DEDENT, the following categories of tokens exist: *identifiers*, *keywords*, *literals*, *operators*, and *delimiters*. Whitespace characters (other than line terminators, discussed earlier) are not tokens, but serve to delimit tokens. Where ambiguity exists, a token comprises the longest possible string that forms a legal token, when read from left to right.
2.3. Identifiers and keywords

Identifiers (also referred to as *names*) are described by the following lexical definitions.

The syntax of identifiers in Python is based on the Unicode standard annex UAX-31, with elaboration and changes as defined below; see also PEP 3131 for further details.

Within the ASCII range (U+0001..U+007F), the valid characters for identifiers are the same as in Python 2.x: the uppercase and lowercase letters A through Z, the underscore _ and, except for the first character, the digits 0 through 9.

Python 3.0 introduces additional characters from outside the ASCII range (see PEP 3131). For these characters, the classification uses the version of the Unicode Character Database as included in the unicodedata module.

Identifiers are unlimited in length. Case is significant.

```
identifier ::= xid_start xid_continue*

id_start ::= <all characters in general categories Lu, Ll, Lt, Lm, Lo, Nl, the underscore, and characters with the Other_ID_Start property>

id_continue ::= <all characters in id_start, plus characters in the categories Mn, Mc, Nd, Pc and others with the Other_ID_Continue property>

xid_start ::= <all characters in id_start whose NFKC normalization is in id_start xid_continue*>.

xid_continue ::= <all characters in id_continue whose NFKC normalization is in id_continue*>
```

The Unicode category codes mentioned above stand for:

- *Lu* - uppercase letters
- *Ll* - lowercase letters
- *Lt* - titlecase letters
- *Lm* - modifier letters
- *Lo* - other letters
- *NI* - letter numbers
- *Mn* - nonspace marks
- *Mc* - spacing combining marks
- *Nd* - decimal numbers
- *Pc* - connector punctuations
- *Other_ID_Start* - explicit list of characters in PropList.txt to support backwards compatibility
- *Other_ID_Continue* - likewise

All identifiers are converted into the normal form NFKC while parsing; comparison of identifiers is based on NFKC.

A non-normative HTML file listing all valid identifier characters for Unicode 4.1 can be found at [http://www.dcl.hpi.uni-potsdam.de/home/loewis/table-3131.html](http://www.dcl.hpi.uni-potsdam.de/home/loewis/table-3131.html).

### 2.3.1. Keywords

The following identifiers are used as reserved words, or *keywords* of the language, and cannot be used as ordinary identifiers. They must be spelled exactly as written here:

<table>
<thead>
<tr>
<th>False</th>
<th>class</th>
<th>finally</th>
<th>is</th>
<th>return</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>continue</td>
<td>for</td>
<td>lambda</td>
<td>try</td>
</tr>
<tr>
<td>True</td>
<td>def</td>
<td>from</td>
<td>nonlocal</td>
<td>while</td>
</tr>
<tr>
<td>and</td>
<td>del</td>
<td>global</td>
<td>not</td>
<td>with</td>
</tr>
<tr>
<td>as</td>
<td>elif</td>
<td>if</td>
<td>or</td>
<td>yield</td>
</tr>
<tr>
<td>assert</td>
<td>else</td>
<td>import</td>
<td>pass</td>
<td></td>
</tr>
<tr>
<td>break</td>
<td>except</td>
<td>in</td>
<td>raise</td>
<td></td>
</tr>
</tbody>
</table>

### 2.3.2. Reserved classes of identifiers
Certain classes of identifiers (besides keywords) have special meanings. These classes are identified by the patterns of leading and trailing underscore characters:

__*__

System-defined names. These names are defined by the interpreter and its implementation (including the standard library). Current system names are discussed in the Special method names section and elsewhere. More will likely be defined in future versions of Python. Any use of __*__ names, in any context, that does not follow explicitly documented use, is subject to breakage without warning.

__*__

Class-private names. Names in this category, when used within the context of a class definition, are re-written to use a mangled form to help avoid name clashes between “private” attributes of base and derived classes. See section Identifiers (Names).
2.4. Literals

Literals are notations for constant values of some built-in types.

2.4.1. String and Bytes literals

String literals are described by the following lexical definitions:

```
stringliteral  ::=  [stringprefix](shortstring  |  longstring)
stringprefix  ::=  "r"  |  "u"  |  "R"  |  "U"
shortstring   ::=  "'"  shortstringitem*  "'"  |  "'
longstring    ::=  "'''"  longstringitem*  "'''"  |  
shortstringitem ::=  shortstringchar  |  stringescapeseq
longstringitem ::=  longstringchar  |  stringescapeseq
shortstringchar ::=  <any source character except '"\nlongstringchar ::=  <any source character except '
stringescapeseq  ::=  "\"  <any source character>
```

```
bytesliteral  ::=  bytesprefix(shortbytes  |  longbytes)
bytesprefix   ::=  "b"  |  "B"  |  "br"  |  "Br"  |  "bR"  |  "BR"  |  "rb"  |  "rB"  |  "Rb"  |  "RB"
shortbytes    ::=  "'"  shortbytesitem*  "'"  |  "'
longbytes     ::=  "'''"  longbytesitem*  "'''"  |  
shortbytesitem ::=  shortbyteschar  |  bytesescapeseq
longbytesitem  ::=  longbyteschar  |  bytesescapeseq
shortbyteschar ::=  <any ASCII character except '"\nlongbyteschar ::=  <any ASCII character except '
bytesescapeseq ::=  "\"  <any ASCII character>
```

One syntactic restriction not indicated by these productions is that whitespace is not allowed between the `stringprefix` or `bytesprefix` and the rest of the literal. The source character set is defined by the encoding declaration; it is UTF-8 if no encoding
declaration is given in the source file; see section Encoding declarations.

In plain English: Both types of literals can be enclosed in matching single quotes (') or double quotes ("}). They can also be enclosed in matching groups of three single or double quotes (these are generally referred to as triple-quoted strings). The backslash (\) character is used to escape characters that otherwise have a special meaning, such as newline, backslash itself, or the quote character.

Bytes literals are always prefixed with 'b' or 'B'; they produce an instance of the bytes type instead of the str type. They may only contain ASCII characters; bytes with a numeric value of 128 or greater must be expressed with escapes.

As of Python 3.3 it is possible again to prefix string literals with a u prefix to simplify maintenance of dual 2.x and 3.x codebases.

Both string and bytes literals may optionally be prefixed with a letter 'r' or 'R'; such strings are called raw strings and treat backslashes as literal characters. As a result, in string literals, '\U' and '\u' escapes in raw strings are not treated specially. Given that Python 2.x's raw unicode literals behave differently than Python 3.x's the 'ur' syntax is not supported.

New in version 3.3: The 'rb' prefix of raw bytes literals has been added as a synonym of 'br'.

New in version 3.3: Support for the unicode legacy literal (u'value') was reintroduced to simplify the maintenance of dual Python 2.x and 3.x codebases. See PEP 414 for more information.

In triple-quoted literals, unescaped newlines and quotes are allowed.
(and are retained), except that three unescaped quotes in a row terminate the literal. (A “quote” is the character used to open the literal, i.e. either ' or ".)

Unless an 'r' or 'R' prefix is present, escape sequences in string and bytes literals are interpreted according to rules similar to those used by Standard C. The recognized escape sequences are:

<table>
<thead>
<tr>
<th>Escape Sequence</th>
<th>Meaning</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>\newline</td>
<td>Backslash and newline ignored</td>
<td></td>
</tr>
<tr>
<td>\</td>
<td>Backslash ()</td>
<td></td>
</tr>
<tr>
<td>'</td>
<td>Single quote (')</td>
<td></td>
</tr>
<tr>
<td>&quot;</td>
<td>Double quote (&quot;)</td>
<td></td>
</tr>
<tr>
<td>\a</td>
<td>ASCII Bell (BEL)</td>
<td></td>
</tr>
<tr>
<td>\b</td>
<td>ASCII Backspace (BS)</td>
<td></td>
</tr>
<tr>
<td>\f</td>
<td>ASCII Formfeed (FF)</td>
<td></td>
</tr>
<tr>
<td>\n</td>
<td>ASCII Linefeed (LF)</td>
<td></td>
</tr>
<tr>
<td>\r</td>
<td>ASCII Carriage Return (CR)</td>
<td></td>
</tr>
<tr>
<td>\t</td>
<td>ASCII Horizontal Tab (TAB)</td>
<td></td>
</tr>
<tr>
<td>\v</td>
<td>ASCII Vertical Tab (VT)</td>
<td></td>
</tr>
<tr>
<td>\ooo</td>
<td>Character with octal value \ooo</td>
<td>(1,3)</td>
</tr>
<tr>
<td>\xhh</td>
<td>Character with hex value \hh</td>
<td>(2,3)</td>
</tr>
</tbody>
</table>

Escape sequences only recognized in string literals are:

<table>
<thead>
<tr>
<th>Escape Sequence</th>
<th>Meaning</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Character named name in the</td>
<td></td>
</tr>
</tbody>
</table>
\N{name}  Unicode database  (4)
\uxxxx  Character with 16-bit hex value xxxx  (5)
\Uxxxxxxxx  Character with 32-bit hex value xxxxxxxx  (6)

Notes:

1. As in Standard C, up to three octal digits are accepted.

2. Unlike in Standard C, exactly two hex digits are required.

3. In a bytes literal, hexadecimal and octal escapes denote the byte with the given value. In a string literal, these escapes denote a Unicode character with the given value.

4. Changed in version 3.3: Support for name aliases [1] has been added.

5. Individual code units which form parts of a surrogate pair can be encoded using this escape sequence. Exactly four hex digits are required.

6. Any Unicode character can be encoded this way. Exactly eight hex digits are required.

Unlike Standard C, all unrecognized escape sequences are left in the string unchanged, i.e., the backslash is left in the result. (This behavior is useful when debugging: if an escape sequence is mistyped, the resulting output is more easily recognized as broken.) It is also important to note that the escape sequences only recognized in string literals fall into the category of unrecognized escapes for bytes literals.

Even in a raw literal, quotes can be escaped with a backslash, but the
backslash remains in the result; for example, r"\"" is a valid string literal consisting of two characters: a backslash and a double quote; r"\" is not a valid string literal (even a raw string cannot end in an odd number of backslashes). Specifically, a raw literal cannot end in a single backslash (since the backslash would escape the following quote character). Note also that a single backslash followed by a newline is interpreted as those two characters as part of the literal, not as a line continuation.

2.4.2. String literal concatenation

Multiple adjacent string or bytes literals (delimited by whitespace), possibly using different quoting conventions, are allowed, and their meaning is the same as their concatenation. Thus, "hello'world" is equivalent to "helloworld". This feature can be used to reduce the number of backslashes needed, to split long strings conveniently across long lines, or even to add comments to parts of strings, for example:

```python
re.compile(r"[A-Za-z_]"     # letter or underscore
           r"[A-Za-z0-9_]"* # letter, digit or underscore)
```

Note that this feature is defined at the syntactical level, but implemented at compile time. The ‘+’ operator must be used to concatenate string expressions at run time. Also note that literal concatenation can use different quoting styles for each component (even mixing raw strings and triple quoted strings).

2.4.3. Numeric literals
There are three types of numeric literals: integers, floating point numbers, and imaginary numbers. There are no complex literals (complex numbers can be formed by adding a real number and an imaginary number).

Note that numeric literals do not include a sign; a phrase like -1 is actually an expression composed of the unary operator ‘-’ and the literal 1.

2.4.4. Integer literals

Integer literals are described by the following lexical definitions:

```
integer ::= decimalinteger | octinteger | hexinteger
decimalinteger ::= nonzerodigit digit* | "0"+
nonzerodigit ::= "1"..."9"
digit ::= "0"..."9"
octinteger ::= "0" ("0" | "O") octdigit+
hexinteger ::= "0" ("x" | "X") hexdigit+
bininteger ::= "0" ("b" | "B") bindigit+
octdigit ::= "0"..."7"
hexdigit ::= digit | "a"..."f" | "A"..."F"
bindigit ::= "0" | "1"
```

There is no limit for the length of integer literals apart from what can be stored in available memory.

Note that leading zeros in a non-zero decimal number are not allowed. This is for disambiguation with C-style octal literals, which Python used before version 3.0.

Some examples of integer literals:
2.4.5. Floating point literals

Floating point literals are described by the following lexical definitions:

\[
\begin{align*}
\text{floatnumber} & ::= \text{pointfloat} \mid \text{exponentfloat} \\
\text{pointfloat} & ::= [\text{intpart}] \text{fraction} \mid \text{intpart }."."
\text{exponentfloat} & ::= (\text{intpart} \mid \text{pointfloat}) \text{exponent} \\
\text{intpart} & ::= \text{digit}^+ \\
\text{fraction} & ::= "." \text{digit}^+ \\
\text{exponent} & ::= ("e" \mid "E") ["+" \mid "]-"] \text{digit}^+
\end{align*}
\]

Note that the integer and exponent parts are always interpreted using radix 10. For example, 077e010 is legal, and denotes the same number as 77e10. The allowed range of floating point literals is implementation-dependent. Some examples of floating point literals:

\[
3.14 \quad 10. \quad .001 \quad 1e100 \quad 3.14e-10 \quad 0e0
\]

Note that numeric literals do not include a sign; a phrase like -1 is actually an expression composed of the unary operator - and the literal 1.

2.4.6. Imaginary literals

Imaginary literals are described by the following lexical definitions:

\[
\text{imagnumber} ::= (\text{floatnumber} \mid \text{intpart}) ("j" \mid "J")
\]

An imaginary literal yields a complex number with a real part of 0.0.
Complex numbers are represented as a pair of floating point numbers and have the same restrictions on their range. To create a complex number with a nonzero real part, add a floating point number to it, e.g., $(3+4j)$. Some examples of imaginary literals:

| 3.14j | 10.j | 10j | .001j | 1e100j | 3.14e-10j |
2.5. Operators

The following tokens are operators:

+  -  *  **  /  //  %
<<  >>  &  |  ^  ~
<  >  <=  >=  ==  !=
2.6. Delimiters

The following tokens serve as delimiters in the grammar:

\[
( \quad ) \quad [ \quad ] \quad \{ \quad \} \\
, \quad : \quad . \quad ; \quad @ \quad = \quad -> \\
+= \quad -= \quad *= \quad /= \quad /= \quad %= \quad @= \\
&= \quad |= \quad ^= \quad >>= \quad <<= \quad **=
\]

The period can also occur in floating-point and imaginary literals. A sequence of three periods has a special meaning as an ellipsis literal. The second half of the list, the augmented assignment operators, serve lexically as delimiters, but also perform an operation.

The following printing ASCII characters have special meaning as part of other tokens or are otherwise significant to the lexical analyzer:

\[
' \quad '' \quad # \quad \backslash
\]

The following printing ASCII characters are not used in Python. Their occurrence outside string literals and comments is an unconditional error:

\[
$ \quad ? \quad \backslash
\]

Footnotes

[1]  http://www.unicode.org/Public/8.0.0/ucd/NameAliases.txt
The Python Software Foundation is a non-profit corporation. Please donate.
Last updated on Dec 06, 2015. Found a bug?
Created using Sphinx 1.3.1.
3. Data model
3.1. Objects, values and types

*Objects* are Python’s abstraction for data. All data in a Python program is represented by objects or by relations between objects. (In a sense, and in conformance to Von Neumann’s model of a “stored program computer,” code is also represented by objects.)

Every object has an identity, a type and a value. An object’s *identity* never changes once it has been created; you may think of it as the object’s address in memory. The `is` operator compares the identity of two objects; the `id()` function returns an integer representing its identity.

**CPython implementation detail:** For CPython, `id(x)` is the memory address where `x` is stored.

An object’s type determines the operations that the object supports (e.g., “does it have a length?”) and also defines the possible values for objects of that type. The `type()` function returns an object’s type (which is an object itself). Like its identity, an object’s *type* is also unchangeable. [1]

The *value* of some objects can change. Objects whose value can change are said to be *mutable*; objects whose value is unchangeable once they are created are called *immutable*. (The value of an immutable container object that contains a reference to a mutable object can change when the latter’s value is changed; however the container is still considered immutable, because the collection of objects it contains cannot be changed. So, immutability is not strictly the same as having an unchangeable value, it is more subtle.) An object’s mutability is determined by its type; for instance, numbers, strings and tuples are immutable, while dictionaries and lists are
mutable.

Objects are never explicitly destroyed; however, when they become unreachable they may be garbage-collected. An implementation is allowed to postpone garbage collection or omit it altogether — it is a matter of implementation quality how garbage collection is implemented, as long as no objects are collected that are still reachable.

**CPython implementation detail:** CPython currently uses a reference-counting scheme with (optional) delayed detection of cyclically linked garbage, which collects most objects as soon as they become unreachable, but is not guaranteed to collect garbage containing circular references. See the documentation of the `gc` module for information on controlling the collection of cyclic garbage. Other implementations act differently and CPython may change. Do not depend on immediate finalization of objects when they become unreachable (so you should always close files explicitly).

Note that the use of the implementation’s tracing or debugging facilities may keep objects alive that would normally be collectable. Also note that catching an exception with a ‘try...except’ statement may keep objects alive.

Some objects contain references to “external” resources such as open files or windows. It is understood that these resources are freed when the object is garbage-collected, but since garbage collection is not guaranteed to happen, such objects also provide an explicit way to release the external resource, usually a `close()` method. Programs are strongly recommended to explicitly close such objects. The ‘try...finally’ statement and the ‘with’ statement provide convenient ways to do this.
Some objects contain references to other objects; these are called containers. Examples of containers are tuples, lists and dictionaries. The references are part of a container’s value. In most cases, when we talk about the value of a container, we imply the values, not the identities of the contained objects; however, when we talk about the mutability of a container, only the identities of the immediately contained objects are implied. So, if an immutable container (like a tuple) contains a reference to a mutable object, its value changes if that mutable object is changed.

Types affect almost all aspects of object behavior. Even the importance of object identity is affected in some sense: for immutable types, operations that compute new values may actually return a reference to any existing object with the same type and value, while for mutable objects this is not allowed. E.g., after

```
a = 1; b = 1,
```

a and b may or may not refer to the same object with the value one, depending on the implementation, but after

```
c = []; d = [],
```

c and d are guaranteed to refer to two different, unique, newly created empty lists. (Note that

```
c = d = [],
```

assigns the same object to both c and d.)
3.2. The standard type hierarchy

Below is a list of the types that are built into Python. Extension modules (written in C, Java, or other languages, depending on the implementation) can define additional types. Future versions of Python may add types to the type hierarchy (e.g., rational numbers, efficiently stored arrays of integers, etc.), although such additions will often be provided via the standard library instead.

Some of the type descriptions below contain a paragraph listing ‘special attributes.’ These are attributes that provide access to the implementation and are not intended for general use. Their definition may change in the future.

None
This type has a single value. There is a single object with this value. This object is accessed through the built-in name None. It is used to signify the absence of a value in many situations, e.g., it is returned from functions that don’t explicitly return anything. Its truth value is false.

NotImplemented
This type has a single value. There is a single object with this value. This object is accessed through the built-in name NotImplemented. Numeric methods and rich comparison methods should return this value if they do not implement the operation for the operands provided. (The interpreter will then try the reflected operation, or some other fallback, depending on the operator.) Its truth value is true.

See Implementing the arithmetic operations for more details.
Ellipsis
This type has a single value. There is a single object with this value. This object is accessed through the literal ... or the built-in name Ellipsis. Its truth value is true.

numbers.Number
These are created by numeric literals and returned as results by arithmetic operators and arithmetic built-in functions. Numeric objects are immutable; once created their value never changes. Python numbers are of course strongly related to mathematical numbers, but subject to the limitations of numerical representation in computers.

Python distinguishes between integers, floating point numbers, and complex numbers:

numbers.Integral
These represent elements from the mathematical set of integers (positive and negative).

There are two types of integers:

Integers (int)
These represent numbers in an unlimited range, subject to available (virtual) memory only. For the purpose of shift and mask operations, a binary representation is assumed, and negative numbers are represented in a variant of 2's complement which gives the illusion of an infinite string of sign bits extending to the left.

Booleans (bool)
These represent the truth values False and True. The two objects representing the values False and True are the
only Boolean objects. The Boolean type is a subtype of the integer type, and Boolean values behave like the values 0 and 1, respectively, in almost all contexts, the exception being that when converted to a string, the strings "False" or "True" are returned, respectively.

The rules for integer representation are intended to give the most meaningful interpretation of shift and mask operations involving negative integers.

**numbers.Real (float)**
These represent machine-level double precision floating point numbers. You are at the mercy of the underlying machine architecture (and C or Java implementation) for the accepted range and handling of overflow. Python does not support single-precision floating point numbers; the savings in processor and memory usage that are usually the reason for using these are dwarfed by the overhead of using objects in Python, so there is no reason to complicate the language with two kinds of floating point numbers.

**numbers.Complex (complex)**
These represent complex numbers as a pair of machine-level double precision floating point numbers. The same caveats apply as for floating point numbers. The real and imaginary parts of a complex number $z$ can be retrieved through the read-only attributes $z.real$ and $z.imag$.

**Sequences**
These represent finite ordered sets indexed by non-negative numbers. The built-in function `len()` returns the number of items of a sequence. When the length of a sequence is $n$, the index set
contains the numbers 0, 1, ..., n-1. Item i of sequence a is selected by a[i].

Sequences also support slicing: a[i:j] selects all items with index k such that i <= k < j. When used as an expression, a slice is a sequence of the same type. This implies that the index set is renumbered so that it starts at 0.

Some sequences also support “extended slicing” with a third “step” parameter: a[i:j:k] selects all items of a with index x where x = i + n*k, n >= 0 and i <= x < j.

Sequences are distinguished according to their mutability:

Immutable sequences

An object of an immutable sequence type cannot change once it is created. (If the object contains references to other objects, these other objects may be mutable and may be changed; however, the collection of objects directly referenced by an immutable object cannot change.)

The following types are immutable sequences:

Strings

A string is a sequence of values that represent Unicode code points. All the code points in the range U+0000 - U+10FFFF can be represented in a string. Python doesn't have a char type; instead, every code point in the string is represented as a string object with length 1. The built-in function ord() converts a code point from its string form to an integer in the range 0 - 10FFFF; chr() converts an integer in the range 0 - 10FFFF to the corresponding
length 1 string object. `str.encode()` can be used to convert a `str` to `bytes` using the given text encoding, and `bytes.decode()` can be used to achieve the opposite.

Tuples
The items of a tuple are arbitrary Python objects. Tuples of two or more items are formed by comma-separated lists of expressions. A tuple of one item (a ‘singleton’) can be formed by affixing a comma to an expression (an expression by itself does not create a tuple, since parentheses must be usable for grouping of expressions). An empty tuple can be formed by an empty pair of parentheses.

Bytes
A bytes object is an immutable array. The items are 8-bit bytes, represented by integers in the range 0 <= x < 256. Bytes literals (like `b'abc'`) and the built-in function `bytes()` can be used to construct bytes objects. Also, bytes objects can be decoded to strings via the `decode()` method.

Mutable sequences
Mutable sequences can be changed after they are created. The subscription and slicing notations can be used as the target of assignment and `del` (delete) statements.

There are currently two intrinsic mutable sequence types:

Lists
The items of a list are arbitrary Python objects. Lists are formed by placing a comma-separated list of expressions in square brackets. (Note that there are no special cases
needed to form lists of length 0 or 1.)

Byte Arrays
A bytearray object is a mutable array. They are created by
the built-in `bytearray()` constructor. Aside from being
mutable (and hence unhashable), byte arrays otherwise
provide the same interface and functionality as immutable
bytes objects.

The extension module `array` provides an additional example of
a mutable sequence type, as does the `collections` module.

Set types
These represent unordered, finite sets of unique, immutable
objects. As such, they cannot be indexed by any subscript.
However, they can be iterated over, and the built-in function `len()`
returns the number of items in a set. Common uses for sets are
fast membership testing, removing duplicates from a sequence,
and computing mathematical operations such as intersection,
union, difference, and symmetric difference.

For set elements, the same immutability rules apply as for
dictionary keys. Note that numeric types obey the normal rules for
numeric comparison: if two numbers compare equal (e.g., 1 and
1.0), only one of them can be contained in a set.

There are currently two intrinsic set types:

Sets
These represent a mutable set. They are created by the built-in
`set()` constructor and can be modified afterwards by several
methods, such as `add()`.
Frozen sets

These represent an immutable set. They are created by the built-in `frozenset()` constructor. As a frozenset is immutable and hashable, it can be used again as an element of another set, or as a dictionary key.

Mappings

These represent finite sets of objects indexed by arbitrary index sets. The subscript notation `a[k]` selects the item indexed by `k` from the mapping `a`; this can be used in expressions and as the target of assignments or `del` statements. The built-in function `len()` returns the number of items in a mapping.

There is currently a single intrinsic mapping type:

Dictionaries

These represent finite sets of objects indexed by nearly arbitrary values. The only types of values not acceptable as keys are values containing lists or dictionaries or other mutable types that are compared by value rather than by object identity, the reason being that the efficient implementation of dictionaries requires a key's hash value to remain constant. Numeric types used for keys obey the normal rules for numeric comparison: if two numbers compare equal (e.g., `1` and `1.0`) then they can be used interchangeably to index the same dictionary entry.

Dictionaries are mutable; they can be created by the `{...}` notation (see section Dictionary displays).

The extension modules `dbm.ndbm` and `dbm.gnu` provide additional examples of mapping types, as does the `collections` module.
Callable types

These are the types to which the function call operation (see section Calls) can be applied:

User-defined functions

A user-defined function object is created by a function definition (see section Function definitions). It should be called with an argument list containing the same number of items as the function’s formal parameter list.

Special attributes:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Meaning</th>
<th>Writable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>doc</strong></td>
<td>The function's documentation string, or None if unavailable; not inherited by subclasses</td>
<td></td>
</tr>
<tr>
<td><strong>name</strong></td>
<td>The function's name</td>
<td></td>
</tr>
<tr>
<td><strong>qualname</strong></td>
<td>The function's qualified name</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>New in version 3.3.</em></td>
<td></td>
</tr>
<tr>
<td><strong>module</strong></td>
<td>The name of the module the function was defined in, or None if unavailable.</td>
<td></td>
</tr>
<tr>
<td><strong>defaults</strong></td>
<td>A tuple containing default argument values for those arguments that have defaults, or None if no arguments have a default value</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The code object</td>
<td></td>
</tr>
<tr>
<td>Attribute</td>
<td>Description</td>
<td>Writability</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td><strong>code</strong></td>
<td>representing the compiled function body.</td>
<td>Writable</td>
</tr>
<tr>
<td><strong>globals</strong></td>
<td>A reference to the dictionary that holds the function’s global variables — the global namespace of the module in which the function was defined.</td>
<td>Read-only</td>
</tr>
<tr>
<td><strong>dict</strong></td>
<td>The namespace supporting arbitrary function attributes.</td>
<td>Writable</td>
</tr>
<tr>
<td><strong>closure</strong></td>
<td>None or a tuple of cells that contain bindings for the function’s free variables.</td>
<td>Read-only</td>
</tr>
<tr>
<td><strong>annotations</strong></td>
<td>A dict containing annotations of parameters. The keys of the dict are the parameter names, and 'return' for the return annotation, if provided.</td>
<td>Writable</td>
</tr>
<tr>
<td><strong>kwdefaults</strong></td>
<td>A dict containing defaults for keyword-only parameters.</td>
<td>Writable</td>
</tr>
</tbody>
</table>

Most of the attributes labelled “Writable” check the type of the assigned value.

Function objects also support getting and setting arbitrary attributes, which can be used, for example, to attach metadata to functions. Regular attribute dot-notation is used to get and set such attributes. *Note that the current implementation only supports function attributes on user-defined functions. Function attributes on built-in functions may be supported in the future.*
Additional information about a function’s definition can be retrieved from its code object; see the description of internal types below.

Instance methods
An instance method object combines a class, a class instance and any callable object (normally a user-defined function).

Special read-only attributes: __self__ is the class instance object, __func__ is the function object; __doc__ is the method’s documentation (same as __func__.doc__); __name__ is the method name (same as __func__.name__); __module__ is the name of the module the method was defined in, or None if unavailable.

Methods also support accessing (but not setting) the arbitrary function attributes on the underlying function object.

User-defined method objects may be created when getting an attribute of a class (perhaps via an instance of that class), if that attribute is a user-defined function object or a class method object.

When an instance method object is created by retrieving a user-defined function object from a class via one of its instances, its __self__ attribute is the instance, and the method object is said to be bound. The new method’s __func__ attribute is the original function object.

When a user-defined method object is created by retrieving another method object from a class or instance, the behaviour is the same as for a function object, except that the __func__ attribute of the new instance is not the original method object.
but its __func__ attribute.

When an instance method object is created by retrieving a class method object from a class or instance, its __self__ attribute is the class itself, and its __func__ attribute is the function object underlying the class method.

When an instance method object is called, the underlying function (__func__) is called, inserting the class instance (__self__) in front of the argument list. For instance, when C is a class which contains a definition for a function f(), and x is an instance of C, calling x.f(1) is equivalent to calling C.f(x, 1).

When an instance method object is derived from a class method object, the “class instance” stored in __self__ will actually be the class itself, so that calling either x.f(1) or C.f(1) is equivalent to calling f(C, 1) where f is the underlying function.

Note that the transformation from function object to instance method object happens each time the attribute is retrieved from the instance. In some cases, a fruitful optimization is to assign the attribute to a local variable and call that local variable. Also notice that this transformation only happens for user-defined functions; other callable objects (and all non-callable objects) are retrieved without transformation. It is also important to note that user-defined functions which are attributes of a class instance are not converted to bound methods; this only happens when the function is an attribute of the class.

Generator functions
A function or method which uses the \texttt{yield} statement (see section \texttt{The yield statement}) is called a \textit{generator function}. Such a function, when called, always returns an iterator object which can be used to execute the body of the function: calling the iterator's \texttt{iterator.__next__()} method will cause the function to execute until it provides a value using the \texttt{yield} statement. When the function executes a \texttt{return} statement or falls off the end, a \texttt{StopIteration} exception is raised and the iterator will have reached the end of the set of values to be returned.

**Coroutine functions**

A function or method which is defined using \texttt{async def} is called a \textit{coroutine function}. Such a function, when called, returns a \texttt{coroutine} object. It may contain \texttt{await} expressions, as well as \texttt{async with} and \texttt{async for} statements. See also the \texttt{Coroutine Objects} section.

**Built-in functions**

A built-in function object is a wrapper around a C function. Examples of built-in functions are \texttt{len()} and \texttt{math.sin()} (\texttt{math} is a standard built-in module). The number and type of the arguments are determined by the C function. Special read-only attributes: \texttt{__doc__} is the function's documentation string, or \texttt{None} if unavailable; \texttt{__name__} is the function's name; \texttt{__self__} is set to \texttt{None} (but see the next item); \texttt{__module__} is the name of the module the function was defined in or \texttt{None} if unavailable.

**Built-in methods**

This is really a different disguise of a built-in function, this time
containing an object passed to the C function as an implicit extra argument. An example of a built-in method is `alist.append()`, assuming `alist` is a list object. In this case, the special read-only attribute `__self__` is set to the object denoted by `alist`.

Classes

Classes are callable. These objects normally act as factories for new instances of themselves, but variations are possible for class types that override `__new__()`. The arguments of the call are passed to `__new__()` and, in the typical case, to `__init__()` to initialize the new instance.

Class Instances

Instances of arbitrary classes can be made callable by defining a `__call__()` method in their class.

Modules

Modules are a basic organizational unit of Python code, and are created by the `import` system as invoked either by the `import` statement (see `import`), or by calling functions such as `importlib.import_module()` and built-in `__import__()`. A module object has a namespace implemented by a dictionary object (this is the dictionary referenced by the `__globals__` attribute of functions defined in the module). Attribute references are translated to lookups in this dictionary, e.g., `m.x` is equivalent to `m.__dict__['x']`. A module object does not contain the code object used to initialize the module (since it isn’t needed once the initialization is done).

Attribute assignment updates the module’s namespace dictionary, e.g., `m.x = 1` is equivalent to `m.__dict__['x'] = 1`. 
Special read-only attribute: __dict__ is the module’s namespace as a dictionary object.

**CPython implementation detail:** Because of the way CPython clears module dictionaries, the module dictionary will be cleared when the module falls out of scope even if the dictionary still has live references. To avoid this, copy the dictionary or keep the module around while using its dictionary directly.

Predefined (writable) attributes: __name__ is the module’s name; __doc__ is the module’s documentation string, or None if unavailable; __file__ is the pathname of the file from which the module was loaded, if it was loaded from a file. The __file__ attribute may be missing for certain types of modules, such as C modules that are statically linked into the interpreter; for extension modules loaded dynamically from a shared library, it is the pathname of the shared library file.

**Custom classes**

Custom class types are typically created by class definitions (see section **Class definitions**). A class has a namespace implemented by a dictionary object. Class attribute references are translated to lookups in this dictionary, e.g., C.x is translated to C.__dict__["x"] (although there are a number of hooks which allow for other means of locating attributes). When the attribute name is not found there, the attribute search continues in the base classes. This search of the base classes uses the C3 method resolution order which behaves correctly even in the presence of ‘diamond’ inheritance structures where there are multiple inheritance paths leading back to a common ancestor. Additional details on the C3 MRO used by Python can be found in the documentation accompanying the 2.3 release at [https://www.python.org/download/releases/2.3/mro/](https://www.python.org/download/releases/2.3/mro/).
When a class attribute reference (for class C, say) would yield a class method object, it is transformed into an instance method object whose __self__ attributes is C. When it would yield a static method object, it is transformed into the object wrapped by the static method object. See section Implementing Descriptors for another way in which attributes retrieved from a class may differ from those actually contained in its __dict__.

Class attribute assignments update the class's dictionary, never the dictionary of a base class.

A class object can be called (see above) to yield a class instance (see below).

Special attributes: __name__ is the class name; __module__ is the module name in which the class was defined; __dict__ is the dictionary containing the class's namespace; __bases__ is a tuple (possibly empty or a singleton) containing the base classes, in the order of their occurrence in the base class list; __doc__ is the class's documentation string, or None if undefined.

Class instances
A class instance is created by calling a class object (see above). A class instance has a namespace implemented as a dictionary which is the first place in which attribute references are searched. When an attribute is not found there, and the instance's class has an attribute by that name, the search continues with the class attributes. If a class attribute is found that is a user-defined function object, it is transformed into an instance method object whose __self__ attribute is the instance. Static method and class method objects are also transformed; see above under “Classes”. See section Implementing Descriptors for another way in which
attributes of a class retrieved via its instances may differ from the objects actually stored in the class's __dict__. If no class attribute is found, and the object's class has a __getattr__() method, that is called to satisfy the lookup.

Attribute assignments and deletions update the instance's dictionary, never a class's dictionary. If the class has a __setattr__() or __delattr__() method, this is called instead of updating the instance dictionary directly.

Class instances can pretend to be numbers, sequences, or mappings if they have methods with certain special names. See section Special method names.

Special attributes: __dict__ is the attribute dictionary; __class__ is the instance's class.

I/O objects (also known as file objects)
A file object represents an open file. Various shortcuts are available to create file objects: the open() built-in function, and also os.popen(), os.fdopen(), and the makefile() method of socket objects (and perhaps by other functions or methods provided by extension modules).

The objects sys.stdin, sys.stdout and sys.stderr are initialized to file objects corresponding to the interpreter's standard input, output and error streams; they are all open in text mode and therefore follow the interface defined by the io.TextIOBase abstract class.

Internal types
A few types used internally by the interpreter are exposed to the user. Their definitions may change with future versions of the
interpreter, but they are mentioned here for completeness.

Code objects

Code objects represent byte-compiled executable Python code, or bytecode. The difference between a code object and a function object is that the function object contains an explicit reference to the function's globals (the module in which it was defined), while a code object contains no context; also the default argument values are stored in the function object, not in the code object (because they represent values calculated at run-time). Unlike function objects, code objects are immutable and contain no references (directly or indirectly) to mutable objects.

Special read-only attributes: co_name gives the function name; co_argcount is the number of positional arguments (including arguments with default values); co_nlocals is the number of local variables used by the function (including arguments); co_varnames is a tuple containing the names of the local variables (starting with the argument names); co_cellvars is a tuple containing the names of local variables that are referenced by nested functions; co_freevars is a tuple containing the names of free variables; co_code is a string representing the sequence of bytecode instructions; co_consts is a tuple containing the literals used by the bytecode; co_names is a tuple containing the names used by the bytecode; co_filename is the filename from which the code was compiled; co_firstlineno is the first line number of the function; co_lnotab is a string encoding the mapping from bytecode offsets to line numbers (for details see the source code of the interpreter); co_stacksize is the required
stack size (including local variables); co_flags is an integer encoding a number of flags for the interpreter.

The following flag bits are defined for co_flags: bit 0x04 is set if the function uses the *arguments syntax to accept an arbitrary number of positional arguments; bit 0x08 is set if the function uses the **keywords syntax to accept arbitrary keyword arguments; bit 0x20 is set if the function is a generator.

Future feature declarations (from __future__ import division) also use bits in co_flags to indicate whether a code object was compiled with a particular feature enabled: bit 0x2000 is set if the function was compiled with future division enabled; bits 0x10 and 0x1000 were used in earlier versions of Python.

Other bits in co_flags are reserved for internal use.

If a code object represents a function, the first item in co_consts is the documentation string of the function, or None if undefined.

Frame objects
Frame objects represent execution frames. They may occur in traceback objects (see below).

Special read-only attributes: f_back is to the previous stack frame (towards the caller), or None if this is the bottom stack frame; f_code is the code object being executed in this frame; f_locals is the dictionary used to look up local variables; f_globals is used for global variables; f_builtins is used
for built-in (intrinsic) names; f_lasti gives the precise instruction (this is an index into the bytecode string of the code object).

Special writable attributes: f_trace, if not None, is a function called at the start of each source code line (this is used by the debugger); f_lineno is the current line number of the frame — writing to this from within a trace function jumps to the given line (only for the bottom-most frame). A debugger can implement a Jump command (aka Set Next Statement) by writing to f_lineno.

Frame objects support one method:

frame.clear()

This method clears all references to local variables held by the frame. Also, if the frame belonged to a generator, the generator is finalized. This helps break reference cycles involving frame objects (for example when catching an exception and storing its traceback for later use).

.RuntimeError is raised if the frame is currently executing.

New in version 3.4.

Traceback objects

Traceback objects represent a stack trace of an exception. A traceback object is created when an exception occurs. When the search for an exception handler unwinds the execution stack, at each unwound level a traceback object is inserted in front of the current traceback. When an exception handler is entered, the stack trace is made available to the program. (See section The try statement.) It is accessible as the third item of
the tuple returned by `sys.exc_info()`. When the program contains no suitable handler, the stack trace is written (nicely formatted) to the standard error stream; if the interpreter is interactive, it is also made available to the user as `sys.last_traceback`.

Special read-only attributes: `tb_next` is the next level in the stack trace (towards the frame where the exception occurred), or `None` if there is no next level; `tb_frame` points to the execution frame of the current level; `tb_lineno` gives the line number where the exception occurred; `tb_lasti` indicates the precise instruction. The line number and last instruction in the traceback may differ from the line number of its frame object if the exception occurred in a `try` statement with no matching `except` clause or with a `finally` clause.

Slice objects
Slice objects are used to represent slices for `__getitem__()` methods. They are also created by the built-in `slice()` function.

Special read-only attributes: `start` is the lower bound; `stop` is the upper bound; `step` is the step value; each is `None` if omitted. These attributes can have any type.

Slice objects support one method:

```
slice.indices(self, length)
```

This method takes a single integer argument `length` and computes information about the slice that the slice object would describe if applied to a sequence of `length` items. It returns a tuple of three integers; respectively these are the
start and stop indices and the step or stride length of the slice. Missing or out-of-bounds indices are handled in a manner consistent with regular slices.

Static method objects
Static method objects provide a way of defeating the transformation of function objects to method objects described above. A static method object is a wrapper around any other object, usually a user-defined method object. When a static method object is retrieved from a class or a class instance, the object actually returned is the wrapped object, which is not subject to any further transformation. Static method objects are not themselves callable, although the objects they wrap usually are. Static method objects are created by the built-in staticmethod() constructor.

Class method objects
A class method object, like a static method object, is a wrapper around another object that alters the way in which that object is retrieved from classes and class instances. The behaviour of class method objects upon such retrieval is described above, under “User-defined methods”. Class method objects are created by the built-in classmethod() constructor.
3.3. Special method names

A class can implement certain operations that are invoked by special syntax (such as arithmetic operations or subscripting and slicing) by defining methods with special names. This is Python's approach to operator overloading, allowing classes to define their own behavior with respect to language operators. For instance, if a class defines a method named \texttt{__getitem__()}, and \texttt{x} is an instance of this class, then \texttt{x[i]} is roughly equivalent to \texttt{type(x).__getitem__(x, i)}. Except where mentioned, attempts to execute an operation raise an exception when no appropriate method is defined (typically \texttt{AttributeError} or \texttt{TypeError}).

When implementing a class that emulates any built-in type, it is important that the emulation only be implemented to the degree that it makes sense for the object being modelled. For example, some sequences may work well with retrieval of individual elements, but extracting a slice may not make sense. (One example of this is the \texttt{NodeList} interface in the W3C’s Document Object Model.)

3.3.1. Basic customization

\texttt{object.__new__(cls[, ...])}

Called to create a new instance of class \texttt{cls}. \texttt{__new__()} is a static method (special-cased so you need not declare it as such) that takes the class of which an instance was requested as its first argument. The remaining arguments are those passed to the object constructor expression (the call to the class). The return value of \texttt{__new__()} should be the new object instance (usually an instance of \texttt{cls}).
Typical implementations create a new instance of the class by invoking the superclass's `__new__()` method using `super(currentclass, cls).__new__(cls[, ...])` with appropriate arguments and then modifying the newly-created instance as necessary before returning it.

If `__new__()` returns an instance of `cls`, then the new instance's `__init__()` method will be invoked like `__init__(self[, ...])`, where `self` is the new instance and the remaining arguments are the same as were passed to `__new__()`.

If `__new__()` does not return an instance of `cls`, then the new instance's `__init__()` method will not be invoked.

`__new__()` is intended mainly to allow subclasses of immutable types (like int, str, or tuple) to customize instance creation. It is also commonly overridden in custom metaclasses in order to customize class creation.

```python
object.__init__(self[, ...])
```

Called after the instance has been created (by `__new__()`), but before it is returned to the caller. The arguments are those passed to the class constructor expression. If a base class has an `__init__()` method, the derived class's `__init__()` method, if any, must explicitly call it to ensure proper initialization of the base class part of the instance; for example: `BaseClass.__init__(self, [args...])`.

Because `__new__()` and `__init__()` work together in constructing objects (`__new__()` to create it, and `__init__()` to customise it), no non-None value may be returned by `__init__()`; doing so will cause a `TypeError` to be raised at
object.__del__(self)

Called when the instance is about to be destroyed. This is also called a destructor. If a base class has a __del__() method, the derived class's __del__() method, if any, must explicitly call it to ensure proper deletion of the base class part of the instance. Note that it is possible (though not recommended!) for the __del__() method to postpone destruction of the instance by creating a new reference to it. It may then be called at a later time when this new reference is deleted. It is not guaranteed that __del__() methods are called for objects that still exist when the interpreter exits.

**Note:** del x doesn't directly call x.__del__() — the former decrements the reference count for x by one, and the latter is only called when x's reference count reaches zero. Some common situations that may prevent the reference count of an object from going to zero include: circular references between objects (e.g., a doubly-linked list or a tree data structure with parent and child pointers); a reference to the object on the stack frame of a function that caught an exception (the traceback stored in sys.exc_info()[2] keeps the stack frame alive); or a reference to the object on the stack frame that raised an unhandled exception in interactive mode (the traceback stored in sys.last_traceback keeps the stack frame alive). The first situation can only be remedied by explicitly breaking the cycles; the second can be resolved by freeing the reference to the traceback object when it is no longer useful, and the third can be resolved by storing None in sys.last_traceback. Circular references which are garbage are detected and cleaned up when the cyclic garbage collector is enabled (it's on by default). Refer
to the documentation for the `gc` module for more information about this topic.

**Warning:** Due to the precarious circumstances under which `__del__()` methods are invoked, exceptions that occur during their execution are ignored, and a warning is printed to `sys.stderr` instead. Also, when `__del__()` is invoked in response to a module being deleted (e.g., when execution of the program is done), other globals referenced by the `__del__()` method may already have been deleted or in the process of being torn down (e.g. the import machinery shutting down). For this reason, `__del__()` methods should do the absolute minimum needed to maintain external invariants. Starting with version 1.5, Python guarantees that globals whose name begins with a single underscore are deleted from their module before other globals are deleted; if no other references to such globals exist, this may help in assuring that imported modules are still available at the time when the `__del__()` method is called.

Python object.__repr__(self)

Called by the `repr()` built-in function to compute the “official” string representation of an object. If at all possible, this should look like a valid Python expression that could be used to recreate an object with the same value (given an appropriate environment). If this is not possible, a string of the form `<...some useful description...>` should be returned. The return value must be a string object. If a class defines `__repr__()` but not `__str__()`, then `__repr__()` is also used when an “informal” string representation of instances of that class is required.

This is typically used for debugging, so it is important that the
representation is information-rich and unambiguous.

object.__str__(self)
Called by str(object) and the built-in functions format() and print() to compute the “informal” or nicely printable string representation of an object. The return value must be a string object.

This method differs from object.__repr__() in that there is no expectation that __str__() return a valid Python expression: a more convenient or concise representation can be used.

The default implementation defined by the built-in type object calls object.__repr__().

object.__bytes__(self)
Called by bytes() to compute a byte-string representation of an object. This should return a bytes object.

object.__format__(self, format_spec)
Called by the format() built-in function (and by extension, the str.format() method of class str) to produce a “formatted” string representation of an object. The format_spec argument is a string that contains a description of the formatting options desired. The interpretation of the format_spec argument is up to the type implementing __format__(), however most classes will either delegate formatting to one of the built-in types, or use a similar formatting option syntax.

The return value must be a string object.

*Changed in version 3.4:* The `__format__` method of `object` itself raises a `TypeError` if passed any non-empty string.

```python
object.__lt__(self, other)
object.__le__(self, other)
object.__eq__(self, other)
object.__ne__(self, other)
object.__gt__(self, other)
object.__ge__(self, other)
```

These are the so-called "rich comparison" methods. The correspondence between operator symbols and method names is as follows: `x<y` calls `x.__lt__(y)`, `x<=y` calls `x.__le__(y)`, `x==y` calls `x.__eq__(y)`, `x!=y` calls `x.__ne__(y)`, `x>y` calls `x.__gt__(y)`, and `x>=y` calls `x.__ge__(y)`.

An rich comparison method may return the singleton `NotImplemented` if it does not implement the operation for a given pair of arguments. By convention, `False` and `True` are returned for a successful comparison. However, these methods can return any value, so if the comparison operator is used in a Boolean context (e.g., in the condition of an `if` statement), Python will call `bool()` on the value to determine if the result is true or false.

By default, `__ne__()` delegates to `__eq__()` and inverts the result unless it is `NotImplemented`. There are no other implied relationships among the comparison operators, for example, the truth of `(x<y or x==y)` does not imply `x<=y`. To automatically generate ordering operations from a single root operation, see `functools.total_ordering()`.
See the paragraph on \texttt{\_\_hash\_()} for some important notes on creating \texttt{hashable} objects which support custom comparison operations and are usable as dictionary keys.

There are no swapped-argument versions of these methods (to be used when the left argument does not support the operation but the right argument does); rather, \texttt{\_\_lt\_()} and \texttt{\_\_gt\_()} are each other's reflection, \texttt{\_\_le\_()} and \texttt{\_\_ge\_()} are each other's reflection, and \texttt{\_\_eq\_()} and \texttt{\_\_ne\_()} are their own reflection. If the operands are of different types, and right operand's type is a direct or indirect subclass of the left operand's type, the reflected method of the right operand has priority, otherwise the left operand's method has priority. Virtual subclassing is not considered.

\texttt{object.\_\_hash\_\!(self)}

Called by built-in function \texttt{hash()} and for operations on members of hashed collections including \texttt{set}, \texttt{frozenset}, and \texttt{dict}. \texttt{\_\_hash\_()} should return an integer. The only required property is that objects which compare equal have the same hash value; it is advised to somehow mix together (e.g. using exclusive or) the hash values for the components of the object that also play a part in comparison of objects.

\begin{quote}
\textbf{Note:} \texttt{hash()} truncates the value returned from an object's custom \texttt{\_\_hash\_()} method to the size of a \texttt{Py\_ssize\_t}. This is typically 8 bytes on 64-bit builds and 4 bytes on 32-bit builds. If an object's \texttt{\_\_hash\_()} must interoperate on builds of different bit sizes, be sure to check the width on all supported builds. An easy way to do this is with python -c "import sys; print(sys.hash_info.width)".
\end{quote}
If a class does not define an `__eq__()` method it should not define a `__hash__()` operation either; if it defines `__eq__()` but not `__hash__()`, its instances will not be usable as items in hashable collections. If a class defines mutable objects and implements an `__eq__()` method, it should not implement `__hash__()`, since the implementation of hashable collections requires that a key's hash value is immutable (if the object's hash value changes, it will be in the wrong hash bucket).

User-defined classes have `__eq__()` and `__hash__()` methods by default; with them, all objects compare unequal (except with themselves) and `x.__hash__()` returns an appropriate value such that `x == y` implies both that `x is y` and `hash(x) == hash(y)`.

A class that overrides `__eq__()` and does not define `__hash__()` will have its `__hash__()` implicitly set to None. When the `__hash__()` method of a class is None, instances of the class will raise an appropriate `TypeError` when a program attempts to retrieve their hash value, and will also be correctly identified as unhashable when checking `isinstance(obj, collections.Hashable)`.

If a class that overrides `__eq__()` needs to retain the implementation of `__hash__()` from a parent class, the interpreter must be told this explicitly by setting `__hash__ = <ParentClass>.__hash__`.

If a class that does not override `__eq__()` wishes to suppress hash support, it should include `__hash__ = None` in the class definition. A class which defines its own `__hash__()` that explicitly
raises a `TypeError` would be incorrectly identified as hashable by an `isinstance(obj, collections.Hashable)` call.

**Note:** By default, the `__hash__()` values of `str`, `bytes` and `datetime` objects are “salted” with an unpredictable random value. Although they remain constant within an individual Python process, they are not predictable between repeated invocations of Python.

This is intended to provide protection against a denial-of-service caused by carefully-chosen inputs that exploit the worst case performance of a dict insertion, O(n^2) complexity. See [http://www.ocert.org/advisories/ocert-2011-003.html](http://www.ocert.org/advisories/ocert-2011-003.html) for details.

Changing hash values affects the iteration order of dicts, sets and other mappings. Python has never made guarantees about this ordering (and it typically varies between 32-bit and 64-bit builds).

See also `PYTHONHASHSEED`.

*Changed in version 3.3:* Hash randomization is enabled by default.

```python
object.__bool__(self)
```

Called to implement truth value testing and the built-in operation `bool()`; should return `False` or `True`. When this method is not defined, `__len__()` is called, if it is defined, and the object is considered true if its result is nonzero. If a class defines neither `__len__()` nor `__bool__()`, all its instances are considered true.

### 3.3.2. Customizing attribute access

The following methods can be defined to customize the meaning of attribute access (use of, assignment to, or deletion of `x.name`) for
class instances.

object.__getattr__(self, name)

Called when an attribute lookup has not found the attribute in the usual places (i.e. it is not an instance attribute nor is it found in the class tree for self). name is the attribute name. This method should return the (computed) attribute value or raise an AttributeError exception.

Note that if the attribute is found through the normal mechanism, __getattr__() is not called. (This is an intentional asymmetry between __getattr__() and __setattr__().) This is done both for efficiency reasons and because otherwise __getattr__() would have no way to access other attributes of the instance. Note that at least for instance variables, you can fake total control by not inserting any values in the instance attribute dictionary (but instead inserting them in another object). See the __getattribute__() method below for a way to actually get total control over attribute access.

object.__getattribute__(self, name)

Called unconditionally to implement attribute accesses for instances of the class. If the class also defines __getattr__(), the latter will not be called unless __getattribute__() either calls it explicitly or raises an AttributeError. This method should return the (computed) attribute value or raise an AttributeError exception. In order to avoid infinite recursion in this method, its implementation should always call the base class method with the same name to access any attributes it needs, for example, object.__getattribute__(self, name).
Note: This method may still be bypassed when looking up special methods as the result of implicit invocation via language syntax or built-in functions. See Special method lookup.

object.__setattr__(self, name, value)
Called when an attribute assignment is attempted. This is called instead of the normal mechanism (i.e. store the value in the instance dictionary). \texttt{name} is the attribute name, \texttt{value} is the value to be assigned to it.

If \texttt{__setattr__()} wants to assign to an instance attribute, it should call the base class method with the same name, for example, \texttt{object.__setattr__(self, name, value)}.

object.__delattr__(self, name)
Like \texttt{__setattr__()} but for attribute deletion instead of assignment. This should only be implemented if \texttt{del obj.name} is meaningful for the object.

object.__dir__(self)
Called when \texttt{dir()} is called on the object. A sequence must be returned. \texttt{dir()} converts the returned sequence to a list and sorts it.

3.3.2.1. Implementing Descriptors

The following methods only apply when an instance of the class containing the method (a so-called descriptor class) appears in an owner class (the descriptor must be in either the owner’s class dictionary or in the class dictionary for one of its parents). In the examples below, “the attribute” refers to the attribute whose name is
the key of the property in the owner class’ `__dict__`

```python
object.__get__(self, instance, owner)
```
Called to get the attribute of the owner class (class attribute access) or of an instance of that class (instance attribute access). `owner` is always the owner class, while `instance` is the instance that the attribute was accessed through, or None when the attribute is accessed through the `owner`. This method should return the (computed) attribute value or raise an `AttributeError` exception.

```python
object.__set__(self, instance, value)
```
Called to set the attribute on an instance `instance` of the owner class to a new value, `value`.

```python
object.__delete__(self, instance)
```
Called to delete the attribute on an instance `instance` of the owner class.

The attribute `__objclass__` is interpreted by the `inspect` module as specifying the class where this object was defined (setting this appropriately can assist in runtime introspection of dynamic class attributes). For callables, it may indicate that an instance of the given type (or a subclass) is expected or required as the first positional argument (for example, CPython sets this attribute for unbound methods that are implemented in C).

### 3.3.2.2. Invoking Descriptors

In general, a descriptor is an object attribute with “binding behavior”, one whose attribute access has been overridden by methods in the descriptor protocol: `__get__()`, `__set__()`, and `__delete__()`. If
any of those methods are defined for an object, it is said to be a descriptor.

The default behavior for attribute access is to get, set, or delete the attribute from an object’s dictionary. For instance, a.x has a lookup chain starting with a.__dict__['x'], then type(a).__dict__['x'], and continuing through the base classes of type(a) excluding metaclasses.

However, if the looked-up value is an object defining one of the descriptor methods, then Python may override the default behavior and invoke the descriptor method instead. Where this occurs in the precedence chain depends on which descriptor methods were defined and how they were called.

The starting point for descriptor invocation is a binding, a.x. How the arguments are assembled depends on a:

**Direct Call**

The simplest and least common call is when user code directly invokes a descriptor method: x.__get__(a).

**Instance Binding**

If binding to an object instance, a.x is transformed into the call: type(a).__dict__['x'].__get__(a, type(a)).

**Class Binding**

If binding to a class, A.x is transformed into the call: A.__dict__['x'].__get__(None, A).

**Super Binding**

If a is an instance of super, then the binding super(B, obj).m() searches obj.__class__.__mro__ for the base class A immediately preceding B and then invokes the descriptor with the call: A.__dict__['m'].__get__(obj,
obj.__class__). For instance bindings, the precedence of descriptor invocation depends on the which descriptor methods are defined. A descriptor can define any combination of __get__(), __set__() and __delete__(). If it does not define __get__(), then accessing the attribute will return the descriptor object itself unless there is a value in the object's instance dictionary. If the descriptor defines __set__() and/or __delete__(), it is a data descriptor; if it defines neither, it is a non-data descriptor. Normally, data descriptors define both __get__() and __set__(), while non-data descriptors have just the __get__() method. Data descriptors with __set__() and __get__() defined always override a redefinition in an instance dictionary. In contrast, non-data descriptors can be overridden by instances.

Python methods (including staticmethod() and classmethod()) are implemented as non-data descriptors. Accordingly, instances can redefine and override methods. This allows individual instances to acquire behaviors that differ from other instances of the same class.

The property() function is implemented as a data descriptor. Accordingly, instances cannot override the behavior of a property.

3.3.2.3. __slots__

By default, instances of classes have a dictionary for attribute storage. This wastes space for objects having very few instance variables. The space consumption can become acute when creating large numbers of instances.

The default can be overridden by defining __slots__ in a class.
definition. The __slots__ declaration takes a sequence of instance variables and reserves just enough space in each instance to hold a value for each variable. Space is saved because __dict__ is not created for each instance.

**object.__slots__**

This class variable can be assigned a string, iterable, or sequence of strings with variable names used by instances. __slots__ reserves space for the declared variables and prevents the automatic creation of __dict__ and __weakref__ for each instance.

### 3.3.2.3.1. Notes on using __slots__

- When inheriting from a class without __slots__, the __dict__ attribute of that class will always be accessible, so a __slots__ definition in the subclass is meaningless.
- Without a __dict__ variable, instances cannot be assigned new variables not listed in the __slots__ definition. Attempts to assign to an unlisted variable name raises AttributeError. If dynamic assignment of new variables is desired, then add '__dict__' to the sequence of strings in the __slots__ declaration.
- Without a __weakref__ variable for each instance, classes defining __slots__ do not support weak references to its instances. If weak reference support is needed, then add '__weakref__' to the sequence of strings in the __slots__ declaration.
- __slots__ are implemented at the class level by creating descriptors *(Implementing Descriptors)* for each variable name. As a result, class attributes cannot be used to set default values for instance variables defined by __slots__; otherwise, the class attribute would overwrite the descriptor assignment.
- The action of a __slots__ declaration is limited to the class where it is defined. As a result, subclasses will have a __dict__ unless
they also define __slots__ (which must only contain names of any additional slots).

- If a class defines a slot also defined in a base class, the instance variable defined by the base class slot is inaccessible (except by retrieving its descriptor directly from the base class). This renders the meaning of the program undefined. In the future, a check may be added to prevent this.
- Nonempty __slots__ does not work for classes derived from “variable-length” built-in types such as int, bytes and tuple.
- Any non-string iterable may be assigned to __slots__. Mappings may also be used; however, in the future, special meaning may be assigned to the values corresponding to each key.
- __class__ assignment works only if both classes have the same __slots__.

3.3.3. Customizing class creation

By default, classes are constructed using type(). The class body is executed in a new namespace and the class name is bound locally to the result of type(name, bases, namespace).

The class creation process can be customised by passing the metaclass keyword argument in the class definition line, or by inheriting from an existing class that included such an argument. In the following example, both MyClass and MySubclass are instances of Meta:

class Meta(type):
    pass

class MyClass(metaclass=Meta):
    pass
class MySubclass(MyClass):
    pass

Any other keyword arguments that are specified in the class definition are passed through to all metaclass operations described below.

When a class definition is executed, the following steps occur:

- the appropriate metaclass is determined
- the class namespace is prepared
- the class body is executed
- the class object is created

3.3.3.1. Determining the appropriate metaclass

The appropriate metaclass for a class definition is determined as follows:

- if no bases and no explicit metaclass are given, then `type()` is used
- if an explicit metaclass is given and it is not an instance of `type()`, then it is used directly as the metaclass
- if an instance of `type()` is given as the explicit metaclass, or bases are defined, then the most derived metaclass is used

The most derived metaclass is selected from the explicitly specified metaclass (if any) and the metaclasses (i.e. `type(cls)`) of all specified base classes. The most derived metaclass is one which is a subtype of all of these candidate metaclasses. If none of the candidate metaclasses meets that criterion, then the class definition will fail with `TypeError`.

3.3.3.2. Preparing the class namespace
Once the appropriate metaclass has been identified, then the class namespace is prepared. If the metaclass has a __prepare__ attribute, it is called as namespace = metaclass.__prepare__(name, bases, **kwds) (where the additional keyword arguments, if any, come from the class definition).

If the metaclass has no __prepare__ attribute, then the class namespace is initialised as an empty dict() instance.

See also:

PEP 3115 - Metaclasses in Python 3000

Introduced the __prepare__ namespace hook

3.3.3.3. Executing the class body

The class body is executed (approximately) as exec(body, globals(), namespace). The key difference from a normal call to exec() is that lexical scoping allows the class body (including any methods) to reference names from the current and outer scopes when the class definition occurs inside a function.

However, even when the class definition occurs inside the function, methods defined inside the class still cannot see names defined at the class scope. Class variables must be accessed through the first parameter of instance or class methods, and cannot be accessed at all from static methods.

3.3.3.4. Creating the class object

Once the class namespace has been populated by executing the class body, the class object is created by calling metaclass(name,
bases, namespace, **kwds) (the additional keywords passed here are the same as those passed to __prepare__).

This class object is the one that will be referenced by the zero-argument form of super(). __class__ is an implicit closure reference created by the compiler if any methods in a class body refer to either __class__ or super. This allows the zero argument form of super() to correctly identify the class being defined based on lexical scoping, while the class or instance that was used to make the current call is identified based on the first argument passed to the method.

After the class object is created, it is passed to the class decorators included in the class definition (if any) and the resulting object is bound in the local namespace as the defined class.

**See also:**

PEP 3135 - New super

Describes the implicit __class__ closure reference

3.3.3.5. Metaclass example

The potential uses for metaclasses are boundless. Some ideas that have been explored include logging, interface checking, automatic delegation, automatic property creation, proxies, frameworks, and automatic resource locking/synchronization.

Here is an example of a metaclass that uses an collections.OrderedDict to remember the order that class variables are defined:

```python
class OrderedClass(type):
```
When the class definition for `A` gets executed, the process begins with calling the metaclass's `__prepare__()` method which returns an empty `collections.OrderedDict`. That mapping records the methods and attributes of `A` as they are defined within the body of the class statement. Once those definitions are executed, the ordered dictionary is fully populated and the metaclass's `__new__()` method gets invoked. That method builds the new type and it saves the ordered dictionary keys in an attribute called `members`.

### 3.3.4. Customizing instance and subclass checks

The following methods are used to override the default behavior of the `isinstance()` and `issubclass()` built-in functions.

In particular, the metaclass `abc.ABCMeta` implements these methods...
in order to allow the addition of Abstract Base Classes (ABCs) as “virtual base classes” to any class or type (including built-in types), including other ABCs.

```python
class.__instancecheck__(self, instance)
    Return true if instance should be considered a (direct or indirect) instance of class. If defined, called to implement isinstance(instance, class).

class.__subclasscheck__(self, subclass)
    Return true if subclass should be considered a (direct or indirect) subclass of class. If defined, called to implement issubclass(subclass, class).
```

Note that these methods are looked up on the type (metaclass) of a class. They cannot be defined as class methods in the actual class. This is consistent with the lookup of special methods that are called on instances, only in this case the instance is itself a class.

See also:

**PEP 3119 - Introducing Abstract Base Classes**

Includes the specification for customizing `isinstance()` and `issubclass()` behavior through `__instancecheck__()` and `__subclasscheck__()`, with motivation for this functionality in the context of adding Abstract Base Classes (see the `abc` module) to the language.

3.3.5. Emulating callable objects

```python
object.__call__(self[, args...])
    Called when the instance is "called" as a function; if this method is
defined, \( x(\text{arg1, arg2, ...} \) is a shorthand for \( x.__call__(\text{arg1, arg2, ...} \).

### 3.3.6. Emulating container types

The following methods can be defined to implement container objects. Containers usually are sequences (such as lists or tuples) or mappings (like dictionaries), but can represent other containers as well. The first set of methods is used either to emulate a sequence or to emulate a mapping; the difference is that for a sequence, the allowable keys should be the integers \( k \) for which \( 0 \leq k < N \) where \( N \) is the length of the sequence, or slice objects, which define a range of items. It is also recommended that mappings provide the methods \( \text{keys()} \), \( \text{values()} \), \( \text{items()} \), \( \text{get()} \), \( \text{clear()} \), \( \text{setdefault()} \), \( \text{pop()} \), \( \text{popitem()} \), \( \text{copy()} \), and \( \text{update()} \) behaving similar to those for Python’s standard dictionary objects. The \texttt{collections} module provides a \texttt{MutableMapping} abstract base class to help create those methods from a base set of \( \text{__getitem__()} \), \( \text{__setitem__()} \), \( \text{__delitem__()} \), and \( \text{keys()} \). Mutable sequences should provide methods \( \text{append()} \), \( \text{count()} \), \( \text{index()} \), \( \text{extend()} \), \( \text{insert()} \), \( \text{pop()} \), \( \text{remove()} \), \( \text{reverse()} \) and \( \text{sort()} \), like Python standard list objects. Finally, sequence types should implement addition (meaning concatenation) and multiplication (meaning repetition) by defining the methods \( \text{__add__()} \), \( \text{__radd__()} \), \( \text{__iadd__()} \), \( \text{__mul__()} \), \( \text{__rmul__()} \) and \( \text{__imul__()} \) described below; they should not define other numerical operators. It is recommended that both mappings and sequences implement the \( \text{__contains__()} \) method to allow efficient use of the \texttt{in} operator; for mappings, \texttt{in} should search the mapping’s keys; for sequences, it should search through the values. It is further
recommended that both mappings and sequences implement the
__iter__() method to allow efficient iteration through the container;
for mappings, __iter__() should be the same as keys(); for
sequences, it should iterate through the values.

object.__len__(self)
Called to implement the built-in function len(). Should return the
length of the object, an integer >= 0. Also, an object that doesn't
define a __bool__() method and whose __len__() method
returns zero is considered to be false in a Boolean context.

object.__length_hint__(self)
Called to implement operator.length_hint(). Should return an
estimated length for the object (which may be greater or less
than the actual length). The length must be an integer >= 0. This
method is purely an optimization and is never required for
correctness.

New in version 3.4.

**Note:** Slicing is done exclusively with the following three methods.
A call like

```python
a[1:2] = b
```

is translated to

```python
a[slice(1, 2, None)] = b
```

and so forth. Missing slice items are always filled in with None.

object.__getitem__(self, key)
Called to implement evaluation of self[key]. For sequence types, the accepted keys should be integers and slice objects. Note that the special interpretation of negative indexes (if the class wishes to emulate a sequence type) is up to the __getitem__() method. If key is of an inappropriate type, TypeError may be raised; if of a value outside the set of indexes for the sequence (after any special interpretation of negative values), IndexError should be raised. For mapping types, if key is missing (not in the container), KeyError should be raised.

Note: for loops expect that an IndexError will be raised for illegal indexes to allow proper detection of the end of the sequence.

object.__missing__(self, key)
Called by dict.__getitem__() to implement self[key] for dict subclasses when key is not in the dictionary.

object.__setitem__(self, key, value)
Called to implement assignment to self[key]. Same note as for __getitem__(). This should only be implemented for mappings if the objects support changes to the values for keys, or if new keys can be added, or for sequences if elements can be replaced. The same exceptions should be raised for improper key values as for the __getitem__() method.

object.__delitem__(self, key)
Called to implement deletion of self[key]. Same note as for __getitem__(). This should only be implemented for mappings if the objects support removal of keys, or for sequences if elements can be removed from the sequence. The same exceptions should
be raised for improper key values as for the `__getitem__() method.

**object.__iter__(self)**

This method is called when an iterator is required for a container. This method should return a new iterator object that can iterate over all the objects in the container. For mappings, it should iterate over the keys of the container.

Iterator objects also need to implement this method; they are required to return themselves. For more information on iterator objects, see Iterator Types.

**object.__reversed__(self)**

Called (if present) by the `reversed()` built-in to implement reverse iteration. It should return a new iterator object that iterates over all the objects in the container in reverse order.

If the `__reversed__()` method is not provided, the `reversed()` built-in will fall back to using the sequence protocol (`__len__()` and `__getitem__()`). Objects that support the sequence protocol should only provide `__reversed__()` if they can provide an implementation that is more efficient than the one provided by `reversed()`.

The membership test operators (`in` and `not in`) are normally implemented as an iteration through a sequence. However, container objects can supply the following special method with a more efficient implementation, which also does not require the object be a sequence.

**object.__contains__(self, item)**

Called to implement membership test operators. Should return true
if item is in self, false otherwise. For mapping objects, this should consider the keys of the mapping rather than the values or the key-item pairs.

For objects that don’t define __contains__(), the membership test first tries iteration via __iter__(), then the old sequence iteration protocol via __getitem__(), see this section in the language reference.

3.3.7. Emulating numeric types

The following methods can be defined to emulate numeric objects. Methods corresponding to operations that are not supported by the particular kind of number implemented (e.g., bitwise operations for non-integral numbers) should be left undefined.

object.__add__(self, other)
object.__sub__(self, other)
object.__mul__(self, other)
object.__matmul__(self, other)
object.__truediv__(self, other)
object.__floordiv__(self, other)
object.__mod__(self, other)
object.__divmod__(self, other)
object.__pow__(self, other[, modulo])
object.__lshift__(self, other)
object.__rshift__(self, other)
object.__and__(self, other)
object.__xor__(self, other)
object.__or__(self, other)

These methods are called to implement the binary arithmetic
operations (+, -, *, @, /, //, %, divmod(), pow(), **, <>, >>, &, ^, |). For instance, to evaluate the expression \(x + y\), where \(x\) is an instance of a class that has an \_\_add\_\_(\) method, \(x.__add__(y)\) is called. The \_\_divmod\_\_(\) method should be the equivalent to using \_\_floordiv\_\_(\) and \_\_mod\_\_(\); it should not be related to \_\_truediv\_\_(\). Note that \_\_pow\_\_(\) should be defined to accept an optional third argument if the ternary version of the built-in \_\_pow\_\_ function is to be supported.

If one of those methods does not support the operation with the supplied arguments, it should return \_\_NotImplemented\_.

```python
object.__radd__(self, other)
object.__rsub__(self, other)
object.__rmul__(self, other)
object.__rmul__(self, other)
object.__rmatmul__(self, other)
object.__rtruediv__(self, other)
object.__rfloordiv__(self, other)
object.__rmod__(self, other)
object.__rdivmod__(self, other)
object.__rpow__(self, other)
object.__rlshift__(self, other)
object.__rrshift__(self, other)
object.__rand__(self, other)
object.__rxor__(self, other)
object.__ror__(self, other)
```

These methods are called to implement the binary arithmetic operations (+, -, *, @, /, //, %, divmod(), pow(), **, <>, >>, &, ^, |) with reflected (swapped) operands. These functions are only called if the left operand does not support the corresponding operation and the operands are of different types. [2] For instance,
to evaluate the expression $x - y$, where $y$ is an instance of a class that has an `__rsub__()` method, $y.__rsub__(x)$ is called if $x.__sub__(y)$ returns `NotImplemented`.

Note that ternary `pow()` will not try calling `__rpow__()` (the coercion rules would become too complicated).

**Note:** If the right operand's type is a subclass of the left operand's type and that subclass provides the reflected method for the operation, this method will be called before the left operand's non-reflected method. This behavior allows subclasses to override their ancestors' operations.

```python
object.__iadd__(self, other)
object.__isub__(self, other)
object.__imul__(self, other)
object.__imatmul__(self, other)
object.__itruediv__(self, other)
object.__ifloordiv__(self, other)
object.__imod__(self, other)
object.__ipow__(self, other[, modulo])
object.__ilshift__(self, other)
object.__irshift__(self, other)
object.__iand__(self, other)
object.__ixor__(self, other)
object.__ior__(self, other)
```

These methods are called to implement the augmented arithmetic assignments (`+=`, `-=` , `*=` , `@=` , `/=` , `//=` , `%=` , `**=` , `<<=` , `>>=` , `&=` , `^=` , `|=` ). These methods should attempt to do the operation in-place (modifying `self`) and return the result (which could be, but does not have to be, `self`). If a specific method is not defined, the augmented
assignment falls back to the normal methods. For instance, if \( x \) is an instance of a class with an \.charCodeAt\( \) method, \( x += y \) is equivalent to \( x = x.__iadd__(y) \). Otherwise, \( x.__add__(y) \) and \( y.__radd__(x) \) are considered, as with the evaluation of \( x + y \). In certain situations, augmented assignment can result in unexpected errors (see Why does a_tuple[i] += ['item'] raise an exception when the addition works?), but this behavior is in fact part of the data model.

```
object.__neg__(self)
object.__pos__(self)
object.__abs__(self)
object.__invert__(self)
```

Called to implement the unary arithmetic operations \( -, +, \) \( \text{abs}() \) and \( \sim \).

```
object.__complex__(self)
object.__int__(self)
object.__float__(self)
object.__round__(self[, n])
```

Called to implement the built-in functions \( \text{complex}() \), \( \text{int}() \), \( \text{float}() \) and \( \text{round}() \). Should return a value of the appropriate type.

```
object.index____(self)
```

Called to implement \( \text{operator.index}() \), and whenever Python needs to losslessly convert the numeric object to an integer object (such as in slicing, or in the built-in \( \text{bin}() \), \( \text{hex}() \) and \( \text{oct}() \) functions). Presence of this method indicates that the numeric object is an integer type. Must return an integer.
3.3.8. With Statement Context Managers

A context manager is an object that defines the runtime context to be established when executing a `with` statement. The context manager handles the entry into, and the exit from, the desired runtime context for the execution of the block of code. Context managers are normally invoked using the `with` statement (described in section The `with` statement), but can also be used by directly invoking their methods.

Typical uses of context managers include saving and restoring various kinds of global state, locking and unlocking resources, closing opened files, etc.

For more information on context managers, see Context Manager Types.

```python
object.__enter__(self)
```

Enter the runtime context related to this object. The `with` statement will bind this method’s return value to the target(s) specified in the `as` clause of the statement, if any.

```python
object.__exit__(self, exc_type, exc_value, traceback)
```

Exit the runtime context related to this object. The parameters describe the exception that caused the context to be exited. If the context was exited without an exception, all three arguments will be `None`.

If an exception is supplied, and the method wishes to suppress the
exception (i.e., prevent it from being propagated), it should return a true value. Otherwise, the exception will be processed normally upon exit from this method.

Note that __exit__() methods should not reraise the passed-in exception; this is the caller’s responsibility.

See also:

**PEP 0343 - The “with” statement**

The specification, background, and examples for the Python with statement.

### 3.3.9. Special method lookup

For custom classes, implicit invocations of special methods are only guaranteed to work correctly if defined on an object’s type, not in the object’s instance dictionary. That behaviour is the reason why the following code raises an exception:

```python
>>> class C:
...     pass
... >>> c = C()
>>> c.__len__ = lambda: 5
>>> len(c)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: object of type 'C' has no len()
```

The rationale behind this behaviour lies with a number of special methods such as __hash__() and __repr__() that are implemented by all objects, including type objects. If the implicit lookup
of these methods used the conventional lookup process, they would fail when invoked on the type object itself:

```python
>>> 1.__hash__() == hash(1)
True
>>> int.__hash__() == hash(int)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: descriptor '__hash__' of 'int' object needs an argument
```

Incorrectly attempting to invoke an unbound method of a class in this way is sometimes referred to as ‘metaclass confusion’, and is avoided by bypassing the instance when looking up special methods:

```python
>>> type(1).__hash__(1) == hash(1)
True
>>> type(int).__hash__(int) == hash(int)
True
```

In addition to bypassing any instance attributes in the interest of correctness, implicit special method lookup generally also bypasses the `__getattribute__()` method even of the object's metaclass:

```python
>>> class Meta(type):
...     def __getattribute__(*args):
...         print("Metaclass getattribute invoked")
...         return type.__getattribute__(*args)
...
>>> class C(object, metaclass=Meta):
...     def __len__(self):
...         return 10
...     def __getattribute__(*args):
...         print("Class getattribute invoked")
...         return object.__getattribute__(*args)
...```
Bypassing the `__getattribute__()` machinery in this fashion provides significant scope for speed optimisations within the interpreter, at the cost of some flexibility in the handling of special methods (the special method *must* be set on the class object itself in order to be consistently invoked by the interpreter).
3.4. Coroutines

3.4.1. Awaitable Objects

An awaitable object generally implements an __await__() method. Coroutine objects returned from async def functions are awaitable.

**Note:** The generator iterator objects returned from generators decorated with types.coroutine() or asyncio.coroutine() are also awaitable, but they do not implement __await__().

object.__await__(self)

Must return an iterator. Should be used to implement awaitable objects. For instance, asyncio.Future implements this method to be compatible with the await expression.

*New in version 3.5.*

**See also:** PEP 492 for additional information about awaitable objects.

3.4.2. Coroutine Objects

Coroutine objects are awaitable objects. A coroutine’s execution can be controlled by calling __await__() and iterating over the result. When the coroutine has finished executing and returns, the iterator raises StopIteration, and the exception’s value attribute holds the return value. If the coroutine raises an exception, it is propagated by the iterator. Coroutines should not directly raise unhandled StopIteration exceptions.
Coroutines also have the methods listed below, which are analogous to those of generators (see Generator-iterator methods). However, unlike generators, coroutines do not directly support iteration.

**coroutine.send(value)**

Starts or resumes execution of the coroutine. If `value` is None, this is equivalent to advancing the iterator returned by `__await__()`. If `value` is not None, this method delegates to the `send()` method of the iterator that caused the coroutine to suspend. The result (return value, `StopIteration`, or other exception) is the same as when iterating over the `__await__()` return value, described above.

**coroutine.throw(type[, value[, traceback]])**

Raises the specified exception in the coroutine. This method delegates to the `throw()` method of the iterator that caused the coroutine to suspend, if it has such a method. Otherwise, the exception is raised at the suspension point. The result (return value, `StopIteration`, or other exception) is the same as when iterating over the `__await__()` return value, described above. If the exception is not caught in the coroutine, it propagates back to the caller.

**coroutine.close()**

Causes the coroutine to clean itself up and exit. If the coroutine is suspended, this method first delegates to the `close()` method of the iterator that caused the coroutine to suspend, if it has such a method. Then it raises `GeneratorExit` at the suspension point, causing the coroutine to immediately clean itself up. Finally, the coroutine is marked as having finished executing, even if it was never started.
Coroutine objects are automatically closed using the above process when they are about to be destroyed.

3.4.3. Asynchronous Iterators

An *asynchronous iterable* is able to call asynchronous code in its `__aiter__` implementation, and an *asynchronous iterator* can call asynchronous code in its `__anext__` method.

Asynchronous iterators can be used in an `async for` statement.

object.`__aiter__`(self)

Must return an *awaitable* resulting in an *asynchronous iterator* object.

object.`__anext__`(self)

Must return an *awaitable* resulting in a next value of the iterator. Should raise a `StopAsyncIteration` error when the iteration is over.

An example of an asynchronous iterable object:

```python
class Reader:
    async def readline(self):
        ...

    async def `__aiter__`(self):
        return self

    async def `__anext__`(self):
        val = await self.readline()
        if val == b'':
            raise StopAsyncIteration
        return val
```
New in version 3.5.

3.4.4. Asynchronous Context Managers

An asynchronous context manager is a context manager that is able to suspend execution in its `__aenter__` and `__aexit__` methods.

Asynchronous context managers can be used in an `async with` statement.

```python
object.__aenter__(self)
    This method is semantically similar to the `__enter__()`, with only difference that it must return an `awaitable`.

object.__aexit__(self, exc_type, exc_value, traceback)
    This method is semantically similar to the `__exit__()`, with only difference that it must return an `awaitable`.
```

An example of an asynchronous context manager class:

```python
class AsyncContextManager:
    async def __aenter__(self):
        await log('entering context')

    async def __aexit__(self, exc_type, exc, tb):
        await log('exiting context')
```

New in version 3.5.

Footnotes

It is possible in some cases to change an object’s type, under certain controlled conditions. It generally isn’t a good idea though, since it can lead to some very strange behaviour if it is
handled incorrectly.

For operands of the same type, it is assumed that if the non-reflected method (such as \texttt{\_\_add\_\_(\ )}) fails the operation is not supported, which is why the reflected method is not called.

\[2\]
4. Execution model
4.1. Structure of a program

A Python program is constructed from code blocks. A block is a piece of Python program text that is executed as a unit. The following are blocks: a module, a function body, and a class definition. Each command typed interactively is a block. A script file (a file given as standard input to the interpreter or specified as a command line argument to the interpreter) is a code block. A script command (a command specified on the interpreter command line with the ‘-c’ option) is a code block. The string argument passed to the built-in functions eval() and exec() is a code block.

A code block is executed in an execution frame. A frame contains some administrative information (used for debugging) and determines where and how execution continues after the code block’s execution has completed.
4.2. Naming and binding

4.2.1. Binding of names

*Names* refer to objects. Names are introduced by name binding operations.

The following constructs bind names: formal parameters to functions, *import* statements, class and function definitions (these bind the class or function name in the defining block), and targets that are identifiers if occurring in an assignment, *for* loop header, or after *as* in a *with* statement or *except* clause. The *import* statement of the form *from ... import * *binds all names defined in the imported module, except those beginning with an underscore. This form may only be used at the module level.

A target occurring in a *del* statement is also considered bound for this purpose (though the actual semantics are to unbind the name).

Each assignment or import statement occurs within a block defined by a class or function definition or at the module level (the top-level code block).

If a name is bound in a block, it is a local variable of that block, unless declared as *nonlocal* or *global*. If a name is bound at the module level, it is a global variable. (The variables of the module code block are local and global.) If a variable is used in a code block but not defined there, it is a *free variable*.

Each occurrence of a name in the program text refers to the *binding* of that name established by the following name resolution rules.
4.2.2. Resolution of names

A *scope* defines the visibility of a name within a block. If a local variable is defined in a block, its scope includes that block. If the definition occurs in a function block, the scope extends to any blocks contained within the defining one, unless a contained block introduces a different binding for the name.

When a name is used in a code block, it is resolved using the nearest enclosing scope. The set of all such scopes visible to a code block is called the block's *environment*.

When a name is not found at all, a *NameError* exception is raised. If the current scope is a function scope, and the name refers to a local variable that has not yet been bound to a value at the point where the name is used, an *UnboundLocalError* exception is raised. *UnboundLocalError* is a subclass of *NameError*.

If a name binding operation occurs anywhere within a code block, all uses of the name within the block are treated as references to the current block. This can lead to errors when a name is used within a block before it is bound. This rule is subtle. Python lacks declarations and allows name binding operations to occur anywhere within a code block. The local variables of a code block can be determined by scanning the entire text of the block for name binding operations.

If the *global* statement occurs within a block, all uses of the name specified in the statement refer to the binding of that name in the top-level namespace. Names are resolved in the top-level namespace by searching the global namespace, i.e. the namespace of the module containing the code block, and the builtins namespace, the namespace of the module *builtins*. The global namespace is
searched first. If the name is not found there, the builtins namespace is searched. The `global` statement must precede all uses of the name.

The `global` statement has the same scope as a name binding operation in the same block. If the nearest enclosing scope for a free variable contains a global statement, the free variable is treated as a global.

The `nonlocal` statement causes corresponding names to refer to previously bound variables in the nearest enclosing function scope. `SyntaxError` is raised at compile time if the given name does not exist in any enclosing function scope.

The namespace for a module is automatically created the first time a module is imported. The main module for a script is always called `__main__`.

Class definition blocks and arguments to `exec()` and `eval()` are special in the context of name resolution. A class definition is an executable statement that may use and define names. These references follow the normal rules for name resolution with an exception that unbound local variables are looked up in the global namespace. The namespace of the class definition becomes the attribute dictionary of the class. The scope of names defined in a class block is limited to the class block; it does not extend to the code blocks of methods – this includes comprehensions and generator expressions since they are implemented using a function scope. This means that the following will fail:

```python
class A:
    a = 42
    b = list(a + i for i in range(10))
```
4.2.3. Builtins and restricted execution

The builtins namespace associated with the execution of a code block is actually found by looking up the name \_\_builtins\_\_ in its global namespace; this should be a dictionary or a module (in the latter case the module's dictionary is used). By default, when in the \_\_main\_\_ module, \_\_builtins\_\_ is the built-in module builtins; when in any other module, \_\_builtins\_\_ is an alias for the dictionary of the builtins module itself. \_\_builtins\_\_ can be set to a user-created dictionary to create a weak form of restricted execution.

**CPython implementation detail:** Users should not touch \_\_builtins\_; it is strictly an implementation detail. Users wanting to override values in the builtins namespace should import the builtins module and modify its attributes appropriately.

4.2.4. Interaction with dynamic features

Name resolution of free variables occurs at runtime, not at compile time. This means that the following code will print 42:

```python
i = 10
def f():
    print(i)
i = 42
f()
```

There are several cases where Python statements are illegal when used in conjunction with nested scopes that contain free variables.

If a variable is referenced in an enclosing scope, it is illegal to delete the name. An error will be reported at compile time.
The `eval()` and `exec()` functions do not have access to the full environment for resolving names. Names may be resolved in the local and global namespaces of the caller. Free variables are not resolved in the nearest enclosing namespace, but in the global namespace. [1] The `exec()` and `eval()` functions have optional arguments to override the global and local namespace. If only one namespace is specified, it is used for both.
4.3. Exceptions

Exceptions are a means of breaking out of the normal flow of control of a code block in order to handle errors or other exceptional conditions. An exception is raised at the point where the error is detected; it may be handled by the surrounding code block or by any code block that directly or indirectly invoked the code block where the error occurred.

The Python interpreter raises an exception when it detects a run-time error (such as division by zero). A Python program can also explicitly raise an exception with the `raise` statement. Exception handlers are specified with the `try ... except` statement. The `finally` clause of such a statement can be used to specify cleanup code which does not handle the exception, but is executed whether an exception occurred or not in the preceding code.

Python uses the “termination” model of error handling: an exception handler can find out what happened and continue execution at an outer level, but it cannot repair the cause of the error and retry the failing operation (except by re-entering the offending piece of code from the top).

When an exception is not handled at all, the interpreter terminates execution of the program, or returns to its interactive main loop. In either case, it prints a stack backtrace, except when the exception is `SystemExit`.

Exceptions are identified by class instances. The `except` clause is selected depending on the class of the instance: it must reference the class of the instance or a base class thereof. The instance can be received by the handler and can carry additional information about the exceptional condition.
Note: Exception messages are not part of the Python API. Their contents may change from one version of Python to the next without warning and should not be relied on by code which will run under multiple versions of the interpreter.

See also the description of the try statement in section The try statement and raise statement in section The raise statement.

Footnotes

[1] This limitation occurs because the code that is executed by these operations is not available at the time the module is compiled.
5. The import system

Python code in one module gains access to the code in another module by the process of importing it. The import statement is the most common way of invoking the import machinery, but it is not the only way. Functions such as importlib.import_module() and built-in __import__() can also be used to invoke the import machinery.

The import statement combines two operations; it searches for the named module, then it binds the results of that search to a name in the local scope. The search operation of the import statement is defined as a call to the __import__() function, with the appropriate arguments. The return value of __import__() is used to perform the name binding operation of the import statement. See the import statement for the exact details of that name binding operation.

A direct call to __import__() performs only the module search and, if found, the module creation operation. While certain side-effects may occur, such as the importing of parent packages, and the updating of various caches (including sys.modules), only the import statement performs a name binding operation.

When calling __import__() as part of an import statement, the import system first checks the module global namespace for a function by that name. If it is not found, then the standard builtin __import__() is called. Other mechanisms for invoking the import system (such as importlib.import_module()) do not perform this check and will always use the standard import system.

When a module is first imported, Python searches for the module and
if found, it creates a module object [1], initializing it. If the named module cannot be found, an `ImportError` is raised. Python implements various strategies to search for the named module when the import machinery is invoked. These strategies can be modified and extended by using various hooks described in the sections below.

*Changed in version 3.3:* The import system has been updated to fully implement the second phase of PEP 302. There is no longer any implicit import machinery - the full import system is exposed through `sys.meta_path`. In addition, native namespace package support has been implemented (see PEP 420).
5.1. `importlib`

The `importlib` module provides a rich API for interacting with the import system. For example `importlib.import_module()` provides a recommended, simpler API than built-in `__import__()` for invoking the import machinery. Refer to the `importlib` library documentation for additional detail.
5.2. Packages

Python has only one type of module object, and all modules are of this type, regardless of whether the module is implemented in Python, C, or something else. To help organize modules and provide a naming hierarchy, Python has a concept of packages.

You can think of packages as the directories on a file system and modules as files within directories, but don’t take this analogy too literally since packages and modules need not originate from the file system. For the purposes of this documentation, we’ll use this convenient analogy of directories and files. Like file system directories, packages are organized hierarchically, and packages may themselves contain subpackages, as well as regular modules.

It’s important to keep in mind that all packages are modules, but not all modules are packages. Or put another way, packages are just a special kind of module. Specifically, any module that contains a \_\_path\_ attribute is considered a package.

All modules have a name. Subpackage names are separated from their parent package name by dots, akin to Python’s standard attribute access syntax. Thus you might have a module called \texttt{sys} and a package called \texttt{email}, which in turn has a subpackage called \texttt{email.mime} and a module within that subpackage called \texttt{email.mime.text}.

5.2.1. Regular packages

Python defines two types of packages, regular packages and namespace packages. Regular packages are traditional packages as
they existed in Python 3.2 and earlier. A regular package is typically implemented as a directory containing an `__init__.py` file. When a regular package is imported, this `__init__.py` file is implicitly executed, and the objects it defines are bound to names in the package's namespace. The `__init__.py` file can contain the same Python code that any other module can contain, and Python will add some additional attributes to the module when it is imported.

For example, the following file system layout defines a top level parent package with three subpackages:

```
parent/
   __init__.py
one/
   __init__.py
two/
   __init__.py
three/
   __init__.py
```

Importing `parent.one` will implicitly execute `parent/__init__.py` and `parent/one/__init__.py`. Subsequent imports of `parent.two` or `parent.three` will execute `parent/two/__init__.py` and `parent/three/__init__.py` respectively.

### 5.2.2. Namespace packages

A namespace package is a composite of various portions, where each portion contributes a subpackage to the parent package. Portions may reside in different locations on the file system. Portions may also be found in zip files, on the network, or anywhere else that Python
searches during import. Namespace packages may or may not correspond directly to objects on the file system; they may be virtual modules that have no concrete representation.

Namespace packages do not use an ordinary list for their __path__ attribute. They instead use a custom iterable type which will automatically perform a new search for package portions on the next import attempt within that package if the path of their parent package (or sys.path for a top level package) changes.

With namespace packages, there is no parent/__init__.py file. In fact, there may be multiple parent directories found during import search, where each one is provided by a different portion. Thus parent/one may not be physically located next to parent/two. In this case, Python will create a namespace package for the top-level parent package whenever it or one of its subpackages is imported.

See also PEP 420 for the namespace package specification.
5.3. Searching

To begin the search, Python needs the fully qualified name of the module (or package, but for the purposes of this discussion, the difference is immaterial) being imported. This name may come from various arguments to the import statement, or from the parameters to the importlib.import_module() or __import__() functions.

This name will be used in various phases of the import search, and it may be the dotted path to a submodule, e.g. foo.bar.baz. In this case, Python first tries to import foo, then foo.bar, and finally foo.bar.baz. If any of the intermediate imports fail, an ImportError is raised.

5.3.1. The module cache

The first place checked during import search is sys.modules. This mapping serves as a cache of all modules that have been previously imported, including the intermediate paths. So if foo.bar.baz was previously imported, sys.modules will contain entries for foo, foo.bar, and foo.bar.baz. Each key will have as its value the corresponding module object.

During import, the module name is looked up in sys.modules and if present, the associated value is the module satisfying the import, and the process completes. However, if the value is None, then an ImportError is raised. If the module name is missing, Python will continue searching for the module.

sys.modules is writable. Deleting a key may not destroy the
associated module (as other modules may hold references to it), but it will invalidate the cache entry for the named module, causing Python to search anew for the named module upon its next import. The key can also be assigned to None, forcing the next import of the module to result in an `ImportError`.

Beware though, as if you keep a reference to the module object, invalidate its cache entry in `sys.modules`, and then re-import the named module, the two module objects will *not* be the same. By contrast, `importlib.reload()` will reuse the *same* module object, and simply reinitialise the module contents by rerunning the module's code.

### 5.3.2. Finders and loaders

If the named module is not found in `sys.modules`, then Python's import protocol is invoked to find and load the module. This protocol consists of two conceptual objects, *finders* and *loaders*. A finder's job is to determine whether it can find the named module using whatever strategy it knows about. Objects that implement both of these interfaces are referred to as *importers* - they return themselves when they find that they can load the requested module.

Python includes a number of default finders and importers. The first one knows how to locate built-in modules, and the second knows how to locate frozen modules. A third default finder searches an *import path* for modules. The *import path* is a list of locations that may name file system paths or zip files. It can also be extended to search for any locatable resource, such as those identified by URLs.

The import machinery is extensible, so new finders can be added to extend the range and scope of module searching.
Finders do not actually load modules. If they can find the named module, they return a module spec, an encapsulation of the module's import-related information, which the import machinery then uses when loading the module.

The following sections describe the protocol for finders and loaders in more detail, including how you can create and register new ones to extend the import machinery.

*Changed in version 3.4:* In previous versions of Python, finders returned loaders directly, whereas now they return module specs which contain loaders. Loaders are still used during import but have fewer responsibilities.

### 5.3.3. Import hooks

The import machinery is designed to be extensible; the primary mechanism for this are the *import hooks*. There are two types of import hooks: *meta hooks* and *import path hooks*.

Meta hooks are called at the start of import processing, before any other import processing has occurred, other than `sys.modules` cache look up. This allows meta hooks to override `sys.path` processing, frozen modules, or even built-in modules. Meta hooks are registered by adding new finder objects to `sys.meta_path`, as described below.

Import path hooks are called as part of `sys.path` (or `package.__path__`) processing, at the point where their associated path item is encountered. Import path hooks are registered by adding new callables to `sys.path_hooks` as described below.
5.3.4. The meta path

When the named module is not found in `sys.modules`, Python next searches `sys.meta_path`, which contains a list of meta path finder objects. These finders are queried in order to see if they know how to handle the named module. Meta path finders must implement a method called `find_spec()` which takes three arguments: a name, an import path, and (optionally) a target module. The meta path finder can use any strategy it wants to determine whether it can handle the named module or not.

If the meta path finder knows how to handle the named module, it returns a spec object. If it cannot handle the named module, it returns None. If `sys.meta_path` processing reaches the end of its list without returning a spec, then an `ImportError` is raised. Any other exceptions raised are simply propagated up, aborting the import process.

The `find_spec()` method of meta path finders is called with two or three arguments. The first is the fully qualified name of the module being imported, for example `foo.bar.baz`. The second argument is the path entries to use for the module search. For top-level modules, the second argument is None, but for submodules or subpackages, the second argument is the value of the parent package's `__path__` attribute. If the appropriate `__path__` attribute cannot be accessed, an `ImportError` is raised. The third argument is an existing module object that will be the target of loading later. The import system passes in a target module only during reload.

The meta path may be traversed multiple times for a single import request. For example, assuming none of the modules involved has
already been cached, importing foo.bar.baz will first perform a top level import, calling mpf.find_spec("foo", None, None) on each meta path finder (mpf). After foo has been imported, foo.bar will be imported by traversing the meta path a second time, calling mpf.find_spec("foo.bar", foo.__path__, None). Once foo.bar has been imported, the final traversal will call mpf.find_spec("foo.bar.baz", foo.bar.__path__, None).

Some meta path finders only support top level imports. These importers will always return None when anything other than None is passed as the second argument.

Python’s default sys.meta_path has three meta path finders, one that knows how to import built-in modules, one that knows how to import frozen modules, and one that knows how to import modules from an import path (i.e. the path based finder).

Changed in version 3.4: The find_spec() method of meta path finders replaced find_module(), which is now deprecated. While it will continue to work without change, the import machinery will try it only if the finder does not implement find_spec().
5.4. Loading

If and when a module spec is found, the import machinery will use it (and the loader it contains) when loading the module. Here is an approximation of what happens during the loading portion of import:

```python
module = None
if spec.loader is not None and hasattr(spec.loader,
    # It is assumed 'exec_module' will also be defined
    'exec_module',
    module = spec.loader.create_module(spec)
if module is None:
    module = ModuleType(spec.name)
    # The import-related module attributes get set here:
    _init_module_attrs(spec, module)

if spec.loader is None:
    if spec.submodule_search_locations is not None:
        # namespace package
        sys.modules[spec.name] = module
    else:
        # unsupported
        raise ImportError
elif not hasattr(spec.loader, 'exec_module'):
    module = spec.loader.load_module(spec.name)
    # Set __loader__ and __package__ if missing.
else:
    sys.modules[spec.name] = module
try:
    spec.loader.exec_module(module)
except BaseException:
    try:
        del sys.modules[spec.name]
    except KeyError:
        pass
raise
```
Note the following details:

- If there is an existing module object with the given name in `sys.modules`, import will have already returned it.
- The module will exist in `sys.modules` before the loader executes the module code. This is crucial because the module code may (directly or indirectly) import itself; adding it to `sys.modules` beforehand prevents unbounded recursion in the worst case and multiple loading in the best.
- If loading fails, the failing module – and only the failing module – gets removed from `sys.modules`. Any module already in the `sys.modules` cache, and any module that was successfully loaded as a side-effect, must remain in the cache. This contrasts with reloading where even the failing module is left in `sys.modules`.
- After the module is created but before execution, the import machinery sets the import-related module attributes ("_init_moduleAttrs" in the pseudo-code example above), as summarized in a later section.
- Module execution is the key moment of loading in which the module's namespace gets populated. Execution is entirely delegated to the loader, which gets to decide what gets populated and how.
- The module created during loading and passed to `exec_module()` may not be the one returned at the end of import [2].

*Changed in version 3.4:* The import system has taken over the boilerplate responsibilities of loaders. These were previously performed by the `importlib.abc.Loader.load_module()` method.
5.4.1. Loaders

Module loaders provide the critical function of loading: module execution. The import machinery calls the `importlib.abc.Loader.exec_module()` method with a single argument, the module object to execute. Any value returned from `exec_module()` is ignored.

Loaders must satisfy the following requirements:

- If the module is a Python module (as opposed to a built-in module or a dynamically loaded extension), the loader should execute the module’s code in the module’s global name space (`module.__dict__`).
- If the loader cannot execute the module, it should raise an `ImportError`, although any other exception raised during `exec_module()` will be propagated.

In many cases, the finder and loader can be the same object; in such cases the `find_spec()` method would just return a spec with the loader set to `self`.

Module loaders may opt in to creating the module object during loading by implementing a `create_module()` method. It takes one argument, the module spec, and returns the new module object to use during loading. `create_module()` does not need to set any attributes on the module object. If the method returns `None`, the import machinery will create the new module itself.

New in version 3.4: The `create_module()` method of loaders.

Changed in version 3.4: The `load_module()` method was replaced by `exec_module()` and the import machinery assumed all the
boilerplate responsibilities of loading.

For compatibility with existing loaders, the import machinery will use the `load_module()` method of loaders if it exists and the loader does not also implement `exec_module()`. However, `load_module()` has been deprecated and loaders should implement `exec_module()` instead.

The `load_module()` method must implement all the boilerplate loading functionality described above in addition to executing the module. All the same constraints apply, with some additional clarification:

- If there is an existing module object with the given name in `sys.modules`, the loader must use that existing module. (Otherwise, `importlib.reload()` will not work correctly.)
- If the named module does not exist in `sys.modules`, the loader must create a new module object and add it to `sys.modules`.
- The module must exist in `sys.modules` before the loader executes the module code, to prevent unbounded recursion or multiple loading.
- If loading fails, the loader must remove any modules it has inserted into `sys.modules`, but it must remove only the failing module(s), and only if the loader itself has loaded the module(s) explicitly.

*Changed in version 3.5:* A `DeprecationWarning` is raised when `exec_module()` is defined but `create_module()` is not. Starting in Python 3.6 it will be an error to not define `create_module()` on a loader attached to a ModuleSpec.

5.4.2. Submodules
When a submodule is loaded using any mechanism (e.g. `importlib` APIs, the `import` or `import-from` statements, or built-in `__import__()`) a binding is placed in the parent module's namespace to the submodule object. For example, if package `spam` has a submodule `foo`, after importing `spam.foo`, `spam` will have an attribute `foo` which is bound to the submodule. Let's say you have the following directory structure:

```
spam/
  __init__.py
  foo.py
  bar.py
```

and `spam/__init__.py` has the following lines in it:

```
from .foo import Foo
from .bar import Bar
```

then executing the following puts a name binding to `foo` and `bar` in the `spam` module:

```
>>> import spam
>>> spam.foo
<module 'spam.foo' from '/tmp/imports/spam/foo.py'>
>>> spam.bar
<module 'spam.bar' from '/tmp/imports/spam/bar.py'>
```

Given Python's familiar name binding rules this might seem surprising, but it's actually a fundamental feature of the import system. The invariant holding is that if you have `sys.modules['spam']` and `sys.modules['spam.foo']` (as you would after the above import), the latter must appear as the `foo` attribute of the former.
5.4.3. Module spec

The import machinery uses a variety of information about each module during import, especially before loading. Most of the information is common to all modules. The purpose of a module’s spec is to encapsulate this import-related information on a per-module basis.

Using a spec during import allows state to be transferred between import system components, e.g. between the finder that creates the module spec and the loader that executes it. Most importantly, it allows the import machinery to perform the boilerplate operations of loading, whereas without a module spec the loader had that responsibility.

See ModuleSpec for more specifics on what information a module’s spec may hold.

*New in version 3.4.*

5.4.4. Import-related module attributes

The import machinery fills in these attributes on each module object during loading, based on the module’s spec, before the loader executes the module.

__name__

The __name__ attribute must be set to the fully-qualified name of the module. This name is used to uniquely identify the module in the import system.

__loader__

The __loader__ attribute must be set to the loader object that the import machinery used when loading the module. This is mostly for
introspection, but can be used for additional loader-specific functionality, for example getting data associated with a loader.

__package__
The module’s __package__ attribute must be set. Its value must be a string, but it can be the same value as its __name__. When the module is a package, its __package__ value should be set to its __name__. When the module is not a package, __package__ should be set to the empty string for top-level modules, or for submodules, to the parent package’s name. See PEP 366 for further details.

This attribute is used instead of __name__ to calculate explicit relative imports for main modules, as defined in PEP 366.

__spec__
The __spec__ attribute must be set to the module spec that was used when importing the module. This is used primarily for introspection and during reloading. Setting __spec__ appropriately applies equally to modules initialized during interpreter startup. The one exception is __main__, where __spec__ is set to None in some cases.

New in version 3.4.

__path__
If the module is a package (either regular or namespace), the module object’s __path__ attribute must be set. The value must be iterable, but may be empty if __path__ has no further significance. If __path__ is not empty, it must produce strings when iterated over. More details on the semantics of __path__ are given below.
Non-package modules should not have a `__path__` attribute.

`__file__`

`__cached__`

`__file__` is optional. If set, this attribute's value must be a string. The import system may opt to leave `__file__` unset if it has no semantic meaning (e.g. a module loaded from a database).

If `__file__` is set, it may also be appropriate to set the `__cached__` attribute which is the path to any compiled version of the code (e.g. byte-compiled file). The file does not need to exist to set this attribute; the path can simply point to where the compiled file would exist (see PEP 3147).

It is also appropriate to set `__cached__` when `__file__` is not set. However, that scenario is quite atypical. Ultimately, the loader is what makes use of `__file__` and/or `__cached__`. So if a loader can load from a cached module but otherwise does not load from a file, that atypical scenario may be appropriate.

5.4.5. module.`__path__`

By definition, if a module has an `__path__` attribute, it is a package, regardless of its value.

A package's `__path__` attribute is used during imports of its subpackages. Within the import machinery, it functions much the same as `sys.path`, i.e. providing a list of locations to search for modules during import. However, `__path__` is typically much more constrained than `sys.path`. 
__path__ must be an iterable of strings, but it may be empty. The same rules used for sys.path also apply to a package's __path__, and sys.path_hooks (described below) are consulted when traversing a package's __path__.

A package's __init__.py file may set or alter the package's __path__ attribute, and this was typically the way namespace packages were implemented prior to PEP 420. With the adoption of PEP 420, namespace packages no longer need to supply __init__.py files containing only __path__ manipulation code; the import machinery automatically sets __path__ correctly for the namespace package.

5.4.6. Module reprs

By default, all modules have a usable repr, however depending on the attributes set above, and in the module’s spec, you can more explicitly control the repr of module objects.

If the module has a spec (__spec__), the import machinery will try to generate a repr from it. If that fails or there is no spec, the import system will craft a default repr using whatever information is available on the module. It will try to use the module.__name__, module.__file__, and module.__loader__ as input into the repr, with defaults for whatever information is missing.

Here are the exact rules used:

- If the module has a __spec__ attribute, the information in the spec is used to generate the repr. The “name”, “loader”, “origin”, and “has_location” attributes are consulted.
- If the module has a __file__ attribute, this is used as part
of the module's repr.

- If the module has no __file__ but does have a __loader__ that is not None, then the loader's repr is used as part of the module's repr.
- Otherwise, just use the module's __name__ in the repr.

Changed in version 3.4: Use of loader.module_repr() has been deprecated and the module spec is now used by the import machinery to generate a module repr.

For backward compatibility with Python 3.3, the module repr will be generated by calling the loader's module_repr() method, if defined, before trying either approach described above. However, the method is deprecated.
5.5. The Path Based Finder

As mentioned previously, Python comes with several default meta path finders. One of these, called the path based finder (*PathFinder*), searches an import path, which contains a list of path entries. Each path entry names a location to search for modules.

The path based finder itself doesn't know how to import anything. Instead, it traverses the individual path entries, associating each of them with a path entry finder that knows how to handle that particular kind of path.

The default set of path entry finders implement all the semantics for finding modules on the file system, handling special file types such as Python source code (.py files), Python byte code (.pyc files) and shared libraries (e.g. .so files). When supported by the *zipimport* module in the standard library, the default path entry finders also handle loading all of these file types (other than shared libraries) from zipfiles.

Path entries need not be limited to file system locations. They can refer to URLs, database queries, or any other location that can be specified as a string.

The path based finder provides additional hooks and protocols so that you can extend and customize the types of searchable path entries. For example, if you wanted to support path entries as network URLs, you could write a hook that implements HTTP semantics to find modules on the web. This hook (a callable) would return a path entry finder supporting the protocol described below, which was then used to get a loader for the module from the web.
A word of warning: this section and the previous both use the term finder, distinguishing between them by using the terms meta path finder and path entry finder. These two types of finders are very similar, support similar protocols, and function in similar ways during the import process, but it's important to keep in mind that they are subtly different. In particular, meta path finders operate at the beginning of the import process, as keyed off the sys.meta_path traversal.

By contrast, path entry finders are in a sense an implementation detail of the path based finder, and in fact, if the path based finder were to be removed from sys.meta_path, none of the path entry finder semantics would be invoked.

5.5.1. Path entry finders

The path based finder is responsible for finding and loading Python modules and packages whose location is specified with a string path entry. Most path entries name locations in the file system, but they need not be limited to this.

As a meta path finder, the path based finder implements the find_spec() protocol previously described, however it exposes additional hooks that can be used to customize how modules are found and loaded from the import path.

Three variables are used by the path based finder, sys.path, sys.path_hooks and sys.path_importer_cache. The __path__ attributes on package objects are also used. These provide additional ways that the import machinery can be customized.

sys.path contains a list of strings providing search locations for
modules and packages. It is initialized from the PYTHONPATH environment variable and various other installation- and implementation-specific defaults. Entries in `sys.path` can name directories on the file system, zip files, and potentially other “locations” (see the `site` module) that should be searched for modules, such as URLs, or database queries. Only strings and bytes should be present on `sys.path`; all other data types are ignored. The encoding of bytes entries is determined by the individual path entry finders.

The path based finder is a meta path finder, so the import machinery begins the import path search by calling the path based finder’s `find_spec()` method as described previously. When the path argument to `find_spec()` is given, it will be a list of string paths to traverse - typically a package’s `__path__` attribute for an import within that package. If the path argument is None, this indicates a top level import and `sys.path` is used.

The path based finder iterates over every entry in the search path, and for each of these, looks for an appropriate path entry finder (PathEntryFinder) for the path entry. Because this can be an expensive operation (e.g. there may be `stat()` call overheads for this search), the path based finder maintains a cache mapping path entries to path entry finders. This cache is maintained in `sys.path_importer_cache` (despite the name, this cache actually stores finder objects rather than being limited to importer objects). In this way, the expensive search for a particular path entry location’s path entry finder need only be done once. User code is free to remove cache entries from `sys.path_importer_cache` forcing the path based finder to perform the path entry search again [3].

If the path entry is not present in the cache, the path based finder iterates over every callable in `sys.path_hooks`. Each of the path
**entry hooks** in this list is called with a single argument, the path entry
to be searched. This callable may either return a path entry finder
can handle the path entry, or it may raise ImportError. An
ImportError is used by the path based finder to signal that the hook
cannot find a path entry finder. for that path entry. The exception is
ignored and import path iteration continues. The hook should expect
either a string or bytes object; the encoding of bytes objects is up to
the hook (e.g. it may be a file system encoding, UTF-8, or something
else), and if the hook cannot decode the argument, it should raise
ImportError.

If sys.path_hooks iteration ends with no path entry finder being
returned, then the path based finder’s find_spec() method will store
None in sys.path_importer_cache (to indicate that there is no
finder for this path entry) and return None, indicating that this meta
path finder could not find the module.

If a path entry finder is returned by one of the path entry hook
callables on sys.path_hooks, then the following protocol is used to ask the
finder for a module spec, which is then used when loading the module.

The current working directory – denoted by an empty string – is
handled slightly differently from other entries on sys.path. First, if the
current working directory is found to not exist, no value is stored in
sys.path_importer_cache. Second, the value for the current
working directory is looked up fresh for each module lookup. Third, the
path used for sys.path_importer_cache and returned by
importlib.machinery.PathFinder.find_spec() will be the
actual current working directory and not the empty string.

5.5.2. Path entry finder protocol
In order to support imports of modules and initialized packages and also to contribute portions to namespace packages, path entry finders must implement the `find_spec()` method.

`find_spec()` takes two arguments, the fully qualified name of the module being imported, and the (optional) target module. `find_spec()` returns a fully populated spec for the module. This spec will always have “loader” set (with one exception).

To indicate to the import machinery that the spec represents a namespace portion, the path entry finder sets “loader” on the spec to None and “submodule_search_locations” to a list containing the portion.

*Changed in version 3.4:* `find_spec()` replaced `find_loader()` and `find_module()`, both of which are now deprecated, but will be used if `find_spec()` is not defined.

Older path entry finders may implement one of these two deprecated methods instead of `find_spec()`. The methods are still respected for the sake of backward compatibility. However, if `find_spec()` is implemented on the path entry finder, the legacy methods are ignored.

`find_loader()` takes one argument, the fully qualified name of the module being imported. `find_loader()` returns a 2-tuple where the first item is the loader and the second item is a namespace portion. When the first item (i.e. the loader) is None, this means that while the path entry finder does not have a loader for the named module, it knows that the path entry contributes to a namespace portion for the named module. This will almost always be the case where Python is asked to import a namespace package that has no physical presence on the file system. When a path entry finder returns None for the
loader, the second item of the 2-tuple return value must be a sequence, although it can be empty.

If `find_loader()` returns a non-None loader value, the portion is ignored and the loader is returned from the path based finder, terminating the search through the path entries.

For backwards compatibility with other implementations of the import protocol, many path entry finders also support the same, traditional `find_module()` method that meta path finders support. However path entry finder `find_module()` methods are never called with a path argument (they are expected to record the appropriate path information from the initial call to the path hook).

The `find_module()` method on path entry finders is deprecated, as it does not allow the path entry finder to contribute portions to namespace packages. If both `find_loader()` and `find_module()` exist on a path entry finder, the import system will always call `find_loader()` in preference to `find_module()`.
5.6. Replacing the standard import system

The most reliable mechanism for replacing the entire import system is to delete the default contents of `sys.meta_path`, replacing them entirely with a custom meta path hook.

If it is acceptable to only alter the behaviour of import statements without affecting other APIs that access the import system, then replacing the builtin `__import__()` function may be sufficient. This technique may also be employed at the module level to only alter the behaviour of import statements within that module.

To selectively prevent import of some modules from a hook early on the meta path (rather than disabling the standard import system entirely), it is sufficient to raise `ImportError` directly from `find_spec()` instead of returning None. The latter indicates that the meta path search should continue, while raising an exception terminates it immediately.
5.7. Special considerations for __main__

The __main__ module is a special case relative to Python’s import system. As noted elsewhere, the __main__ module is directly initialized at interpreter startup, much like sys and builtins. However, unlike those two, it doesn’t strictly qualify as a built-in module. This is because the manner in which __main__ is initialized depends on the flags and other options with which the interpreter is invoked.

5.7.1. __main__.__spec__

Depending on how __main__ is initialized, __main__.__spec__ gets set appropriately or to None.

When Python is started with the -m option, __spec__ is set to the module spec of the corresponding module or package. __spec__ is also populated when the __main__ module is loaded as part of executing a directory, zipfile or other sys.path entry.

In the remaining cases __main__.__spec__ is set to None, as the code used to populate the __main__ does not correspond directly with an importable module:

- interactive prompt
- -c switch
- running from stdin
- running directly from a source or bytecode file

Note that __main__.__spec__ is always None in the last case, even if the file could technically be imported directly as a module instead.
Use the `-m` switch if valid module metadata is desired in `__main__`.

Note also that even when `__main__` corresponds with an importable module and `__main__.__spec__` is set accordingly, they're still considered *distinct* modules. This is due to the fact that blocks guarded by `if __name__ == "__main__"`: checks only execute when the module is used to populate the `__main__` namespace, and not during normal import.
5.8. Open issues

XXX It would be really nice to have a diagram.

XXX * (import_machinery.rst) how about a section devoted just to the attributes of modules and packages, perhaps expanding upon or supplanting the related entries in the data model reference page?

XXX runpy, pkgutil, et al in the library manual should all get “See Also” links at the top pointing to the new import system section.

XXX Add more explanation regarding the different ways in which __main__ is initialized?

XXX Add more info on __main__ quirks/pitfalls (i.e. copy from PEP 395).
5.9. References

The import machinery has evolved considerably since Python’s early days. The original specification for packages is still available to read, although some details have changed since the writing of that document.

The original specification for `sys.meta_path` was **PEP 302**, with subsequent extension in **PEP 420**.

**PEP 420** introduced namespace packages for Python 3.3. **PEP 420** also introduced the `find_loader()` protocol as an alternative to `find_module()`.

**PEP 366** describes the addition of the `__package__` attribute for explicit relative imports in main modules.

**PEP 328** introduced absolute and explicit relative imports and initially proposed `__name__` for semantics **PEP 366** would eventually specify for `__package__`.

**PEP 338** defines executing modules as scripts.

**PEP 451** adds the encapsulation of per-module import state in spec objects. It also off-loads most of the boilerplate responsibilities of loaders back onto the import machinery. These changes allow the deprecation of several APIs in the import system and also addition of new methods to finders and loaders.

Footnotes

The importlib implementation avoids using the return value directly. Instead, it gets the module object by looking the module name up in `sys.modules`. The indirect effect of this is that an imported module may replace itself in `sys.modules`. This is implementation-specific behavior that is not guaranteed to work in other Python implementations.

In legacy code, it is possible to find instances of `imp.NullImporter` in the `sys.path_importer_cache`. It is recommended that code be changed to use `None` instead. See Porting Python code for more details.
6. Expressions

This chapter explains the meaning of the elements of expressions in Python.

**Syntax Notes:** In this and the following chapters, extended BNF notation will be used to describe syntax, not lexical analysis. When (one alternative of) a syntax rule has the form

```
name ::= othername
```

and no semantics are given, the semantics of this form of name are the same as for othername.
6.1. Arithmetic conversions

When a description of an arithmetic operator below uses the phrase “the numeric arguments are converted to a common type,” this means that the operator implementation for built-in types works as follows:

- If either argument is a complex number, the other is converted to complex;
- otherwise, if either argument is a floating point number, the other is converted to floating point;
- otherwise, both must be integers and no conversion is necessary.

Some additional rules apply for certain operators (e.g., a string as a left argument to the ‘%’ operator). Extensions must define their own conversion behavior.
6.2. Atoms

Atoms are the most basic elements of expressions. The simplest atoms are identifiers or literals. Forms enclosed in parentheses, brackets or braces are also categorized syntactically as atoms. The syntax for atoms is:

\[
\begin{align*}
atom & ::= \text{identifier} \mid \text{literal} \mid \text{enclosure} \\
enclosure & ::= \text{parenth\_form} \mid \text{list\_display} \mid \text{dict\_display} \\
& \quad \mid \text{generator\_expression} \mid \text{yield\_atom}
\end{align*}
\]

6.2.1. Identifiers (Names)

An identifier occurring as an atom is a name. See section Identifiers and keywords for lexical definition and section Naming and binding for documentation of naming and binding.

When the name is bound to an object, evaluation of the atom yields that object. When a name is not bound, an attempt to evaluate it raises a NameError exception.

**Private name mangling:** When an identifier that textually occurs in a class definition begins with two or more underscore characters and does not end in two or more underscores, it is considered a private name of that class. Private names are transformed to a longer form before code is generated for them. The transformation inserts the class name, with leading underscores removed and a single underscore inserted, in front of the name. For example, the identifier __spam occurring in a class named Ham will be transformed to _Ham__spam. This transformation is independent of the syntactical context in which the identifier is used. If the transformed name is
extremely long (longer than 255 characters), implementation defined truncation may happen. If the class name consists only of underscores, no transformation is done.

6.2.2. Literals

Python supports string and bytes literals and various numeric literals:

\[
\text{literal ::= stringliteral | bytesliteral | integer | floatnumber | imagnumber}
\]

Evaluation of a literal yields an object of the given type (string, bytes, integer, floating point number, complex number) with the given value. The value may be approximated in the case of floating point and imaginary (complex) literals. See section Literals for details.

All literals correspond to immutable data types, and hence the object’s identity is less important than its value. Multiple evaluations of literals with the same value (either the same occurrence in the program text or a different occurrence) may obtain the same object or a different object with the same value.

6.2.3. Parenthesized forms

A parenthesized form is an optional expression list enclosed in parentheses:

\[
\text{parenth_form ::= "(" [expression_list] ")"}
\]

A parenthesized expression list yields whatever that expression list yields: if the list contains at least one comma, it yields a tuple; otherwise, it yields the single expression that makes up the expression
list.

An empty pair of parentheses yields an empty tuple object. Since tuples are immutable, the rules for literals apply (i.e., two occurrences of the empty tuple may or may not yield the same object).

Note that tuples are not formed by the parentheses, but rather by use of the comma operator. The exception is the empty tuple, for which parentheses are required — allowing unparenthesized “nothing” in expressions would cause ambiguities and allow common typos to pass uncaught.

6.2.4. Displays for lists, sets and dictionaries

For constructing a list, a set or a dictionary Python provides special syntax called “displays”, each of them in two flavors:

- either the container contents are listed explicitly, or
- they are computed via a set of looping and filtering instructions, called a comprehension.

Common syntax elements for comprehensions are:

```
comprehension ::= expression comp_for
comp_for ::= "for" target_list "in" or_test [comp_iter]
comp_iter ::= comp_for | comp_if
comp_if ::= "if" expression_nocond [comp_iter]
```

The comprehension consists of a single expression followed by at least one for clause and zero or more for or if clauses. In this case, the elements of the new container are those that would be produced by considering each of the for or if clauses a block, nesting from left to right, and evaluating the expression to produce an
element each time the innermost block is reached.

Note that the comprehension is executed in a separate scope, so names assigned to in the target list don’t “leak” into the enclosing scope.

6.2.5. List displays

A list display is a possibly empty series of expressions enclosed in square brackets:

```
list_display ::= "[" [expression_list | comprehension] "]"
```

A list display yields a new list object, the contents being specified by either a list of expressions or a comprehension. When a comma-separated list of expressions is supplied, its elements are evaluated from left to right and placed into the list object in that order. When a comprehension is supplied, the list is constructed from the elements resulting from the comprehension.

6.2.6. Set displays

A set display is denoted by curly braces and distinguishable from dictionary displays by the lack of colons separating keys and values:

```
set_display ::= 
"{" (expression_list | comprehension)
```

A set display yields a new mutable set object, the contents being specified by either a sequence of expressions or a comprehension. When a comma-separated list of expressions is supplied, its elements are evaluated from left to right and added to the set object. When a
comprehension is supplied, the set is constructed from the elements resulting from the comprehension.

An empty set cannot be constructed with \{\}; this literal constructs an empty dictionary.

6.2.7. Dictionary displays

A dictionary display is a possibly empty series of key/datum pairs enclosed in curly braces:

```
dict_display ::= "{" [key_datum_list | dict_comprehension] |
key_datum_list ::= key_datum ("," key_datum)* [
key_datum ::= expression ":" expression |
dict_comprehension ::= expression ":" expression comp_for
```

A dictionary display yields a new dictionary object.

If a comma-separated sequence of key/datum pairs is given, they are evaluated from left to right to define the entries of the dictionary: each key object is used as a key into the dictionary to store the corresponding datum. This means that you can specify the same key multiple times in the key/datum list, and the final dictionary's value for that key will be the last one given.

A dict comprehension, in contrast to list and set comprehensions, needs two expressions separated with a colon followed by the usual “for” and “if” clauses. When the comprehension is run, the resulting key and value elements are inserted in the new dictionary in the order they are produced.

Restrictions on the types of the key values are listed earlier in section The standard type hierarchy. (To summarize, the key type should be
hashable, which excludes all mutable objects.) Clashes between duplicate keys are not detected; the last datum (textually rightmost in the display) stored for a given key value prevails.

6.2.8. Generator expressions

A generator expression is a compact generator notation in parentheses:

```
generator_expression ::= "(" expression comp_for ")"
```

A generator expression yields a new generator object. Its syntax is the same as for comprehensions, except that it is enclosed in parentheses instead of brackets or curly braces.

Variables used in the generator expression are evaluated lazily when the `__next__()` method is called for the generator object (in the same fashion as normal generators). However, the leftmost `for` clause is immediately evaluated, so that an error produced by it can be seen before any other possible error in the code that handles the generator expression. Subsequent `for` clauses cannot be evaluated immediately since they may depend on the previous `for` loop. For example: `(x*y for x in range(10) for y in bar(x))`.

The parentheses can be omitted on calls with only one argument. See section Calls for details.

6.2.9. Yield expressions

```
yield_atom ::= "(" yield_expression ")"
yield_expression ::= "yield" [expression_list | "from"
```

References

- Section Calls for details.
The yield expression is only used when defining a generator function and thus can only be used in the body of a function definition. Using a yield expression in a function's body causes that function to be a generator.

When a generator function is called, it returns an iterator known as a generator. That generator then controls the execution of the generator function. The execution starts when one of the generator’s methods is called. At that time, the execution proceeds to the first yield expression, where it is suspended again, returning the value of expression_list to the generator’s caller. By suspended, we mean that all local state is retained, including the current bindings of local variables, the instruction pointer, the internal evaluation stack, and the state of any exception handling. When the execution is resumed by calling one of the generator’s methods, the function can proceed exactly as if the yield expression were just another external call. The value of the yield expression after resuming depends on the method which resumed the execution. If __next__() is used (typically via either a for or the next() builtin) then the result is None. Otherwise, if send() is used, then the result will be the value passed in to that method.

All of this makes generator functions quite similar to coroutines; they yield multiple times, they have more than one entry point and their execution can be suspended. The only difference is that a generator function cannot control where the execution should continue after it yields; the control is always transferred to the generator’s caller.

Yield expressions are allowed anywhere in a try construct. If the generator is not resumed before it is finalized (by reaching a zero reference count or by being garbage collected), the generator-
iterator’s `close()` method will be called, allowing any pending `finally` clauses to execute.

When `yield from <expr>` is used, it treats the supplied expression as a subiterator. All values produced by that subiterator are passed directly to the caller of the current generator’s methods. Any values passed in with `send()` and any exceptions passed in with `throw()` are passed to the underlying iterator if it has the appropriate methods. If this is not the case, then `send()` will raise `AttributeError` or `TypeError`, while `throw()` will just raise the passed in exception immediately.

When the underlying iterator is complete, the value attribute of the raised `StopIteration` instance becomes the value of the yield expression. It can be either set explicitly when raising `StopIteration`, or automatically when the sub-iterator is a generator (by returning a value from the sub-generator).

`Changed in version 3.3:` Added `yield from <expr>` to delegate control flow to a subiterator.

The parentheses may be omitted when the yield expression is the sole expression on the right hand side of an assignment statement.

**See also:**

**PEP 0255 - Simple Generators**

The proposal for adding generators and the `yield` statement to Python.

**PEP 0342 - Coroutines via Enhanced Generators**

The proposal to enhance the API and syntax of generators, making them usable as simple coroutines.
**PEP 0380 - Syntax for Delegating to a Subgenerator**

The proposal to introduce the `yield_from` syntax, making delegation to sub-generators easy.

### 6.2.9.1. Generator-iterator methods

This subsection describes the methods of a generator iterator. They can be used to control the execution of a generator function.

Note that calling any of the generator methods below when the generator is already executing raises a `ValueError` exception.

**`generator.__next__()`**

Starts the execution of a generator function or resumes it at the last executed yield expression. When a generator function is resumed with a `__next__()` method, the current yield expression always evaluates to `None`. The execution then continues to the next yield expression, where the generator is suspended again, and the value of the `expression_list` is returned to `__next__()`'s caller. If the generator exits without yielding another value, a `StopIteration` exception is raised.

This method is normally called implicitly, e.g. by a `for` loop, or by the built-in `next()` function.

**`generator.send(value)`**

Resumes the execution and “sends” a value into the generator function. The `value` argument becomes the result of the current yield expression. The `send()` method returns the next value yielded by the generator, or raises `StopIteration` if the generator exits without yielding another value. When `send()` is called to start the generator, it must be called with `None` as the
argument, because there is no yield expression that could receive the value.

generator.*\texttt{\textbf{throw}(type[, value[, traceback]])}\textnormal{)*}

Raises an exception of type type at the point where the generator was paused, and returns the next value yielded by the generator function. If the generator exits without yielding another value, a StopIteration exception is raised. If the generator function does not catch the passed-in exception, or raises a different exception, then that exception propagates to the caller.

generator.*\texttt{\textbf{close}()}\textnormal{)*}

 Raises a GeneratorExit at the point where the generator function was paused. If the generator function then exits gracefully, is already closed, or raises GeneratorExit (by not catching the exception), close returns to its caller. If the generator yields a value, a RuntimeError is raised. If the generator raises any other exception, it is propagated to the caller. close() does nothing if the generator has already exited due to an exception or normal exit.

6.2.9.2. Examples

Here is a simple example that demonstrates the behavior of generators and generator functions:

```python
>>> def echo(value=\texttt{None}):
...     print("Execution starts when 'next()' is called.
...     try:
...         while True:
...             try:
...                 value = (yield value)
...             except Exception as e:
```

```
...  
...    finally:
...      print("Don't forget to clean up when 'close()'
...  
>>> generator = echo(1)
>>> print(next(generator))
Execution starts when 'next()' is called for the first time.
1
>>> print(next(generator))
None
>>> print(generator.send(2))
2
>>> generator.throw(TypeError, "spam")
TypeError('spam',)
>>> generator.close()
Don't forget to clean up when 'close()' is called.

For examples using yield from, see PEP 380: Syntax for Delegating to a Subgenerator in “What’s New in Python.”
6.3. Primaries

Primaries represent the most tightly bound operations of the language. Their syntax is:

\[
\text{primary} ::= \text{atom} \mid \text{attributeref} \mid \text{subscription} \mid \text{slicing}
\]

6.3.1. Attribute references

An attribute reference is a primary followed by a period and a name:

\[
\text{attributeref} ::= \text{primary} \ \text{"."} \ \text{identifier}
\]

The primary must evaluate to an object of a type that supports attribute references, which most objects do. This object is then asked to produce the attribute whose name is the identifier. This production can be customized by overriding the \text{__getattr__}() method. If this attribute is not available, the exception \text{AttributeError} is raised. Otherwise, the type and value of the object produced is determined by the object. Multiple evaluations of the same attribute reference may yield different objects.

6.3.2. Subscriptions

A subscription selects an item of a sequence (string, tuple or list) or mapping (dictionary) object:

\[
\text{subscription} ::= \text{primary} \ \text{"["} \ \text{expression_list} \ \text{"]"}
\]

The primary must evaluate to an object that supports subscription (lists
or dictionaries for example). User-defined objects can support subscription by defining a \texttt{\_\_getitem\_()} method.

For built-in objects, there are two types of objects that support subscription:

If the primary is a mapping, the expression list must evaluate to an object whose value is one of the keys of the mapping, and the subscription selects the value in the mapping that corresponds to that key. (The expression list is a tuple except if it has exactly one item.)

If the primary is a sequence, the expression (list) must evaluate to an integer or a slice (as discussed in the following section).

The formal syntax makes no special provision for negative indices in sequences; however, built-in sequences all provide a \texttt{\_\_getitem\_()} method that interprets negative indices by adding the length of the sequence to the index (so that \texttt{x[-1]} selects the last item of \texttt{x}). The resulting value must be a nonnegative integer less than the number of items in the sequence, and the subscription selects the item whose index is that value (counting from zero). Since the support for negative indices and slicing occurs in the object’s \texttt{\_\_getitem\_()} method, subclasses overriding this method will need to explicitly add that support.

A string’s items are characters. A character is not a separate data type but a string of exactly one character.

6.3.3. Slicings

A slicing selects a range of items in a sequence object (e.g., a string, tuple or list). Slicings may be used as expressions or as targets in
assignment or `del` statements. The syntax for a slicing:

```
slicing ::= primary "[" slice_list "]"
slice_list ::= slice_item ("," slice_item)* [","]
slice_item ::= expression | proper_slice
proper_slice ::= [lower_bound] ":" [upper_bound] [lower_bound ::= expression
upper_bound ::= expression
stride ::= expression
```

There is ambiguity in the formal syntax here: anything that looks like an expression list also looks like a slice list, so any subscription can be interpreted as a slicing. Rather than further complicating the syntax, this is disambiguated by defining that in this case the interpretation as a subscription takes priority over the interpretation as a slicing (this is the case if the slice list contains no proper slice).

The semantics for a slicing are as follows. The primary is indexed (using the same `__getitem__()` method as normal subscription) with a key that is constructed from the slice list, as follows. If the slice list contains at least one comma, the key is a tuple containing the conversion of the slice items; otherwise, the conversion of the lone slice item is the key. The conversion of a slice item that is an expression is that expression. The conversion of a proper slice is a slice object (see section The standard type hierarchy) whose start, stop and step attributes are the values of the expressions given as lower bound, upper bound and stride, respectively, substituting `None` for missing expressions.

### 6.3.4. Calls

A call calls a callable object (e.g., a `function`) with a possibly empty
A series of arguments:

```plaintext
call ::= primary "(" [argument_list]
argument_list ::= positional_arguments ["", 
               ["", "**" expression] ["", 
               ["", "***" expression]
               | keyword_arguments ["", " 
               ["", keyword_arguments]
               | "**" expression ["", keyword_ 
               | "***" expression

positional_arguments ::= expression ["", expression
keyword_arguments ::= keyword_item ["", keyword_ 
keyword_item ::= identifier "=" expression
```

An optional trailing comma may be present after the positional and keyword arguments but does not affect the semantics.

The primary must evaluate to a callable object (user-defined functions, built-in functions, methods of built-in objects, class objects, methods of class instances, and all objects having a `__call__()` method are callable). All argument expressions are evaluated before the call is attempted. Please refer to section Function definitions for the syntax of formal parameter lists.

If keyword arguments are present, they are first converted to positional arguments, as follows. First, a list of unfilled slots is created for the formal parameters. If there are N positional arguments, they are placed in the first N slots. Next, for each keyword argument, the identifier is used to determine the corresponding slot (if the identifier is the same as the first formal parameter name, the first slot is used, and so on). If the slot is already filled, a `TypeError` exception is raised. Otherwise, the value of the argument is placed in the slot, filling it (even if the expression is None, it fills the slot). When all arguments
have been processed, the slots that are still unfilled are filled with the corresponding default value from the function definition. (Default values are calculated, once, when the function is defined; thus, a mutable object such as a list or dictionary used as default value will be shared by all calls that don’t specify an argument value for the corresponding slot; this should usually be avoided.) If there are any unfilled slots for which no default value is specified, a `TypeError` exception is raised. Otherwise, the list of filled slots is used as the argument list for the call.

**CPython implementation detail:** An implementation may provide built-in functions whose positional parameters do not have names, even if they are ‘named' for the purpose of documentation, and which therefore cannot be supplied by keyword. In CPython, this is the case for functions implemented in C that use `PyArg_ParseTuple()` to parse their arguments.

If there are more positional arguments than there are formal parameter slots, a `TypeError` exception is raised, unless a formal parameter using the syntax `*identifier` is present; in this case, that formal parameter receives a tuple containing the excess positional arguments (or an empty tuple if there were no excess positional arguments).

If any keyword argument does not correspond to a formal parameter name, a `TypeError` exception is raised, unless a formal parameter using the syntax `**identifier` is present; in this case, that formal parameter receives a dictionary containing the excess keyword arguments (using the keywords as keys and the argument values as corresponding values), or a (new) empty dictionary if there were no excess keyword arguments.

If the syntax `*expression` appears in the function call, expression
must evaluate to an iterable. Elements from this iterable are treated as if they were additional positional arguments; if there are positional arguments \(x_1, \ldots, x_N\), and expression evaluates to a sequence \(y_1, \ldots, y_M\), this is equivalent to a call with \(M+N\) positional arguments \(x_1, \ldots, x_N, y_1, \ldots, y_M\).

A consequence of this is that although the \(*expression\) syntax may appear \textit{after} some keyword arguments, it is processed \textit{before} the keyword arguments (and the **expression argument, if any – see below). So:

```python
>>> def f(a, b):
...    print(a, b)
...
>>> f(b=1, *(2,))
2 1
>>> f(a=1, *(2,))
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: f() got multiple values for keyword argument 'a'
>>> f(1, *(2,))
1 2
```

It is unusual for both keyword arguments and the \(*expression\) syntax to be used in the same call, so in practice this confusion does not arise.

If the syntax **expression appears in the function call, expression must evaluate to a mapping, the contents of which are treated as additional keyword arguments. In the case of a keyword appearing in both expression and as an explicit keyword argument, a \texttt{TypeError} exception is raised.
Formal parameters using the syntax `*identifier` or `**identifier` cannot be used as positional argument slots or as keyword argument names.

A call always returns some value, possibly `None`, unless it raises an exception. How this value is computed depends on the type of the callable object.

If it is—

a user-defined function:
   The code block for the function is executed, passing it the argument list. The first thing the code block will do is bind the formal parameters to the arguments; this is described in section Function definitions. When the code block executes a `return` statement, this specifies the return value of the function call.

a built-in function or method:
   The result is up to the interpreter; see Built-in Functions for the descriptions of built-in functions and methods.

a class object:
   A new instance of that class is returned.

a class instance method:
   The corresponding user-defined function is called, with an argument list that is one longer than the argument list of the call: the instance becomes the first argument.

a class instance:
   The class must define a `__call__()` method; the effect is then the same as if that method was called.
6.4. Await expression

Suspend the execution of coroutine on an awaitable object. Can only be used inside a coroutine function.

```
await ::= ["await"] primary
```

New in version 3.5.
6.5. The power operator

The power operator binds more tightly than unary operators on its left; it binds less tightly than unary operators on its right. The syntax is:

```
power ::= await "**" u_expr
```

Thus, in an unparenthesized sequence of power and unary operators, the operators are evaluated from right to left (this does not constrain the evaluation order for the operands): 

- `1**2` results in `-1`.

The power operator has the same semantics as the built-in `pow()` function, when called with two arguments: it yields its left argument raised to the power of its right argument. The numeric arguments are first converted to a common type, and the result is of that type.

For `int` operands, the result has the same type as the operands unless the second argument is negative; in that case, all arguments are converted to `float` and a `float` result is delivered. For example, `10**2` returns `100`, but `10**-2` returns `0.01`.

Raising `0.0` to a negative power results in a `ZeroDivisionError`. Raising a negative number to a fractional power results in a `complex` number. (In earlier versions it raised a `ValueError`.)
6.6. Unary arithmetic and bitwise operations

All unary arithmetic and bitwise operations have the same priority:

\[
\text{u_expr ::= power | "-" u_expr | "+" u_expr | "~" u_expr}
\]

The unary - (minus) operator yields the negation of its numeric argument.

The unary + (plus) operator yields its numeric argument unchanged.

The unary ~ (invert) operator yields the bitwise inversion of its integer argument. The bitwise inversion of \( x \) is defined as \( -(x+1) \). It only applies to integral numbers.

In all three cases, if the argument does not have the proper type, a \texttt{TypeError} exception is raised.
6.7. Binary arithmetic operations

The binary arithmetic operations have the conventional priority levels. Note that some of these operations also apply to certain non-numeric types. Apart from the power operator, there are only two levels, one for multiplicative operators and one for additive operators:

```
m_expr ::= u_expr | m_expr "*" u_expr | m_expr "@"
m_expr "//" u_expr | m_expr "/" u_expr | 
m_expr "%" u_expr
a_expr ::= m_expr | a_expr "+" m_expr | a_expr "-"
```

The * (multiplication) operator yields the product of its arguments. The arguments must either both be numbers, or one argument must be an integer and the other must be a sequence. In the former case, the numbers are converted to a common type and then multiplied together. In the latter case, sequence repetition is performed; a negative repetition factor yields an empty sequence.

The @ (at) operator is intended to be used for matrix multiplication. No builtin Python types implement this operator.

*New in version 3.5.*

The / (division) and // (floor division) operators yield the quotient of their arguments. The numeric arguments are first converted to a common type. Division of integers yields a float, while floor division of integers results in an integer; the result is that of mathematical division with the ‘floor’ function applied to the result. Division by zero raises the `ZeroDivisionError` exception.

The % (modulo) operator yields the remainder from the division of the
first argument by the second. The numeric arguments are first converted to a common type. A zero right argument raises the \texttt{ZeroDivisionError} exception. The arguments may be floating point numbers, e.g., 3.14\%0.7 equals 0.34 (since 3.14 equals 4*0.7 + 0.34.) The modulo operator always yields a result with the same sign as its second operand (or zero); the absolute value of the result is strictly smaller than the absolute value of the second operand \footnote{1}.

The floor division and modulo operators are connected by the following identity: \(x = (x//y)\cdot y + (x\%y)\). Floor division and modulo are also connected with the built-in function \texttt{divmod()}: \texttt{divmod(x, y) = (x//y, x\%y)}. \footnote{2}

In addition to performing the modulo operation on numbers, the \% operator is also overloaded by string objects to perform old-style string formatting (also known as interpolation). The syntax for string formatting is described in the Python Library Reference, section printf-style String Formatting.

The floor division operator, the modulo operator, and the \texttt{divmod()} function are not defined for complex numbers. Instead, convert to a floating point number using the \texttt{abs()} function if appropriate.

The + (addition) operator yields the sum of its arguments. The arguments must either both be numbers or both be sequences of the same type. In the former case, the numbers are converted to a common type and then added together. In the latter case, the sequences are concatenated.

The - (subtraction) operator yields the difference of its arguments. The numeric arguments are first converted to a common type.
6.8. Shifting operations

The shifting operations have lower priority than the arithmetic operations:

```
shift_expr ::= a_expr | shift_expr ( "<<" | ">>" )
```

These operators accept integers as arguments. They shift the first argument to the left or right by the number of bits given by the second argument.

A right shift by \( n \) bits is defined as floor division by \( \text{pow}(2, n) \). A left shift by \( n \) bits is defined as multiplication with \( \text{pow}(2, n) \).

**Note:** In the current implementation, the right-hand operand is required to be at most \( \text{sys.maxsize} \). If the right-hand operand is larger than \( \text{sys.maxsize} \) an \text{OverflowError} exception is raised.
6.9. Binary bitwise operations

Each of the three bitwise operations has a different priority level:

```
and_expr ::= shift_expr | and_expr "&" shift_expr
xor_expr ::= and_expr | xor_expr "^" and_expr
or_expr  ::= xor_expr | or_expr "|" xor_expr
```

The & operator yields the bitwise AND of its arguments, which must be integers.

The ^ operator yields the bitwise XOR (exclusive OR) of its arguments, which must be integers.

The | operator yields the bitwise (inclusive) OR of its arguments, which must be integers.
6.10. Comparisons

Unlike C, all comparison operations in Python have the same priority, which is lower than that of any arithmetic, shifting or bitwise operation. Also unlike C, expressions like $a < b < c$ have the interpretation that is conventional in mathematics:


comparison ::= or_expr ( comp_operator or_expr )
comp_operator ::= "<" | ">" | "==" | ">=" | "<=" |
| "is" ["not"] | ["not"] "in"

Comparisons yield boolean values: True or False.

Comparisons can be chained arbitrarily, e.g., $x < y <= z$ is equivalent to $x < y$ and $y <= z$, except that $y$ is evaluated only once (but in both cases $z$ is not evaluated at all when $x < y$ is found to be false).

Formally, if $a, b, c, ..., y, z$ are expressions and $op1, op2, ..., opN$ are comparison operators, then $a \ op1 \ b \ op2 \ c \ ... \ y \ opN \ z$ is equivalent to $a \ op1 \ b$ and $b \ op2 \ c$ and $... \ y \ opN \ z$, except that each expression is evaluated at most once.

Note that $a \ op1 \ b \ op2 \ c$ doesn’t imply any kind of comparison between $a$ and $c$, so that, e.g., $x < y > z$ is perfectly legal (though perhaps not pretty).

6.10.1. Value comparisons

The operators $<, >, ==, >=, <=, and !=$ compare the values of two objects. The objects do not need to have the same type.
Chapter **Objects, values and types** states that objects have a value (in addition to type and identity). The value of an object is a rather abstract notion in Python: For example, there is no canonical access method for an object’s value. Also, there is no requirement that the value of an object should be constructed in a particular way, e.g. comprised of all its data attributes. Comparison operators implement a particular notion of what the value of an object is. One can think of them as defining the value of an object indirectly, by means of their comparison implementation.

Because all types are (direct or indirect) subtypes of `object`, they inherit the default comparison behavior from `object`. Types can customize their comparison behavior by implementing *rich comparison methods* like `__lt__( )`, described in *Basic customization*.

The default behavior for equality comparison (`==` and `!=`) is based on the identity of the objects. Hence, equality comparison of instances with the same identity results in equality, and equality comparison of instances with different identities results in inequality. A motivation for this default behavior is the desire that all objects should be reflexive (i.e. `x is y` implies `x == y`).

A default order comparison (`<`, `>`, `<=`, and `>=`) is not provided; an attempt raises `TypeError`. A motivation for this default behavior is the lack of a similar invariant as for equality.

The behavior of the default equality comparison, that instances with different identities are always unequal, may be in contrast to what types will need that have a sensible definition of object value and value-based equality. Such types will need to customize their comparison behavior, and in fact, a number of built-in types have done that.
The following list describes the comparison behavior of the most important built-in types.

- Numbers of built-in numeric types (Numeric Types — int, float, complex) and of the standard library types fractions.Fraction and decimal.Decimal can be compared within and across their types, with the restriction that complex numbers do not support order comparison. Within the limits of the types involved, they compare mathematically (algorithmically) correct without loss of precision.

  The not-a-number values float('NaN') and Decimal('NaN') are special. They are identical to themselves (x is x is true) but are not equal to themselves (x == x is false). Additionally, comparing any number to a not-a-number value will return False. For example, both 3 < float('NaN') and float('NaN') < 3 will return False.

- Binary sequences (instances of bytes or bytearray) can be compared within and across their types. They compare lexicographically using the numeric values of their elements.

- Strings (instances of str) compare lexicographically using the numerical Unicode code points (the result of the built-in function ord()) of their characters. [3]

  Strings and binary sequences cannot be directly compared.

- Sequences (instances of tuple, list, or range) can be compared only within each of their types, with the restriction that ranges do not support order comparison. Equality comparison across these types results in unequality, and ordering comparison across these types raises TypeError.
Sequences compare lexicographically using comparison of corresponding elements, whereby reflexivity of the elements is enforced.

In enforcing reflexivity of elements, the comparison of collections assumes that for a collection element \( x \), \( x == x \) is always true. Based on that assumption, element identity is compared first, and element comparison is performed only for distinct elements. This approach yields the same result as a strict element comparison would, if the compared elements are reflexive. For non-reflexive elements, the result is different than for strict element comparison, and may be surprising: The non-reflexive not-a-number values for example result in the following comparison behavior when used in a list:

```python
>>> nan = float('NaN')
>>> nan is nan
True
>>> nan == nan
False
```

Lexicographical comparison between built-in collections works as follows:

- For two collections to compare equal, they must be of the same type, have the same length, and each pair of corresponding elements must compare equal (for example, \([1,2] == (1,2)\) is false because the type is not the same).
- Collections that support order comparison are ordered the
same as their first unequal elements (for example, [1, 2, x] <= [1, 2, y] has the same value as x <= y). If a corresponding element does not exist, the shorter collection is ordered first (for example, [1, 2] < [1, 2, 3] is true).

- Mappings (instances of `dict`) compare equal if and only if they have equal (key, value) pairs. Equality comparison of the keys and elements enforces reflexivity.

Order comparisons (<, >, <=, and >=) raise `TypeError`.

- Sets (instances of `set` or `frozenset`) can be compared within and across their types.

They define order comparison operators to mean subset and superset tests. Those relations do not define total orderings (for example, the two sets {1, 2} and {2, 3} are not equal, nor subsets of one another, nor supersets of one another). Accordingly, sets are not appropriate arguments for functions which depend on total ordering (for example, `min()`, `max()`, and `sorted()` produce undefined results given a list of sets as inputs).

Comparison of sets enforces reflexivity of its elements.

- Most other built-in types have no comparison methods implemented, so they inherit the default comparison behavior.

User-defined classes that customize their comparison behavior should follow some consistency rules, if possible:

- Equality comparison should be reflexive. In other words, identical objects should compare equal:

\[ x \text{ is } y \implies x == y \]
Comparison should be symmetric. In other words, the following expressions should have the same result:

\[
\begin{align*}
  x \ == \ y & \text{ and } y \ == \ x \\
  x \ != \ y & \text{ and } y \ != \ x \\
  x \ < \ y & \text{ and } y \ > \ x \\
  x \ <= \ y & \text{ and } y \ >= \ x
\end{align*}
\]

Comparison should be transitive. The following (non-exhaustive) examples illustrate that:

\[
\begin{align*}
  x \ > \ y & \text{ and } y \ > \ z \implies x \ > \ z \\
  x \ < \ y & \text{ and } y \ <= \ z \implies x \ < \ z
\end{align*}
\]

Inverse comparison should result in the boolean negation. In other words, the following expressions should have the same result:

\[
\begin{align*}
  x \ == \ y & \text{ and } \text{not } x \ != \ y \\
  x \ < \ y & \text{ and } \text{not } x \ >= \ y \quad \text{(for total ordering)} \\
  x \ > \ y & \text{ and } \text{not } x \ <= \ y \quad \text{(for total ordering)}
\end{align*}
\]

The last two expressions apply to totally ordered collections (e.g. to sequences, but not to sets or mappings). See also the `total_ordering()` decorator.

Python does not enforce these consistency rules. In fact, the not-a-number values are an example for not following these rules.
6.10.2. Membership test operations

The operators `in` and `not in` test for membership. `x in s` evaluates to true if `x` is a member of `s`, and false otherwise. `x not in s` returns the negation of `x in s`. All built-in sequences and set types support this as well as dictionary, for which `in` tests whether the dictionary has a given key. For container types such as list, tuple, set, frozenset, dict, or collections.deque, the expression `x in y` is equivalent to `any(x is e or x == e for e in y).

For the string and bytes types, `x in y` is true if and only if `x` is a substring of `y`. An equivalent test is `y.find(x) != -1`. Empty strings are always considered to be a substring of any other string, so "" in "abc" will return True.

For user-defined classes which define the `__contains__()` method, `x in y` is true if and only if `y.__contains__(x)` is true.

For user-defined classes which do not define `__contains__()` but do define `__iter__()`, `x in y` is true if some value `z` with `x == z` is produced while iterating over `y`. If an exception is raised during the iteration, it is as if `in` raised that exception.

Lastly, the old-style iteration protocol is tried: if a class defines `__getitem__()`, `x in y` is true if and only if there is a non-negative integer index `i` such that `x == y[i]`, and all lower integer indices do not raise `IndexError` exception. (If any other exception is raised, it is as if `in` raised that exception).

The operator `not in` is defined to have the inverse true value of `in`. 
6.10.3. Identity comparisons

The operators \texttt{is} and \texttt{is not} test for object identity: \texttt{x is y} is true if and only if \texttt{x} and \texttt{y} are the same object. \texttt{x is not y} yields the inverse truth value. [4]
6.11. Boolean operations

| or_test  ::=  and_test | or_test "or" and_test  |
| and_test ::=  not_test | and_test "and" not_test  |
| not_test ::=  comparison | "not" not_test  |

In the context of Boolean operations, and also when expressions are used by control flow statements, the following values are interpreted as false: False, None, numeric zero of all types, and empty strings and containers (including strings, tuples, lists, dictionaries, sets and frozensets). All other values are interpreted as true. User-defined objects can customize their truth value by providing a `__bool__()` method.

The operator `not` yields True if its argument is false, False otherwise.

The expression `x and y` first evaluates `x`; if `x` is false, its value is returned; otherwise, `y` is evaluated and the resulting value is returned.

The expression `x or y` first evaluates `x`; if `x` is true, its value is returned; otherwise, `y` is evaluated and the resulting value is returned.

(Note that neither `and` nor `or` restrict the value and type they return to False and True, but rather return the last evaluated argument. This is sometimes useful, e.g., if `s` is a string that should be replaced by a default value if it is empty, the expression `s or 'foo'` yields the desired value. Because `not` has to create a new value, it returns a boolean value regardless of the type of its argument (for example, not 'foo' produces False rather than '').)
Conditional expressions (sometimes called a “ternary operator”) have the lowest priority of all Python operations.

The expression \( x \text{ if } C \text{ else } y \) first evaluates the condition, \( C \) rather than \( x \). If \( C \) is true, \( x \) is evaluated and its value is returned; otherwise, \( y \) is evaluated and its value is returned.

See PEP 308 for more details about conditional expressions.
Lambda expressions (sometimes called lambda forms) are used to create anonymous functions. The expression `lambda` arguments: expression yields a function object. The unnamed object behaves like a function object defined with

```python
def <lambda>(arguments):
    return expression
```

See section Function definitions for the syntax of parameter lists. Note that functions created with lambda expressions cannot contain statements or annotations.
6.14. Expression lists

An expression list containing at least one comma yields a tuple. The length of the tuple is the number of expressions in the list. The expressions are evaluated from left to right.

The trailing comma is required only to create a single tuple (a.k.a. a singleton); it is optional in all other cases. A single expression without a trailing comma doesn't create a tuple, but rather yields the value of that expression. (To create an empty tuple, use an empty pair of parentheses: ( ).)
6.15. Evaluation order

Python evaluates expressions from left to right. Notice that while evaluating an assignment, the right-hand side is evaluated before the left-hand side.

In the following lines, expressions will be evaluated in the arithmetic order of their suffixes:

```
expr1, expr2, expr3, expr4
(expr1, expr2, expr3, expr4)
{expr1: expr2, expr3: expr4}
expr1 + expr2 * (expr3 - expr4)
expr1(expr2, expr3, *expr4, **expr5)
expr3, expr4 = expr1, expr2
```
6.16. Operator precedence

The following table summarizes the operator precedence in Python, from lowest precedence (least binding) to highest precedence (most binding). Operators in the same box have the same precedence. Unless the syntax is explicitly given, operators are binary. Operators in the same box group left to right (except for exponentiation, which groups from right to left).

Note that comparisons, membership tests, and identity tests, all have the same precedence and have a left-to-right chaining feature as described in the Comparisons section.

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<th>Description</th>
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<td>in, not in, is, is not, &lt;, &lt;=, &gt;, &gt;=, !=, ==</td>
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<td></td>
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<tr>
<td>----------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>*, @, /, //, %</td>
<td>multiplication division, remainder [5]</td>
</tr>
<tr>
<td>+x, -x, ~x</td>
<td>Positive, negative, bitwise NOT</td>
</tr>
<tr>
<td>**</td>
<td>Exponentiation [6]</td>
</tr>
<tr>
<td>await x</td>
<td>Await expression</td>
</tr>
<tr>
<td>x[index], x[index:index], x(arguments...), x.attribute</td>
<td>Subscription, slicing, call, attribute reference</td>
</tr>
<tr>
<td>(expressions...), [expressions...], {key: value...}, {expressions...}</td>
<td>Binding or tuple display, list display, dictionary display, set display</td>
</tr>
</tbody>
</table>

## Footnotes

**[1]** While $\text{abs}(x \% y) < \text{abs}(y)$ is true mathematically, for floats it may not be true numerically due to roundoff. For example, and assuming a platform on which a Python float is an IEEE 754 double-precision number, in order that $-1e-100 \% 1e100$ have the same sign as $1e100$, the computed result is $-1e-100 + 1e100$, which is numerically exactly equal to $1e100$. The function `math.fmod()` returns a result whose sign matches the sign of the first argument instead, and so returns $-1e-100$ in this case. Which approach is more appropriate depends on the application.

**[2]** If $x$ is very close to an exact integer multiple of $y$, it's possible for $x//y$ to be one larger than $(x-x\%y)//y$ due to rounding. In such cases, Python returns the latter result, in order to preserve that `divmod(x,y)[0] * y + x % y` be very close to $x$.

The Unicode standard distinguishes between code points (e.g. U+0041) and abstract characters (e.g. “LATIN CAPITAL LETTER A”). While most abstract characters in Unicode are
only represented using one code point, there is a number of abstract characters that can in addition be represented using a sequence of more than one code point. For example, the abstract character “LATIN CAPITAL LETTER C WITH CEDILLA” can be represented as a single precomposed character at code position U+00C7, or as a sequence of a base character at code position U+0043 (LATIN CAPITAL LETTER C), followed by a combining character at code position U+0327 (COMBINING CEDILLA).

The comparison operators on strings compare at the level of Unicode code points. This may be counter-intuitive to humans. For example, "\u00C7" == "\u0043\u0327" is False, even though both strings represent the same abstract character “LATIN CAPITAL LETTER C WITH CEDILLA”.

To compare strings at the level of abstract characters (that is, in a way intuitive to humans), use `unicodedata.normalize()`.

Due to automatic garbage-collection, free lists, and the dynamic nature of descriptors, you may notice seemingly unusual behaviour in certain uses of the `is` operator, like those involving comparisons between instance methods, or constants. Check their documentation for more info.

The `%` operator is also used for string formatting; the same precedence applies.

The power operator `**` binds less tightly than an arithmetic or bitwise unary operator on its right, that is, `2**-1` is `0.5`. 
7. Simple statements

A simple statement is comprised within a single logical line. Several simple statements may occur on a single line separated by semicolons. The syntax for simple statements is:

```
simple_stmt ::= expression_stmt
              | assert_stmt
              | assignment_stmt
              | augmented_assignment_stmt
              | pass_stmt
              | del_stmt
              | return_stmt
              | yield_stmt
              | raise_stmt
              | break_stmt
              | continue_stmt
              | import_stmt
              | global_stmt
              | nonlocal_stmt
```
7.1. Expression statements

Expression statements are used (mostly interactively) to compute and write a value, or (usually) to call a procedure (a function that returns no meaningful result; in Python, procedures return the value None). Other uses of expression statements are allowed and occasionally useful. The syntax for an expression statement is:

```
expression_stmt ::= expression_list
```

An expression statement evaluates the expression list (which may be a single expression).

In interactive mode, if the value is not None, it is converted to a string using the built-in `repr()` function and the resulting string is written to standard output on a line by itself (except if the result is None, so that procedure calls do not cause any output.)
7.2. Assignment statements

Assignment statements are used to (re)bind names to values and to modify attributes or items of mutable objects:

```
assignment_stmt ::= (target_list "=")+ (expression_list 

| target_list ::= target ("," target)* ["","
| target ::= identifier
| "(" target_list ")"
| "[" target_list "]"
| attributeref
| subscription
| slicing
| "*" target
```

(See section Primaries for the syntax definitions for attributeref, subscription, and slicing.)

An assignment statement evaluates the expression list (remember that this can be a single expression or a comma-separated list, the latter yielding a tuple) and assigns the single resulting object to each of the target lists, from left to right.

Assignment is defined recursively depending on the form of the target (list). When a target is part of a mutable object (an attribute reference, subscription or slicing), the mutable object must ultimately perform the assignment and decide about its validity, and may raise an exception if the assignment is unacceptable. The rules observed by various types and the exceptions raised are given with the definition of the object types (see section The standard type hierarchy).

Assignment of an object to a target list, optionally enclosed in parentheses or square brackets, is recursively defined as follows.
• If the target list is a single target: The object is assigned to that target.
• If the target list is a comma-separated list of targets: The object must be an iterable with the same number of items as there are targets in the target list, and the items are assigned, from left to right, to the corresponding targets.
  • If the target list contains one target prefixed with an asterisk, called a “starred” target: The object must be a sequence with at least as many items as there are targets in the target list, minus one. The first items of the sequence are assigned, from left to right, to the targets before the starred target. The final items of the sequence are assigned to the targets after the starred target. A list of the remaining items in the sequence is then assigned to the starred target (the list can be empty).
  • Else: The object must be a sequence with the same number of items as there are targets in the target list, and the items are assigned, from left to right, to the corresponding targets.

Assignment of an object to a single target is recursively defined as follows.

• If the target is an identifier (name):
  • If the name does not occur in a global or nonlocal statement in the current code block: the name is bound to the object in the current local namespace.
  • Otherwise: the name is bound to the object in the global namespace or the outer namespace determined by nonlocal, respectively.

The name is rebound if it was already bound. This may cause the reference count for the object previously bound to the name to reach zero, causing the object to be deallocated and its destructor
(if it has one) to be called.

- If the target is a target list enclosed in parentheses or in square brackets: The object must be an iterable with the same number of items as there are targets in the target list, and its items are assigned, from left to right, to the corresponding targets.

- If the target is an attribute reference: The primary expression in the reference is evaluated. It should yield an object with assignable attributes; if this is not the case, `TypeError` is raised. That object is then asked to assign the assigned object to the given attribute; if it cannot perform the assignment, it raises an exception (usually but not necessarily `AttributeError`).

Note: If the object is a class instance and the attribute reference occurs on both sides of the assignment operator, the RHS expression, `a.x` can access either an instance attribute or (if no instance attribute exists) a class attribute. The LHS target `a.x` is always set as an instance attribute, creating it if necessary. Thus, the two occurrences of `a.x` do not necessarily refer to the same attribute: if the RHS expression refers to a class attribute, the LHS creates a new instance attribute as the target of the assignment:

```python
class Cls:
    x = 3  # class variable
inst = Cls()
inst.x = inst.x + 1  # writes inst.x as 4 leaving Cls.x as 3
```

This description does not necessarily apply to descriptor attributes, such as properties created with `property()`.

- If the target is a subscription: The primary expression in the reference is evaluated. It should yield either a mutable sequence
object (such as a list) or a mapping object (such as a dictionary). Next, the subscript expression is evaluated.

If the primary is a mutable sequence object (such as a list), the subscript must yield an integer. If it is negative, the sequence's length is added to it. The resulting value must be a nonnegative integer less than the sequence's length, and the sequence is asked to assign the assigned object to its item with that index. If the index is out of range, IndexError is raised (assignment to a subscripted sequence cannot add new items to a list).

If the primary is a mapping object (such as a dictionary), the subscript must have a type compatible with the mapping’s key type, and the mapping is then asked to create a key/datum pair which maps the subscript to the assigned object. This can either replace an existing key/value pair with the same key value, or insert a new key/value pair (if no key with the same value existed).

For user-defined objects, the __setitem__() method is called with appropriate arguments.

- If the target is a slicing: The primary expression in the reference is evaluated. It should yield a mutable sequence object (such as a list). The assigned object should be a sequence object of the same type. Next, the lower and upper bound expressions are evaluated, insofar they are present; defaults are zero and the sequence's length. The bounds should evaluate to integers. If either bound is negative, the sequence's length is added to it. The resulting bounds are clipped to lie between zero and the sequence's length, inclusive. Finally, the sequence object is asked to replace the slice with the items of the assigned sequence. The length of the slice may be different from the length of the assigned
sequence, thus changing the length of the target sequence, if the target sequence allows it.

**CPython implementation detail:** In the current implementation, the syntax for targets is taken to be the same as for expressions, and invalid syntax is rejected during the code generation phase, causing less detailed error messages.

Although the definition of assignment implies that overlaps between the left-hand side and the right-hand side are ‘simultaneous’ (for example \( a, b = b, a \) swaps two variables), overlaps within the collection of assigned-to variables occur left-to-right, sometimes resulting in confusion. For instance, the following program prints \([0, 2]\):

```python
x = [0, 1]
i = 0
i, x[i] = 1, 2  # i is updated, then x[i] is updated
print(x)
```

**See also:**

**PEP 3132 - Extended Iterable Unpacking**

The specification for the *target* feature.

### 7.2.1. Augmented assignment statements

Augmented assignment is the combination, in a single statement, of a binary operation and an assignment statement:

```python
augmented_assignment_stmt ::= augtarget augop (expr)
augtarget ::= identifier | attribut
```
An augmented assignment evaluates the target (which, unlike normal assignment statements, cannot be an unpacking) and the expression list, performs the binary operation specific to the type of assignment on the two operands, and assigns the result to the original target. The target is only evaluated once.

An augmented assignment expression like \( x += 1 \) can be rewritten as \( x = x + 1 \) to achieve a similar, but not exactly equal effect. In the augmented version, \( x \) is only evaluated once. Also, when possible, the actual operation is performed \textit{in-place}, meaning that rather than creating a new object and assigning that to the target, the old object is modified instead.

Unlike normal assignments, augmented assignments evaluate the left-hand side \textit{before} evaluating the right-hand side. For example, \( a[i] += f(x) \) first looks-up \( a[i] \), then it evaluates \( f(x) \) and performs the addition, and lastly, it writes the result back to \( a[i] \).

With the exception of assigning to tuples and multiple targets in a single statement, the assignment done by augmented assignment statements is handled the same way as normal assignments. Similarly, with the exception of the possible \textit{in-place} behavior, the binary operation performed by augmented assignment is the same as the normal binary operations.

For targets which are attribute references, the same \textit{caveat about}
class and instance attributes applies as for regular assignments.
7.3. The `assert` statement

Assert statements are a convenient way to insert debugging assertions into a program:

```
assert_stmt ::= "assert" expression ["," expression]
```

The simple form, `assert expression`, is equivalent to

```
if __debug__:
    if not expression: raise AssertionError
```

The extended form, `assert expression1, expression2`, is equivalent to

```
if __debug__:
    if not expression1: raise AssertionError(expression2)
```

These equivalences assume that `__debug__` and `AssertionError` refer to the built-in variables with those names. In the current implementation, the built-in variable `__debug__` is True under normal circumstances, False when optimization is requested (command line option `-O`). The current code generator emits no code for an assert statement when optimization is requested at compile time. Note that it is unnecessary to include the source code for the expression that failed in the error message; it will be displayed as part of the stack trace.

Assignments to `__debug__` are illegal. The value for the built-in variable is determined when the interpreter starts.
7.4. The **pass** statement

```
pass_stmt ::= "pass"
```

`pass` is a null operation — when it is executed, nothing happens. It is useful as a placeholder when a statement is required syntactically, but no code needs to be executed, for example:

```
def f(arg): pass  # a function that does nothing (yet)
class C: pass     # a class with no methods (yet)
```
7.5. The **del** statement

```
```

Deletion is recursively defined very similar to the way assignment is defined. Rather than spelling it out in full details, here are some hints.

Deletion of a target list recursively deletes each target, from left to right.

Deletion of a name removes the binding of that name from the local or global namespace, depending on whether the name occurs in a `global` statement in the same code block. If the name is unbound, a `NameError` exception will be raised.

Deletion of attribute references, subscriptions and slicings is passed to the primary object involved; deletion of a slicing is in general equivalent to assignment of an empty slice of the right type (but even this is determined by the sliced object).

*Changed in version 3.2:* Previously it was illegal to delete a name from the local namespace if it occurs as a free variable in a nested block.
7.6. The `return` statement

```
return_stmt ::= "return" [expression_list]
```

The `return` statement may only occur syntactically nested in a function definition, not within a nested class definition.

If an expression list is present, it is evaluated, else `None` is substituted.

`return` leaves the current function call with the expression list (or `None`) as return value.

When `return` passes control out of a `try` statement with a `finally` clause, that `finally` clause is executed before really leaving the function.

In a generator function, the `return` statement indicates that the generator is done and will cause `StopIteration` to be raised. The returned value (if any) is used as an argument to construct `StopIteration` and becomes the `StopIteration.value` attribute.
7.7. The `yield` statement

```
yield_stmt ::= yield_expression
```

A `yield` statement is semantically equivalent to a `yield expression`. The yield statement can be used to omit the parentheses that would otherwise be required in the equivalent yield expression statement. For example, the yield statements

```
yield <expr>
yield from <expr>
```

are equivalent to the yield expression statements

```
(yield <expr>)
(yield from <expr>)
```

Yield expressions and statements are only used when defining a `generator` function, and are only used in the body of the generator function. Using yield in a function definition is sufficient to cause that definition to create a generator function instead of a normal function.

For full details of `yield` semantics, refer to the Yield expressions section.
7.8. The `raise` statement

```plaintext
raise_stmt ::= "raise" [expression ["from" expression]]
```

If no expressions are present, `raise` re-raises the last exception that was active in the current scope. If no exception is active in the current scope, a `RuntimeError` exception is raised indicating that this is an error.

Otherwise, `raise` evaluates the first expression as the exception object. It must be either a subclass or an instance of `BaseException`. If it is a class, the exception instance will be obtained when needed by instantiating the class with no arguments.

The type of the exception is the exception instance’s class, the value is the instance itself.

A traceback object is normally created automatically when an exception is raised and attached to it as the `__traceback__` attribute, which is writable. You can create an exception and set your own traceback in one step using the `with_traceback()` exception method (which returns the same exception instance, with its traceback set to its argument), like so:

```plaintext
raise Exception("foo occurred").with_traceback(tracebackobj)
```

The from clause is used for exception chaining: if given, the second `expression` must be another exception class or instance, which will then be attached to the raised exception as the `__cause__` attribute (which is writable). If the raised exception is not handled, both
exceptions will be printed:

```python
>>> try:
...     print(1 / 0)
... except Exception as exc:
...     raise RuntimeError("Something bad happened")
...
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
ZeroDivisionError: int division or modulo by zero
```

The above exception was the direct cause of the following exception:

```python
Traceback (most recent call last):
  File "<stdin>", line 4, in <module>
RuntimeError: Something bad happened
```

A similar mechanism works implicitly if an exception is raised inside an exception handler or a `finally` clause: the previous exception is then attached as the new exception's `__context__` attribute:

```python
>>> try:
...     print(1 / 0)
... except:
...     raise RuntimeError("Something bad happened")
...
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
ZeroDivisionError: int division or modulo by zero
```

During handling of the above exception, another exception occurred:

```python
Traceback (most recent call last):
  File "<stdin>", line 4, in <module>
RuntimeError: Something bad happened
```
Additional information on exceptions can be found in section Exceptions, and information about handling exceptions is in section The try statement.
7.9. The **break** statement

```
break_stmt ::= "break"
```

**break** may only occur syntactically nested in a **for** or **while** loop, but not nested in a function or class definition within that loop.

It terminates the nearest enclosing loop, skipping the optional **else** clause if the loop has one.

If a **for** loop is terminated by **break**, the loop control target keeps its current value.

When **break** passes control out of a **try** statement with a **finally** clause, that **finally** clause is executed before really leaving the loop.
7.10. The **continue** statement

```plaintext
continue_stmt ::= "continue"
```

**continue** may only occur syntactically nested in a **for** or **while** loop, but not nested in a function or class definition or **finally** clause within that loop. It continues with the next cycle of the nearest enclosing loop.

When **continue** passes control out of a **try** statement with a **finally** clause, that **finally** clause is executed before really starting the next loop cycle.
7.11. The *import* statement

The basic import statement (no *from* clause) is executed in two steps:

1. find a module, loading and initializing it if necessary
2. define a name or names in the local namespace for the scope where the *import* statement occurs.

When the statement contains multiple clauses (separated by commas) the two steps are carried out separately for each clause, just as though the clauses had been separated out into individual import statements.

The details of the first step, finding and loading modules are described in greater detail in the section on the *import system*, which also describes the various types of packages and modules that can be imported, as well as all the hooks that can be used to customize the import system. Note that failures in this step may indicate either that the module could not be located, or that an error occurred while initializing the module, which includes execution of the module's code.

If the requested module is retrieved successfully, it will be made available in the local namespace in one of three ways:
If the module name is followed by `as`, then the name following `as` is bound directly to the imported module.

If no other name is specified, and the module being imported is a top level module, the module’s name is bound in the local namespace as a reference to the imported module.

If the module being imported is not a top level module, then the name of the top level package that contains the module is bound in the local namespace as a reference to the top level package. The imported module must be accessed using its full qualified name rather than directly.

The `from` form uses a slightly more complex process:

1. find the module specified in the `from` clause, loading and initializing it if necessary;
2. for each of the identifiers specified in the `import` clauses:
   1. check if the imported module has an attribute by that name
   2. if not, attempt to import a submodule with that name and then check the imported module again for that attribute
   3. if the attribute is not found, `ImportError` is raised.
   4. otherwise, a reference to that value is stored in the local namespace, using the name in the `as` clause if it is present, otherwise using the attribute name

Examples:

```
import foo  # foo imported and bound locally
import foo.bar.baz  # foo.bar.baz imported, foo bound locally
import foo.bar.baz as fbb  # foo.bar.baz imported and bound as fbb
from foo.bar import baz  # foo.bar.baz imported and baz bound
from foo import attr  # foo imported and foo.attr bound as attr
```

If the list of identifiers is replaced by a star (`'*'`), all public names
defined in the module are bound in the local namespace for the scope where the `import` statement occurs.

The *public names* defined by a module are determined by checking the module’s namespace for a variable named `__all__`; if defined, it must be a sequence of strings which are names defined or imported by that module. The names given in `__all__` are all considered public and are required to exist. If `__all__` is not defined, the set of public names includes all names found in the module’s namespace which do not begin with an underscore character (`'_'`). `__all__` should contain the entire public API. It is intended to avoid accidentally exporting items that are not part of the API (such as library modules which were imported and used within the module).

The wild card form of import — `from module import *` — is only allowed at the module level. Attempting to use it in class or function definitions will raise a `SyntaxError`.

When specifying what module to import you do not have to specify the absolute name of the module. When a module or package is contained within another package it is possible to make a relative import within the same top package without having to mention the package name. By using leading dots in the specified module or package after `from` you can specify how high to traverse up the current package hierarchy without specifying exact names. One leading dot means the current package where the module making the import exists. Two dots means up one package level. Three dots is up two levels, etc. So if you execute `from . import mod` from a module in the `pkg` package then you will end up importing `pkg.mod`. If you execute `from ..subpkg2 import mod` from within `pkg.subpkg1` you will import `pkg.subpkg2.mod`. The specification for relative imports is contained within PEP 328.
`importlib.import_module()` is provided to support applications that determine dynamically the modules to be loaded.

### 7.11.1. Future statements

A *future statement* is a directive to the compiler that a particular module should be compiled using syntax or semantics that will be available in a specified future release of Python where the feature becomes standard.

The future statement is intended to ease migration to future versions of Python that introduce incompatible changes to the language. It allows use of the new features on a per-module basis before the release in which the feature becomes standard.

```
future_statement ::= "from" "__future__" "import" f ("," feature ["as" name])* | "from" "__future__" "import" ("," feature ["as" name])* [,
feature ::= identifier
name ::= identifier
```

A future statement must appear near the top of the module. The only lines that can appear before a future statement are:

- the module docstring (if any),
- comments,
- blank lines, and
- other future statements.

The features recognized by Python 3.0 are `absolute_import`, `division`, `generators`, `unicode_literals`, `print_function`, `nested_scopes` and `with_statement`. They are all redundant
because they are always enabled, and only kept for backwards compatibility.

A future statement is recognized and treated specially at compile time: Changes to the semantics of core constructs are often implemented by generating different code. It may even be the case that a new feature introduces new incompatible syntax (such as a new reserved word), in which case the compiler may need to parse the module differently. Such decisions cannot be pushed off until runtime.

For any given release, the compiler knows which feature names have been defined, and raises a compile-time error if a future statement contains a feature not known to it.

The direct runtime semantics are the same as for any import statement: there is a standard module `__future__`, described later, and it will be imported in the usual way at the time the future statement is executed.

The interesting runtime semantics depend on the specific feature enabled by the future statement.

Note that there is nothing special about the statement:

```
import __future__ [as name]
```

That is not a future statement; it’s an ordinary import statement with no special semantics or syntax restrictions.

Code compiled by calls to the built-in functions `exec()` and `compile()` that occur in a module `M` containing a future statement will, by default, use the new syntax or semantics associated with the future statement. This can be controlled by optional arguments to
compile() — see the documentation of that function for details.

A future statement typed at an interactive interpreter prompt will take effect for the rest of the interpreter session. If an interpreter is started with the `-i` option, is passed a script name to execute, and the script includes a future statement, it will be in effect in the interactive session started after the script is executed.

**See also:**

**PEP 236 - Back to the `__future__`**

The original proposal for the `__future__` mechanism.
7.12. The **global** statement

\[
\text{global_stmt ::= "global" identifier ("," identifier) }
\]

The **global** statement is a declaration which holds for the entire current code block. It means that the listed identifiers are to be interpreted as globals. It would be impossible to assign to a global variable without **global**, although free variables may refer to globals without being declared global.

Names listed in a **global** statement must not be used in the same code block textually preceding that **global** statement.

Names listed in a **global** statement must not be defined as formal parameters or in a **for** loop control target, **class** definition, function definition, or **import** statement.

**CPython implementation detail:** The current implementation does not enforce the two restrictions, but programs should not abuse this freedom, as future implementations may enforce them or silently change the meaning of the program.

**Programmer’s note:** the **global** is a directive to the parser. It applies only to code parsed at the same time as the **global** statement. In particular, a **global** statement contained in a string or code object supplied to the built-in **exec()** function does not affect the code block containing the function call, and code contained in such a string is unaffected by **global** statements in the code containing the function call. The same applies to the **eval()** and **compile()** functions.
7.13. The nonlocal statement

```
nonlocal_stmt ::= "nonlocal" identifier ("," identifier)*
```

The `nonlocal` statement causes the listed identifiers to refer to previously bound variables in the nearest enclosing scope excluding globals. This is important because the default behavior for binding is to search the local namespace first. The statement allows encapsulated code to rebind variables outside of the local scope besides the global (module) scope.

Names listed in a `nonlocal` statement, unlike those listed in a `global` statement, must refer to pre-existing bindings in an enclosing scope (the scope in which a new binding should be created cannot be determined unambiguously).

Names listed in a `nonlocal` statement must not collide with pre-existing bindings in the local scope.

See also:

**PEP 3104 - Access to Names in Outer Scopes**

The specification for the `nonlocal` statement.
8. Compound statements

Compound statements contain (groups of) other statements; they affect or control the execution of those other statements in some way. In general, compound statements span multiple lines, although in simple incarnations a whole compound statement may be contained in one line.

The `if`, `while` and `for` statements implement traditional control flow constructs. `try` specifies exception handlers and/or cleanup code for a group of statements, while the `with` statement allows the execution of initialization and finalization code around a block of code. Function and class definitions are also syntactically compound statements.

A compound statement consists of one or more ‘clauses.’ A clause consists of a header and a ‘suite.’ The clause headers of a particular compound statement are all at the same indentation level. Each clause header begins with a uniquely identifying keyword and ends with a colon. A suite is a group of statements controlled by a clause. A suite can be one or more semicolon-separated simple statements on the same line as the header, following the header’s colon, or it can be one or more indented statements on subsequent lines. Only the latter form of a suite can contain nested compound statements; the following is illegal, mostly because it wouldn’t be clear to which `if` clause a following `else` clause would belong:

```plaintext
if test1: if test2: print(x)
```

Also note that the semicolon binds tighter than the colon in this context, so that in the following example, either all or none of the `print()` calls are executed:
```python
if x < y < z: print(x); print(y); print(z)
```

Summarizing:

<table>
<thead>
<tr>
<th><code>compound_stmt</code> ::=</th>
<th><code>if_stmt</code></th>
</tr>
</thead>
<tbody>
<tr>
<td><code>while_stmt</code></td>
<td></td>
</tr>
<tr>
<td><code>for_stmt</code></td>
<td></td>
</tr>
<tr>
<td><code>try_stmt</code></td>
<td></td>
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<td><code>with_stmt</code></td>
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<tr>
<td><code>funcdef</code></td>
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<td><code>classdef</code></td>
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<tr>
<td><code>async_with_stmt</code></td>
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<tr>
<td><code>async_for_stmt</code></td>
<td></td>
</tr>
<tr>
<td><code>async_funcdef</code></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><code>suite</code> ::=</th>
<th><code>stmt_list</code> NEWLINE</th>
<th>NEWLINE INDENT</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><code>statement</code> ::=</th>
<th><code>stmt_list</code> NEWLINE</th>
<th><code>compound_stmt</code></th>
</tr>
</thead>
</table>

| `stmt_list` ::= | `simple_stmt` (";" `simple_stmt`)* |

Note that statements always end in a NEWLINE possibly followed by a DEDENT. Also note that optional continuation clauses always begin with a keyword that cannot start a statement, thus there are no ambiguities (the ‘dangling else‘ problem is solved in Python by requiring nested `if` statements to be indented).

The formatting of the grammar rules in the following sections places each clause on a separate line for clarity.
8.1. The **if** statement

The **if** statement is used for conditional execution:

```plaintext
if_stmt ::= "if" expression ":" suite
             ( "elif" expression ":" suite )*
             ["else" ":" suite]
```

It selects exactly one of the suites by evaluating the expressions one by one until one is found to be true (see section Boolean operations for the definition of true and false); then that suite is executed (and no other part of the **if** statement is executed or evaluated). If all expressions are false, the suite of the **else** clause, if present, is executed.
8.2. The while statement

The while statement is used for repeated execution as long as an expression is true:

```
while_stmt ::= "while" expression "::" suite
              ["else" "::" suite]
```

This repeatedly tests the expression and, if it is true, executes the first suite; if the expression is false (which may be the first time it is tested) the suite of the else clause, if present, is executed and the loop terminates.

A break statement executed in the first suite terminates the loop without executing the else clause's suite. A continue statement executed in the first suite skips the rest of the suite and goes back to testing the expression.
8.3. The **for** statement

The **for** statement is used to iterate over the elements of a sequence (such as a string, tuple or list) or other iterable object:

```
for_stmt ::=  "for"  target_list  "in"  expression_list
             ["else"  "":"  suite]
```

The expression list is evaluated once; it should yield an iterable object. An iterator is created for the result of the expression_list. The suite is then executed once for each item provided by the iterator, in the order returned by the iterator. Each item in turn is assigned to the target list using the standard rules for assignments (see Assignment statements), and then the suite is executed. When the items are exhausted (which is immediately when the sequence is empty or an iterator raises a **StopIteration** exception), the suite in the **else** clause, if present, is executed, and the loop terminates.

A **break** statement executed in the first suite terminates the loop without executing the **else** clause’s suite. A **continue** statement executed in the first suite skips the rest of the suite and continues with the next item, or with the **else** clause if there is no next item.

The for-loop makes assignments to the variables(s) in the target list. This overwrites all previous assignments to those variables including those made in the suite of the for-loop:

```
for  i  in  range(10):
    print(i)
    i = 5
        # this will not affect the for
        # because i will be overwritten
        # index in the range
```
Names in the target list are not deleted when the loop is finished, but if the sequence is empty, they will not have been assigned to at all by the loop. Hint: the built-in function `range()` returns an iterator of integers suitable to emulate the effect of Pascal's `for i := a to b do;` e.g., `list(range(3))` returns the list `[0, 1, 2]`.

**Note:** There is a subtlety when the sequence is being modified by the loop (this can only occur for mutable sequences, i.e., lists). An internal counter is used to keep track of which item is used next, and this is incremented on each iteration. When this counter has reached the length of the sequence the loop terminates. This means that if the suite deletes the current (or a previous) item from the sequence, the next item will be skipped (since it gets the index of the current item which has already been treated). Likewise, if the suite inserts an item in the sequence before the current item, the current item will be treated again the next time through the loop. This can lead to nasty bugs that can be avoided by making a temporary copy using a slice of the whole sequence, e.g.,

```python
for x in a[:]:
    if x < 0: a.remove(x)
```
8.4. The **try** statement

The **try** statement specifies exception handlers and/or cleanup code for a group of statements:

```
try_stmt ::= try1_stmt | try2_stmt
try1_stmt ::= "try" ":" suite
              ("except" [expression ["as" identifier]
                      ["else" ":" suite]
                      ["finally" ":" suite]
            try2_stmt ::= "try" ":" suite
                      "finally" ":" suite
```

The **except** clause(s) specify one or more exception handlers. When no exception occurs in the **try** clause, no exception handler is executed. When an exception occurs in the **try** suite, a search for an exception handler is started. This search inspects the except clauses in turn until one is found that matches the exception. An expression-less except clause, if present, must be last; it matches any exception. For an except clause with an expression, that expression is evaluated, and the clause matches the exception if the resulting object is “compatible” with the exception. An object is compatible with an exception if it is the class or a base class of the exception object or a tuple containing an item compatible with the exception.

If no except clause matches the exception, the search for an exception handler continues in the surrounding code and on the invocation stack. [1]

If the evaluation of an expression in the header of an except clause raises an exception, the original search for a handler is canceled and a search starts for the new exception in the surrounding code and on the
call stack (it is treated as if the entire `try` statement raised the exception).

When a matching except clause is found, the exception is assigned to the target specified after the `as` keyword in that except clause, if present, and the except clause's suite is executed. All except clauses must have an executable block. When the end of this block is reached, execution continues normally after the entire try statement. (This means that if two nested handlers exist for the same exception, and the exception occurs in the try clause of the inner handler, the outer handler will not handle the exception.)

When an exception has been assigned using `as target`, it is cleared at the end of the except clause. This is as if

```python
except E as N:
    foo
```

was translated to

```python
except E as N:
    try:
        foo
    finally:
        del N
```

This means the exception must be assigned to a different name to be able to refer to it after the except clause. Exceptions are cleared because with the traceback attached to them, they form a reference cycle with the stack frame, keeping all locals in that frame alive until the next garbage collection occurs.

Before an except clause’s suite is executed, details about the exception are stored in the `sys` module and can be accessed via
The `sys.exc_info()` function returns a 3-tuple consisting of the exception class, the exception instance and a traceback object (see section The standard type hierarchy) identifying the point in the program where the exception occurred. `sys.exc_info()` values are restored to their previous values (before the call) when returning from a function that handled an exception.

The optional `else` clause is executed if and when control flows off the end of the `try` clause. [2] Exceptions in the `else` clause are not handled by the preceding `except` clauses.

If `finally` is present, it specifies a ‘cleanup’ handler. The `try` clause is executed, including any `except` and `else` clauses. If an exception occurs in any of the clauses and is not handled, the exception is temporarily saved. The `finally` clause is executed. If there is a saved exception it is re-raised at the end of the `finally` clause. If the `finally` clause raises another exception, the saved exception is set as the context of the new exception. If the `finally` clause executes a `return` or `break` statement, the saved exception is discarded:

```python
>>> def f():
...    try:
...        1/0
...    finally:
...        return 42
...>
>>> f()
42
```

The exception information is not available to the program during execution of the `finally` clause.

When a `return`, `break` or `continue` statement is executed in the
try suite of a try...finally statement, the finally clause is also executed ‘on the way out.’ A continue statement is illegal in the finally clause. (The reason is a problem with the current implementation — this restriction may be lifted in the future).

The return value of a function is determined by the last return statement executed. Since the finally clause always executes, a return statement executed in the finally clause will always be the last one executed:

```python
>>> def foo():
...     try:
...         return 'try'
...     finally:
...         return 'finally'
...
>>> foo()
'finally'
```

Additional information on exceptions can be found in section Exceptions, and information on using the raise statement to generate exceptions may be found in section The raise statement.
8.5. The **with** statement

The **with** statement is used to wrap the execution of a block with methods defined by a context manager (see section With Statement Context Managers). This allows common `try...except...finally` usage patterns to be encapsulated for convenient reuse.

```python
going to
```

The execution of the **with** statement with one “item” proceeds as follows:

1. The context expression (the expression given in the `with_item`) is evaluated to obtain a context manager.

2. The context manager’s `__exit__()` is loaded for later use.

3. The context manager’s `__enter__()` method is invoked.

4. If a target was included in the **with** statement, the return value from `__enter__()` is assigned to it.

   **Note:** The **with** statement guarantees that if the `__enter__()` method returns without an error, then `__exit__()` will always be called. Thus, if an error occurs during the assignment to the target list, it will be treated the same as an error occurring within the suite would be. See step 6 below.

5. The suite is executed.
6. The context manager’s `__exit__() method is invoked. If an exception caused the suite to be exited, its type, value, and traceback are passed as arguments to `__exit__()`. Otherwise, three `None` arguments are supplied.

If the suite was exited due to an exception, and the return value from the `__exit__()` method was false, the exception is reraised. If the return value was true, the exception is suppressed, and execution continues with the statement following the `with` statement.

If the suite was exited for any reason other than an exception, the return value from `__exit__()` is ignored, and execution proceeds at the normal location for the kind of exit that was taken.

With more than one item, the context managers are processed as if multiple `with` statements were nested:

```python
with A() as a, B() as b:
    suite
```

is equivalent to

```python
with A() as a:
    with B() as b:
        suite
```

Changed in version 3.1: Support for multiple context expressions.

See also:

**PEP 0343 - The “with” statement**

The specification, background, and examples for the Python
with statement.
8.6. Function definitions

A function definition defines a user-defined function object (see section The standard type hierarchy):

```
funcdef ::= [decorators] "def" funcname "(" parameter_list "")"
decorators ::= decorator+
decorator ::= "@" dotted_name ["(" [parameter_list dotted_name ::= identifier ("." identifier)*
parameter_list ::= (defparameter ",")* | ")" [parameter] ("," defparameter | "**" parameter | "***" parameter defparameter ::= parameter ["=" expression]
funcname ::= identifier
```

A function definition is an executable statement. Its execution binds the function name in the current local namespace to a function object (a wrapper around the executable code for the function). This function object contains a reference to the current global namespace as the global namespace to be used when the function is called.

The function definition does not execute the function body; this gets executed only when the function is called. [3]

A function definition may be wrapped by one or more decorator expressions. Decorator expressions are evaluated when the function is defined, in the scope that contains the function definition. The result must be a callable, which is invoked with the function object as the only argument. The returned value is bound to the function name instead of the function object. Multiple decorators are applied in nested fashion. For example, the following code
is equivalent to

```
def func(): pass
func = f1(arg)(f2(func))
```

When one or more parameters have the form parameter = expression, the function is said to have “default parameter values.” For a parameter with a default value, the corresponding argument may be omitted from a call, in which case the parameter’s default value is substituted. If a parameter has a default value, all following parameters up until the “*” must also have a default value — this is a syntactic restriction that is not expressed by the grammar.

**Default parameter values are evaluated from left to right when the function definition is executed.** This means that the expression is evaluated once, when the function is defined, and that the same “pre-computed” value is used for each call. This is especially important to understand when a default parameter is a mutable object, such as a list or a dictionary: if the function modifies the object (e.g. by appending an item to a list), the default value is in effect modified. This is generally not what was intended. A way around this is to use None as the default, and explicitly test for it in the body of the function, e.g.:

```
def whats_on_the_telly(penguin=None):
    if penguin is None:
        penguin = []
penguin.append("property of the zoo")
return penguin
```
Function call semantics are described in more detail in section calls. A function call always assigns values to all parameters mentioned in the parameter list, either from position arguments, from keyword arguments, or from default values. If the form “*identifier” is present, it is initialized to a tuple receiving any excess positional parameters, defaulting to the empty tuple. If the form “**identifier” is present, it is initialized to a new dictionary receiving any excess keyword arguments, defaulting to a new empty dictionary. Parameters after “*” or “*identifier” are keyword-only parameters and may only be passed used keyword arguments.

Parameters may have annotations of the form “: expression” following the parameter name. Any parameter may have an annotation even those of the form *identifier or **identifier. Functions may have “return” annotation of the form “- > expression” after the parameter list. These annotations can be any valid Python expression and are evaluated when the function definition is executed. Annotations may be evaluated in a different order than they appear in the source code. The presence of annotations does not change the semantics of a function. The annotation values are available as values of a dictionary keyed by the parameters' names in the __annotations__ attribute of the function object.

It is also possible to create anonymous functions (functions not bound to a name), for immediate use in expressions. This uses lambda expressions, described in section Lambdas. Note that the lambda expression is merely a shorthand for a simplified function definition; a function defined in a “def” statement can be passed around or assigned to another name just like a function defined by a lambda expression. The “def” form is actually more powerful since it allows the execution of multiple statements and annotations.
**Programmer’s note:** Functions are first-class objects. A “def” statement executed inside a function definition defines a local function that can be returned or passed around. Free variables used in the nested function can access the local variables of the function containing the def. See section *Naming and binding* for details.

**See also:**

**PEP 3107 - Function Annotations**

The original specification for function annotations.
8.7. Class definitions

A class definition defines a class object (see section The standard type hierarchy):

```
classdef ::= [decorators] "class" classname [inheritance]
inheritance ::= "(" [parameter_list] ")"
classname ::= identifier
```

A class definition is an executable statement. The inheritance list usually gives a list of base classes (see Customizing class creation for more advanced uses), so each item in the list should evaluate to a class object which allows subclassing. Classes without an inheritance list inherit, by default, from the base class `object`; hence,

```
class Foo:
    pass
```

is equivalent to

```
class Foo(object):
    pass
```

The class's suite is then executed in a new execution frame (see Naming and binding), using a newly created local namespace and the original global namespace. (Usually, the suite contains mostly function definitions.) When the class's suite finishes execution, its execution frame is discarded but its local namespace is saved. [4] A class object is then created using the inheritance list for the base classes and the saved local namespace for the attribute dictionary. The class name is bound to this class object in the original local namespace.
Class creation can be customized heavily using metaclasses.

Classes can also be decorated: just like when decorating functions,

```python
@f1(arg)
@f2
class Foo: pass
```

is equivalent to

```python
class Foo: pass
Foo = f1(arg)(f2(Foo))
```

The evaluation rules for the decorator expressions are the same as for function decorators. The result must be a class object, which is then bound to the class name.

**Programmer’s note:** Variables defined in the class definition are class attributes; they are shared by instances. Instance attributes can be set in a method with `self.name = value`. Both class and instance attributes are accessible through the notation “`self.name`”, and an instance attribute hides a class attribute with the same name when accessed in this way. Class attributes can be used as defaults for instance attributes, but using mutable values there can lead to unexpected results. Descriptors can be used to create instance variables with different implementation details.

**See also:** PEP 3115 - Metaclasses in Python 3 PEP 3129 - Class Decorators
8.8. Coroutines

New in version 3.5.

8.8.1. Coroutine function definition

```python
async_funcdef ::= [decorators] "async" "def" funcname
```

Execution of Python coroutines can be suspended and resumed at many points (see coroutine). In the body of a coroutine, any await and async identifiers become reserved keywords; await expressions, `async for` and `async with` can only be used in coroutine bodies.

Functions defined with `async def` syntax are always coroutine functions, even if they do not contain `await` or `async` keywords.

It is a `SyntaxError` to use `yield` expressions in `async def` coroutines.

An example of a coroutine function:

```python
async def func(param1, param2):
    do_stuff()
    await some_coroutine()
```

8.8.2. The `async for` statement

```python
async_for_stmt ::= "async" for_stmt
```
An **asynchronous iterable** is able to call asynchronous code in its *iter* implementation, and **asynchronous iterator** can call asynchronous code in its *next* method.

The async for statement allows convenient iteration over asynchronous iterators.

The following code:

```python
async for TARGET in ITER:
    BLOCK
else:
    BLOCK2
```

Is semantically equivalent to:

```python
iter = (ITER)
iter = await type(iter).__aiter__(iter)
running = True
while running:
    try:
        TARGET = await type(iter).__anext__(iter)
    except StopAsyncIteration:
        running = False
    else:
        BLOCK
else:
    BLOCK2
```

See also **__aiter__()** and **__anext__()** for details.

It is a **SyntaxError** to use async for statement outside of an async def function.

**8.8.3. The async with statement**
async_with_stmt ::= "async" with_stmt

An asynchronous context manager is a context manager that is able to suspend execution in its enter and exit methods.

The following code:

```python
async with EXPR as VAR:
    BLOCK
```

Is semantically equivalent to:

```python
mgr = (EXPR)
aexit = type(mgr).__aexit__
aenter = type(mgr).__aenter__(mgr)
exc = True

VAR = await aenter
try:
    BLOCK
except:
    if not await aexit(mgr, *sys.exc_info()):
        raise
else:
    await aexit(mgr, None, None, None)
```

See also __aenter__() and __aexit__() for details.

It is a SyntaxError to use async with statement outside of an async def function.

See also: PEP 492 - Coroutines with async and await syntax
Footnotes

[1] The exception is propagated to the invocation stack unless there is a `finally` clause which happens to raise another exception. That new exception causes the old one to be lost.

Currently, control “flows off the end” except in the case of an exception or the execution of a `return`, `continue`, or `break` statement.

[3] A string literal appearing as the first statement in the function body is transformed into the function’s `__doc__` attribute and therefore the function’s docstring.

[4] A string literal appearing as the first statement in the class body is transformed into the namespace’s `__doc__` item and therefore the class’s docstring.
9. Top-level components

The Python interpreter can get its input from a number of sources: from a script passed to it as standard input or as program argument, typed in interactively, from a module source file, etc. This chapter gives the syntax used in these cases.
9.1. Complete Python programs

While a language specification need not prescribe how the language interpreter is invoked, it is useful to have a notion of a complete Python program. A complete Python program is executed in a minimally initialized environment: all built-in and standard modules are available, but none have been initialized, except for sys (various system services), builtins (built-in functions, exceptions and None) and __main__. The latter is used to provide the local and global namespace for execution of the complete program.

The syntax for a complete Python program is that for file input, described in the next section.

The interpreter may also be invoked in interactive mode; in this case, it does not read and execute a complete program but reads and executes one statement (possibly compound) at a time. The initial environment is identical to that of a complete program; each statement is executed in the namespace of __main__.

Under Unix, a complete program can be passed to the interpreter in three forms: with the -c string command line option, as a file passed as the first command line argument, or as standard input. If the file or standard input is a tty device, the interpreter enters interactive mode; otherwise, it executes the file as a complete program.
9.2. File input

All input read from non-interactive files has the same form:

```
file_input ::= (NEWLINE | statement)*
```

This syntax is used in the following situations:

- when parsing a complete Python program (from a file or from a string);
- when parsing a module;
- when parsing a string passed to the `exec()` function;
9.3. Interactive input

Input in interactive mode is parsed using the following grammar:

```
interactive_input ::= [stmt_list] NEWLINE | compound_stmt
```

Note that a (top-level) compound statement must be followed by a blank line in interactive mode; this is needed to help the parser detect the end of the input.
9.4. Expression input

`eval()` is used for expression input. It ignores leading whitespace. The string argument to `eval()` must have the following form:

```
expr
```

```latex
\begin{eqnarray}
\texttt{eval} \text{\_input} \ ::= \ \texttt{expression\_list} \ \text{NEWLINE}^{*}
\end{eqnarray}
```
10. Full Grammar specification

This is the full Python grammar, as it is read by the parser generator and used to parse Python source files:

```
# Grammar for Python

# Note: Changing the grammar specified in this file require corresponding changes in the parser
# (../Modules/parsermodule.c). If you can't that module yourself, please co-ordinate that with someone who can; ask around on python-dev
# Drake <fdrake@acm.org> will probably be listed

# NOTE WELL: You should also follow all the steps listed at
# https://docs.python.org/devguide/grammar.html

# Start symbols for the grammar:
#   single_input is a single interactive statement
#   file_input is a module or sequence of commands read from an input file
#   eval_input is the input for the eval() function
# NB: compound_stmt in single_input is followed by extra NEWLINE!

single_input: NEWLINE | simple_stmt | compound_stmt
file_input: (NEWLINE | stmt)* ENDMARKER
eval_input: testlist NEWLINE* ENDMARKER
decorator: '@' dotted_name [ '(' [arglist] ')' ] NEWLINE
decorators: decorator+
decorated: decorators (classdef | funcdef | async_funcdef)
async_funcdef: ASYNC funcdef
funcdef: 'def' NAME parameters ['->' test] ':' suite
parameters: '(' [typedargslist] ')
typedargslist: (tpfdef ['=' test] (',' tpfdef ['=' test])*)
```
nonlocal_stmt: 'nonlocal' NAME (',', NAME)*
assert_stmt: 'assert' test [';', test]

compound_stmt: if_stmt | while_stmt | for_stmt | try_stmt
async_stmt: ASYNC (funcdef | with_stmt | for_stmt)
if_stmt: 'if' test ':' suite ('elif' test ':' suite)*
while_stmt: 'while' test ':' suite ['else' ':' suite]
for_stmt: 'for' exprlist 'in' testlist ':' suite ['else' ':' suite]
try_stmt: ('try' ':' suite ((except_clause ':' suite)+
  ['else' ':' suite] ['finally' ':' suite] |
  ['finally' ':' suite]))
with_stmt: 'with' with_item (',', with_item)* ':' suite
with_item: test ['as' expr]

# NB compile.c makes sure that the default except clause is last
except_clause: 'except' [test ['as' NAME]]
suite: simple_stmt | NEWLINE INDENT stmt+ DEDENT

test: or_test ['if' or_test 'else' test] | lambdef
lambdef: 'lambda' [varargslist] ':' test
lambdef_nocond: 'lambda' [varargslist] ':' test_nocond
or_test: and_test ('or' and_test)*
and_test: not_test ('and' not_test)*
not_test: 'not' not_test | comparison

comparison: expr (comp_op expr)*
# <> isn't actually a valid comparison operator in Python;
# sake of a __future__ import described in PEP 401 (comp_op: '<' | '!'|= | '!=' | '<'|'>|= | '<'|'>'|'!'|'|in'|'not'
star_expr: '*' expr
eexpr: xor_expr ('|' xor_expr)*
xor_expr: and_expr ('^' and_expr)*
and_expr: shift_expr ('&' shift_expr)*
shift_expr: arith_expr (('|' arith_expr)*
arith_expr: term ('|'|'>'|'<'|'!='|'|in'|'not'
term: factor (('*'|'@'|'/'|'*'|'//') factor)*
# The reason that keywords are test nodes instead of NAME results in an ambiguity. ast.c makes sure it's a NAME. "test '=' test" is really "keyword '=' test", but these need to be in a single rule to avoid grammar to our LL(1) parser. Even though 'test' includes '*', we explicitly match '*' here, too, to give it proper precedence. Illegal combinations and orderings are blocked in: multiple (test comp_for) arguements are blocked; keyword unpackings that precede iterable unpackings are blocked; etc.

factor: ('+' | '-' | '~') factor | power
power: atom_expr ['**' factor]
atom_expr: [AWAIT] atom trailer*
atom: ('[' yield_expr|testlist_comp ']') | ['' [testlist_comp ']'] | '{' [dictorsetmaker '}']
atom: NAME | NUMBER | STRING+ | '...' | 'None' | 'T

# illegal combinations and orderings are blocked in:
# multiple (test comp_for) arguments are blocked; keyword unpackings that precede iterable unpackings are blocked; etc.
comp_iter: comp_for | comp_if
comp_for: 'for' exprlist 'in' or_test [comp_iter]
comp_if: 'if' test_nocond [comp_iter]

# not used in grammar, but may appear in "node" pass
encoding_decl: NAME

yield_expr: 'yield' [yield_arg]
yield_arg: 'from' test | testlist
1. Introduction

The “Python library” contains several different kinds of components.

It contains data types that would normally be considered part of the “core” of a language, such as numbers and lists. For these types, the Python language core defines the form of literals and places some constraints on their semantics, but does not fully define the semantics. (On the other hand, the language core does define syntactic properties like the spelling and priorities of operators.)

The library also contains built-in functions and exceptions — objects that can be used by all Python code without the need of an import statement. Some of these are defined by the core language, but many are not essential for the core semantics and are only described here.

The bulk of the library, however, consists of a collection of modules. There are many ways to dissect this collection. Some modules are written in C and built in to the Python interpreter; others are written in Python and imported in source form. Some modules provide interfaces that are highly specific to Python, like printing a stack trace; some provide interfaces that are specific to particular operating systems, such as access to specific hardware; others provide interfaces that are specific to a particular application domain, like the World Wide Web. Some modules are available in all versions and ports of Python; others are only available when the underlying system supports or requires them; yet others are available only when a particular configuration option was chosen at the time when Python was compiled and installed.

This manual is organized “from the inside out:” it first describes the
built-in functions, data types and exceptions, and finally the modules, grouped in chapters of related modules.

This means that if you start reading this manual from the start, and skip to the next chapter when you get bored, you will get a reasonable overview of the available modules and application areas that are supported by the Python library. Of course, you don't have to read it like a novel — you can also browse the table of contents (in front of the manual), or look for a specific function, module or term in the index (in the back). And finally, if you enjoy learning about random subjects, you choose a random page number (see module random) and read a section or two. Regardless of the order in which you read the sections of this manual, it helps to start with chapter Built-in Functions, as the remainder of the manual assumes familiarity with this material.

Let the show begin!
2. Built-in Functions

The Python interpreter has a number of functions and types built into it that are always available. They are listed here in alphabetical order.

<table>
<thead>
<tr>
<th>Function</th>
<th>Function</th>
<th>Function</th>
<th>Function</th>
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**abs(x)**

Return the absolute value of a number. The argument may be an integer or a floating point number. If the argument is a complex number, its magnitude is returned.
**all(iterable)**

Return True if all elements of the *iterable* are true (or if the iterable is empty). Equivalent to:

```python
def all(iterable):
    for element in iterable:
        if not element:
            return False
    return True
```

**any(iterable)**

Return True if any element of the *iterable* is true. If the iterable is empty, return False. Equivalent to:

```python
def any(iterable):
    for element in iterable:
        if element:
            return True
    return False
```

**ascii(object)**

As `repr()`, return a string containing a printable representation of an object, but escape the non-ASCII characters in the string returned by `repr()` using \x, \u or \U escapes. This generates a string similar to that returned by `repr()` in Python 2.

**bin(x)**

Convert an integer number to a binary string. The result is a valid Python expression. If `x` is not a Python `int` object, it has to define an `__index__()` method that returns an integer.

**class bool([x])**
Return a Boolean value, i.e. one of True or False. \( x \) is converted using the standard truth testing procedure. If \( x \) is false or omitted, this returns False; otherwise it returns True. The `bool` class is a subclass of `int` (see Numeric Types — `int`, `float`, `complex`). It cannot be subclassed further. Its only instances are False and True (see Boolean Values).

```python
class bytearray([source[, encoding[, errors]]])
```

Return a new array of bytes. The `bytearray` class is a mutable sequence of integers in the range \( 0 \leq x < 256 \). It has most of the usual methods of mutable sequences, described in Mutable Sequence Types, as well as most methods that the `bytes` type has, see Bytes and Bytearray Operations.

The optional `source` parameter can be used to initialize the array in a few different ways:

- If it is a `string`, you must also give the `encoding` (and optionally, `errors`) parameters; `bytearray()` then converts the string to bytes using `str.encode()`.
- If it is an `integer`, the array will have that size and will be initialized with null bytes.
- If it is an object conforming to the `buffer` interface, a read-only buffer of the object will be used to initialize the bytes array.
- If it is an `iterable`, it must be an iterable of integers in the range \( 0 \leq x < 256 \), which are used as the initial contents of the array.

Without an argument, an array of size 0 is created.

See also Binary Sequence Types — `bytes`, `bytearray`, `memoryview` and Bytearray Objects.
class bytes([source[, encoding[, errors]]])

Return a new “bytes” object, which is an immutable sequence of integers in the range $0 \leq x < 256$. bytes is an immutable version of bytearray — it has the same non-mutating methods and the same indexing and slicing behavior.

Accordingly, constructor arguments are interpreted as for bytearray().

Bytes objects can also be created with literals, see String and Bytes literals.

See also Binary Sequence Types — bytes, bytearray, memoryview, Bytes, and Bytes and Bytarray Operations.

callable(object)

Return True if the object argument appears callable, False if not. If this returns true, it is still possible that a call fails, but if it is false, calling object will never succeed. Note that classes are callable (calling a class returns a new instance); instances are callable if their class has a __call__() method.

New in version 3.2: This function was first removed in Python 3.0 and then brought back in Python 3.2.

chr(i)

Return the string representing a character whose Unicode code point is the integer i. For example, chr(97) returns the string 'a', while chr(957) returns the string 'ν'. This is the inverse of ord().

The valid range for the argument is from 0 through 1,114,111
(0x10FFFF in base 16). \texttt{ValueError} will be raised if \( i \) is outside that range.

\textbf{classmethod(}function\textbf{)}

Return a class method for \texttt{function}.

A class method receives the class as implicit first argument, just like an instance method receives the instance. To declare a class method, use this idiom:

\begin{verbatim}
class C:
    @classmethod
    def f(cls, arg1, arg2, ...):
        ...
\end{verbatim}

The @classmethod form is a function \texttt{decorator} – see the description of function definitions in \texttt{Function definitions} for details.

It can be called either on the class (such as \texttt{C.f()}) or on an instance (such as \texttt{C().f()}). The instance is ignored except for its class. If a class method is called for a derived class, the derived class object is passed as the implied first argument.

Class methods are different than C++ or Java static methods. If you want those, see \texttt{classmethod()} in this section.

For more information on class methods, consult the documentation on the standard type hierarchy in \texttt{The standard type hierarchy}.

\textbf{compile(}source, filename, mode, flags=0, dont_inherit=False, optimize=-1\textbf{)}

Compile the \texttt{source} into a code or AST object. Code objects can be executed by \texttt{exec()} or \texttt{eval()}. \texttt{source} can either be a normal string, a byte string, or an AST object. Refer to the \texttt{ast} module
documentation for information on how to work with AST objects.

The *filename* argument should give the file from which the code was read; pass some recognizable value if it wasn’t read from a file ('<string>' is commonly used).

The *mode* argument specifies what kind of code must be compiled; it can be 'exec' if *source* consists of a sequence of statements, 'eval' if it consists of a single expression, or 'single' if it consists of a single interactive statement (in the latter case, expression statements that evaluate to something other than None will be printed).

The optional arguments *flags* and *dont_inherit* control which future statements (see PEP 236) affect the compilation of *source*. If neither is present (or both are zero) the code is compiled with those future statements that are in effect in the code that is calling *compile()*. If the *flags* argument is given and *dont_inherit* is not (or is zero) then the future statements specified by the *flags* argument are used in addition to those that would be used anyway. If *dont_inherit* is a non-zero integer then the *flags* argument is it – the future statements in effect around the call to compile are ignored.

Future statements are specified by bits which can be bitwise ORed together to specify multiple statements. The bitfield required to specify a given feature can be found as the *compiler_flag* attribute on the _Feature instance in the __future__ module.

The argument *optimize* specifies the optimization level of the compiler; the default value of -1 selects the optimization level of the interpreter as given by -O options. Explicit levels are 0 (no
optimization; __debug__ is true), 1 (asserts are removed, __debug__ is false) or 2 (docstrings are removed too).

This function raises `SyntaxError` if the compiled source is invalid, and `TypeError` if the source contains null bytes.

If you want to parse Python code into its AST representation, see `ast.parse()`.

```
Note: When compiling a string with multi-line code in 'single' or 'eval' mode, input must be terminated by at least one newline character. This is to facilitate detection of incomplete and complete statements in the code module.

Changed in version 3.2: Allowed use of Windows and Mac newlines. Also input in 'exec' mode does not have to end in a newline anymore. Added the optimize parameter.
```

class `complex([real[, imag]])`

Return a complex number with the value `real + imag*1j` or convert a string or number to a complex number. If the first parameter is a string, it will be interpreted as a complex number and the function must be called without a second parameter. The second parameter can never be a string. Each argument may be any numeric type (including complex). If `imag` is omitted, it defaults to zero and the constructor serves as a numeric conversion like `int` and `float`. If both arguments are omitted, returns `0j`.

```
Note: When converting from a string, the string must not contain whitespace around the central + or - operator. For example, complex('1+2j') is fine, but complex('1 + 2j') raises ValueError.
```
The complex type is described in Numeric Types — int, float, complex.

delattr(object, name)
This is a relative of setattr(). The arguments are an object and a string. The string must be the name of one of the object's attributes. The function deletes the named attribute, provided the object allows it. For example, delattr(x, 'foobar') is equivalent to del x.foobar.

class dict(**kwarg)
class dict(mapping, **kwarg)
class dict(iterable, **kwarg)
Create a new dictionary. The dict object is the dictionary class. See dict and Mapping Types — dict for documentation about this class.

For other containers see the built-in list, set, and tuple classes, as well as the collections module.

dir([object])
Without arguments, return the list of names in the current local scope. With an argument, attempt to return a list of valid attributes for that object.

If the object has a method named __dir__(), this method will be called and must return the list of attributes. This allows objects that implement a custom __getattr__() or __getattribute__() function to customize the way dir() reports their attributes.

If the object does not provide __dir__(), the function tries its
best to gather information from the object's \_dict\_ attribute, if
defined, and from its type object. The resulting list is not
necessarily complete, and may be inaccurate when the object has
a custom \_getattr\_().

The default \texttt{dir()} mechanism behaves differently with different
types of objects, as it attempts to produce the most relevant, rather
than complete, information:

- If the object is a module object, the list contains the names of
  the module's attributes.
- If the object is a type or class object, the list contains the
  names of its attributes, and recursively of the attributes of its
  bases.
- Otherwise, the list contains the object's attributes' names, the
  names of its class's attributes, and recursively of the attributes
  of its class's base classes.

The resulting list is sorted alphabetically. For example:

```python
>>> import struct
>>> dir()       # show the names in the module namespace
['__builtins__', '__name__', 'struct']
>>> dir(struct) # show the names in the struct module
['Struct', '__all__', '__builtins__', '__cached__', '__initializing__', '__loader__', '__name__', '__clearcache', 'calcszize', 'error', 'pack', 'pack_into', 'unpack', 'unpack_from']
>>> class Shape:
...     def __dir__(self):
...         return ['area', 'perimeter', 'location']
>>> s = Shape()
>>> dir(s)      # show the names in the object namespace
['area', 'location', 'perimeter']
```
Note: Because `dir()` is supplied primarily as a convenience for use at an interactive prompt, it tries to supply an interesting set of names more than it tries to supply a rigorously or consistently defined set of names, and its detailed behavior may change across releases. For example, metaclass attributes are not in the result list when the argument is a class.

`divmod(a, b)`
Take two (non complex) numbers as arguments and return a pair of numbers consisting of their quotient and remainder when using integer division. With mixed operand types, the rules for binary arithmetic operators apply. For integers, the result is the same as `(a // b, a % b). For floating point numbers the result is `(q, a % b)`, where `q` is usually `math.floor(a / b)` but may be 1 less than that. In any case `q * b + a % b` is very close to `a`, if `a % b` is non-zero it has the same sign as `b`, and `0 <= abs(a % b) < abs(b)`.

`enumerate(iterable, start=0)`
Return an enumerate object. `iterable` must be a sequence, an iterator, or some other object which supports iteration. The `__next__()` method of the iterator returned by `enumerate()` returns a tuple containing a count (from `start` which defaults to 0) and the values obtained from iterating over `iterable`.

```python
>>> seasons = ['Spring', 'Summer', 'Fall', 'Winter'
>>> list(enumerate(seasons))
[(0, 'Spring'), (1, 'Summer'), (2, 'Fall'), (3, 'Winter')
>>> list(enumerate(seasons, start=1))
[(1, 'Spring'), (2, 'Summer'), (3, 'Fall'), (4, 'Winter')]```
Equivalent to:

```python
def enumerate(sequence, start=0):
    n = start
    for elem in sequence:
        yield n, elem
    n += 1
```

eval(expression, globals=None, locals=None)

The arguments are a string and optional globals and locals. If provided, `globals` must be a dictionary. If provided, `locals` can be any mapping object.

The `expression` argument is parsed and evaluated as a Python expression (technically speaking, a condition list) using the `globals` and `locals` dictionaries as global and local namespace. If the `globals` dictionary is present and lacks '__builtins__', the current globals are copied into `globals` before `expression` is parsed. This means that `expression` normally has full access to the standard `builtins` module and restricted environments are propagated. If the `locals` dictionary is omitted it defaults to the `globals` dictionary. If both dictionaries are omitted, the expression is executed in the environment where `eval()` is called. The return value is the result of the evaluated expression. Syntax errors are reported as exceptions. Example:

```python
>>> x = 1
>>> eval('x+1')
2
```

This function can also be used to execute arbitrary code objects (such as those created by `compile()`). In this case pass a code object instead of a string. If the code object has been compiled with
'exec' as the mode argument, eval()'s return value will be None.

Hints: dynamic execution of statements is supported by the exec() function. The globals() and locals() functions returns the current global and local dictionary, respectively, which may be useful to pass around for use by eval() or exec().

See ast.literal_eval() for a function that can safely evaluate strings with expressions containing only literals.

exec(object[, globals[, locals]])

This function supports dynamic execution of Python code. object must be either a string or a code object. If it is a string, the string is parsed as a suite of Python statements which is then executed (unless a syntax error occurs). [1] If it is a code object, it is simply executed. In all cases, the code that's executed is expected to be valid as file input (see the section “File input” in the Reference Manual). Be aware that the return and yield statements may not be used outside of function definitions even within the context of code passed to the exec() function. The return value is None.

In all cases, if the optional parts are omitted, the code is executed in the current scope. If only globals is provided, it must be a dictionary, which will be used for both the global and the local variables. If globals and locals are given, they are used for the global and local variables, respectively. If provided, locals can be any mapping object. Remember that at module level, globals and locals are the same dictionary. If exec gets two separate objects as globals and locals, the code will be executed as if it were embedded in a class definition.
If the `globals` dictionary does not contain a value for the key `__builtins__`, a reference to the dictionary of the built-in module `builtins` is inserted under that key. That way you can control what builtins are available to the executed code by inserting your own `__builtins__` dictionary into `globals` before passing it to `exec()`.

**Note:** The built-in functions `globals()` and `locals()` return the current global and local dictionary, respectively, which may be useful to pass around for use as the second and third argument to `exec()`.

**Note:** The default `locals` act as described for function `locals()` below: modifications to the default `locals` dictionary should not be attempted. Pass an explicit `locals` dictionary if you need to see effects of the code on `locals` after function `exec()` returns.

**filter(function, iterable)**

Construct an iterator from those elements of `iterable` for which `function` returns true. `iterable` may be either a sequence, a container which supports iteration, or an iterator. If `function` is None, the identity function is assumed, that is, all elements of `iterable` that are false are removed.

Note that `filter(function, iterable)` is equivalent to the generator expression `(item for item in iterable if function(item))` if `function` is not None and `(item for item in iterable if item)` if `function` is None.

See `itertools.filterfalse()` for the complementary
function that returns elements of iterable for which function returns false.

class float([x])

Return a floating point number constructed from a number or string x.

If the argument is a string, it should contain a decimal number, optionally preceded by a sign, and optionally embedded in whitespace. The optional sign may be '+' or '-'; a '+' sign has no effect on the value produced. The argument may also be a string representing a NaN (not-a-number), or a positive or negative infinity. More precisely, the input must conform to the following grammar after leading and trailing whitespace characters are removed:

```plaintext
sign      ::=  "+" | "-
infinity  ::=  "Infinity" | "inf"
nan       ::=  "nan"
numeric_value ::= floatnumber | infinity | nan
numeric_string ::= [sign] numeric_value
```

Here floatnumber is the form of a Python floating-point literal, described in Floating point literals. Case is not significant, so, for example, “inf”, “Inf”, “INFINITY” and “iNfINity” are all acceptable spellings for positive infinity.

Otherwise, if the argument is an integer or a floating point number, a floating point number with the same value (within Python’s floating point precision) is returned. If the argument is outside the range of a Python float, an OverflowError will be raised.

For a general Python object x, float(x) delegates to
x.__float__().

If no argument is given, 0.0 is returned.

Examples:

```python
>>> float('+1.23')
1.23
>>> float(' -12345\n')
-12345.0
>>> float('1e-003')
0.001
>>> float('+1E6')
1000000.0
>>> float('-Infinity')
-inf
```

The float type is described in *Numeric Types — int, float, complex*.

`format(value[, format_spec])`  
Convert a `value` to a “formatted” representation, as controlled by `format_spec`. The interpretation of `format_spec` will depend on the type of the `value` argument, however there is a standard formatting syntax that is used by most built-in types: Format Specification Mini-Language.

The default `format_spec` is an empty string which usually gives the same effect as calling `str(value)`.

A call to `format(value, format_spec)` is translated to `type(value).__format__(value, format_spec)` which bypasses the instance dictionary when searching for the value's `__format__() method. A TypeError exception is raised if the method search reaches `object` and the `format_spec` is non-
empty, or if either the *format_spec* or the return value are not strings.

*Changed in version 3.4:* object().``__format__(format_spec)`` raises `TypeError` if
*format_spec* is not an empty string.

class `frozenset`([`iterable`])

Return a new `frozenset` object, optionally with elements taken from `iterable`. `frozenset` is a built-in class. See `frozenset` and `Set Types — set, frozenset` for documentation about this class.

For other containers see the built-in `set, list, tuple, and dict` classes, as well as the `collections` module.

g`ettattr`(object, name[, default])

Return the value of the named attribute of `object`. *name* must be a string. If the string is the name of one of the object's attributes, the result is the value of that attribute. For example, `getattr(x, 'foobar')` is equivalent to `x.foobar`. If the named attribute does not exist, *default* is returned if provided, otherwise `AttributeError` is raised.

globals()

Return a dictionary representing the current global symbol table. This is always the dictionary of the current module (inside a function or method, this is the module where it is defined, not the module from which it is called).

h`asattr`(object, name)

The arguments are an object and a string. The result is `True` if the string is the name of one of the object's attributes, `False` if not.
(This is implemented by calling `getattr(object, name)` and seeing whether it raises an `AttributeError` or not.)

**hash(object)**

Return the hash value of the object (if it has one). Hash values are integers. They are used to quickly compare dictionary keys during a dictionary lookup. Numeric values that compare equal have the same hash value (even if they are of different types, as is the case for 1 and 1.0).

**Note:** For object's with custom `__hash__()` methods, note that `hash()` truncates the return value based on the bit width of the host machine. See `__hash__()` for details.

**help([object])**

Invoke the built-in help system. (This function is intended for interactive use.) If no argument is given, the interactive help system starts on the interpreter console. If the argument is a string, then the string is looked up as the name of a module, function, class, method, keyword, or documentation topic, and a help page is printed on the console. If the argument is any other kind of object, a help page on the object is generated.

This function is added to the built-in namespace by the `site` module.

*Changed in version 3.4:* Changes to `pydoc` and `inspect` mean that the reported signatures for callables are now more comprehensive and consistent.

**hex(x)**
Convert an integer number to a lowercase hexadecimal string prefixed with “0x”, for example:

```
>>> hex(255)
'0xff'
>>> hex(-42)
'-0x2a'
```

If x is not a Python int object, it has to define an `__index__()` method that returns an integer.

See also `int()` for converting a hexadecimal string to an integer using a base of 16.

**Note:** To obtain a hexadecimal string representation for a float, use the `float.hex()` method.

**id**(object)

Return the “identity” of an object. This is an integer which is guaranteed to be unique and constant for this object during its lifetime. Two objects with non-overlapping lifetimes may have the same `id()` value.

*CPython implementation detail:* This is the address of the object in memory.

**input**([prompt])

If the *prompt* argument is present, it is written to standard output without a trailing newline. The function then reads a line from input, converts it to a string (stripping a trailing newline), and returns that. When EOF is read, *EOFError* is raised. Example:

```
>>> s = input('---> ')```
If the `readline` module was loaded, then `input()` will use it to provide elaborate line editing and history features.

```python
class int(x=0)
class int(x, base=10)
```

Return an integer object constructed from a number or string `x`, or return `0` if no arguments are given. If `x` is a number, return `x.__int__()`. For floating point numbers, this truncates towards zero.

If `x` is not a number or if `base` is given, then `x` must be a string, `bytes`, or `bytearray` instance representing an integer literal in radix `base`. Optionally, the literal can be preceded by + or - (with no space in between) and surrounded by whitespace. A base-n literal consists of the digits 0 to n-1, with a to z (or A to Z) having values 10 to 35. The default `base` is 10. The allowed values are 0 and 2-36. Base-2, -8, and -16 literals can be optionally prefixed with `0b/0B`, `0o/0O`, or `0x/0X`, as with integer literals in code. Base 0 means to interpret exactly as a code literal, so that the actual base is 2, 8, 10, or 16, and so that `int('010', 0)` is not legal, while `int('010')` is, as well as `int('010', 8)

The integer type is described in `Numeric Types — int, float, complex`.

*Changed in version 3.4:* If `base` is not an instance of `int` and the `base` object has a `base.__index__` method, that method is called to obtain an integer for the base. Previous versions used
base.__int__ instead of base.__index__.

**isinstance**(object, classinfo)
Return true if the object argument is an instance of the classinfo argument, or of a (direct, indirect or virtual) subclass thereof. If object is not an object of the given type, the function always returns false. If classinfo is a tuple of type objects (or recursively, other such tuples), return true if object is an instance of any of the types. If classinfo is not a type or tuple of types and such tuples, a TypeError exception is raised.

**issubclass**(class, classinfo)
Return true if class is a subclass (direct, indirect or virtual) of classinfo. A class is considered a subclass of itself. classinfo may be a tuple of class objects, in which case every entry in classinfo will be checked. In any other case, a TypeError exception is raised.

**iter**(object[, sentinel])
Return an iterator object. The first argument is interpreted very differently depending on the presence of the second argument. Without a second argument, object must be a collection object which supports the iteration protocol (the __iter__() method), or it must support the sequence protocol (the __getitem__() method with integer arguments starting at 0). If it does not support either of those protocols, TypeError is raised. If the second argument, sentinel, is given, then object must be a callable object. The iterator created in this case will call object with no arguments for each call to its __next__() method; if the value returned is equal to sentinel, StopIteration will be raised, otherwise the value will be returned.
See also **Iterator Types**.

One useful application of the second form of `iter()` is to read lines of a file until a certain line is reached. The following example reads a file until the `readline()` method returns an empty string:

```python
with open('mydata.txt') as fp:
    for line in iter(fp.readline, ''):
        process_line(line)
```

**len(s)**

Return the length (the number of items) of an object. The argument may be a sequence (such as a string, bytes, tuple, list, or range) or a collection (such as a dictionary, set, or frozen set).

**class list([iterable])**

Rather than being a function, `list` is actually a mutable sequence type, as documented in Lists and Sequence Types — list, tuple, range.

**locals()**

Update and return a dictionary representing the current local symbol table. Free variables are returned by `locals()` when it is called in function blocks, but not in class blocks.

**Note:** The contents of this dictionary should not be modified; changes may not affect the values of local and free variables used by the interpreter.

**map(function, iterable, ...)**

Return an iterator that applies `function` to every item of `iterable`, yielding the results. If additional `iterable` arguments are passed,
*function* must take that many arguments and is applied to the items from all iterables in parallel. With multiple iterables, the iterator stops when the shortest iterable is exhausted. For cases where the function inputs are already arranged into argument tuples, see *itertools.starmap()*.

\[
\text{max}(\text{iterable}, *, \text{key}, \text{default})
\]
\[
\text{max}(\text{arg1, arg2, *args}, \text{key})
\]

Return the largest item in an iterable or the largest of two or more arguments.

If one positional argument is provided, it should be an *iterable*. The largest item in the iterable is returned. If two or more positional arguments are provided, the largest of the positional arguments is returned.

There are two optional keyword-only arguments. The *key* argument specifies a one-argument ordering function like that used for *list.sort()* (with an unused optional second argument). The *default* argument specifies an object to return if the provided iterable is empty. If the iterable is empty and *default* is not provided, a *ValueError* is raised.

If multiple items are maximal, the function returns the first one encountered. This is consistent with other sort-stability preserving tools such as *sorted(iterable, key=keyfunc, reverse=True)[0]* and *heapq.nlargest(1, iterable, key=keyfunc)*.

*New in version 3.4:* The *default* keyword-only argument.

\[
\text{memoryview}(\text{obj})
\]

Return a “memory view” object created from the given argument.
See Memory Views for more information.

\[ \text{min}(\text{iterable}, *, \text{key, default})] \\
\[ \text{min}((\text{arg1, arg2}, *\text{args}[, \text{key}]))] \\
Return the smallest item in an iterable or the smallest of two or more arguments.

If one positional argument is provided, it should be an iterable. The smallest item in the iterable is returned. If two or more positional arguments are provided, the smallest of the positional arguments is returned.

There are two optional keyword-only arguments. The \text{key} argument specifies a one-argument ordering function like that used for \text{list.sort()}. The \text{default} argument specifies an object to return if the provided iterable is empty. If the iterable is empty and \text{default} is not provided, a \text{ValueError} is raised.

If multiple items are minimal, the function returns the first one encountered. This is consistent with other sort-stability preserving tools such as \text{sorted(iterable, key=keyfunc)[0]} and \text{heapq.nsmallest(1, iterable, key=keyfunc)}.

\textit{New in version 3.4:} The \text{default} keyword-only argument.

\[ \text{next}(\text{iterator}[, \text{default}])] \\
Retrieve the next item from the \text{iterator} by calling its \text{__next__()} method. If \text{default} is given, it is returned if the iterator is exhausted, otherwise \text{StopIteration} is raised.

\texttt{class object} \\
Return a new featureless object. \texttt{object} is a base for all classes.
It has the methods that are common to all instances of Python classes. This function does not accept any arguments.

**Note:** object does not have a __dict__, so you can’t assign arbitrary attributes to an instance of the object class.

oct(x)

Convert an integer number to an octal string. The result is a valid Python expression. If x is not a Python int object, it has to define an __index__() method that returns an integer.

open(file, mode='r', buffering=-1, encoding=None, errors=None, newline=None, closefd=True, opener=None)

Open file and return a corresponding file object. If the file cannot be opened, an OSError is raised.

file is either a string or bytes object giving the pathname (absolute or relative to the current working directory) of the file to be opened or an integer file descriptor of the file to be wrapped. (If a file descriptor is given, it is closed when the returned I/O object is closed, unless closefd is set to False.)

mode is an optional string that specifies the mode in which the file is opened. It defaults to 'r' which means open for reading in text mode. Other common values are 'w' for writing (truncating the file if it already exists), 'x' for exclusive creation and 'a' for appending (which on some Unix systems, means that all writes append to the end of the file regardless of the current seek position). In text mode, if encoding is not specified the encoding used is platform dependent: locale.getpreferredencoding(False) is called to get the current locale encoding. (For reading and writing raw bytes use
binary mode and leave *encoding* unspecified.) The available modes are:

<table>
<thead>
<tr>
<th>Character</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'r'</td>
<td>open for reading (default)</td>
</tr>
<tr>
<td>'w'</td>
<td>open for writing, truncating the file first</td>
</tr>
<tr>
<td>'x'</td>
<td>open for exclusive creation, failing if the file already exists</td>
</tr>
<tr>
<td>'a'</td>
<td>open for writing, appending to the end of the file if it exists</td>
</tr>
<tr>
<td>'b'</td>
<td>binary mode</td>
</tr>
<tr>
<td>'t'</td>
<td>text mode (default)</td>
</tr>
<tr>
<td>'+'</td>
<td>open a disk file for updating (reading and writing)</td>
</tr>
<tr>
<td>'U'</td>
<td>universal newlines mode (deprecated)</td>
</tr>
</tbody>
</table>

The default mode is 'r' (open for reading text, synonym of 'rt'). For binary read-write access, the mode 'w+b' opens and truncates the file to 0 bytes. 'r+b' opens the file without truncation.

As mentioned in the Overview, Python distinguishes between binary and text I/O. Files opened in binary mode (including 'b' in the *mode* argument) return contents as *bytes* objects without any decoding. In text mode (the default, or when 't' is included in the *mode* argument), the contents of the file are returned as *str*, the bytes having been first decoded using a platform-dependent encoding or using the specified *encoding* if given.

**Note:** Python doesn’t depend on the underlying operating system’s notion of text files; all the processing is done by Python
buffering is an optional integer used to set the buffering policy. Pass 0 to switch buffering off (only allowed in binary mode), 1 to select line buffering (only usable in text mode), and an integer > 1 to indicate the size in bytes of a fixed-size chunk buffer. When no buffering argument is given, the default buffering policy works as follows:

- Binary files are buffered in fixed-size chunks; the size of the buffer is chosen using a heuristic trying to determine the underlying device’s “block size” and falling back on `io.DEFAULT_BUFFER_SIZE`. On many systems, the buffer will typically be 4096 or 8192 bytes long.
- “Interactive” text files (files for which `isatty()` returns True) use line buffering. Other text files use the policy described above for binary files.

encoding is the name of the encoding used to decode or encode the file. This should only be used in text mode. The default encoding is platform dependent (whatever `locale.getpreferredencoding()` returns), but any text encoding supported by Python can be used. See the codecs module for the list of supported encodings.

disallowed for use in binary mode. A variety of standard error handlers are available (listed under Error Handlers), though any error handling name that has been registered with `codecs.register_error()` is also valid. The standard names include:

- 'strict' to raise a `ValueError` exception if there is an encoding error. The default value of None has the same effect.
• 'ignore' ignores errors. Note that ignoring encoding errors can lead to data loss.
• 'replace' causes a replacement marker (such as '?') to be inserted where there is malformed data.
• 'surrogateescape' will represent any incorrect bytes as code points in the Unicode Private Use Area ranging from U+DC80 to U+DCFF. These private code points will then be turned back into the same bytes when the surrogateescape error handler is used when writing data. This is useful for processing files in an unknown encoding.
• 'xmlcharrefreplace' is only supported when writing to a file. Characters not supported by the encoding are replaced with the appropriate XML character reference \&\#nnn;.
• 'backslashreplace' replaces malformed data by Python's backslashed escape sequences.
• 'namereplace' (also only supported when writing) replaces unsupported characters with \N{...} escape sequences.

newline controls how universal newlines mode works (it only applies to text mode). It can be None, '\', '\n', '\r', and '\r\n'. It works as follows:

• When reading input from the stream, if newline is None, universal newlines mode is enabled. Lines in the input can end in '\n', '\r', or '\r\n', and these are translated into '\n' before being returned to the caller. If it is '\', universal newlines mode is enabled, but line endings are returned to the caller untranslated. If it has any of the other legal values, input lines are only terminated by the given string, and the line ending is returned to the caller untranslated.
• When writing output to the stream, if newline is None, any '\n' characters written are translated to the system default line separator, os.linesep. If newline is '\' or '\n', no
translation takes place. If newline is any of the other legal values, any \n characters written are translated to the given string.

If closefd is False and a file descriptor rather than a filename was given, the underlying file descriptor will be kept open when the file is closed. If a filename is given closefd must be True (the default) otherwise an error will be raised.

A custom opener can be used by passing a callable as opener. The underlying file descriptor for the file object is then obtained by calling opener with (file, flags). opener must return an open file descriptor (passing os.open as opener results in functionality similar to passing None).

The newly created file is non-inheritable.

The following example uses the dir_fd parameter of the os.open() function to open a file relative to a given directory:

```python
>>> import os
>>> dir_fd = os.open('somedir', os.O_RDONLY)
>>> def opener(path, flags):
...     return os.open(path, flags, dir_fd=dir_fd
...     ...
>>> with open('spamspam.txt', 'w', opener=opener)
...     print('This will be written to somedir/sp
...     ...
>>> os.close(dir_fd)  # don't leak a file descri
```

The type of file object returned by the open() function depends on the mode. When open() is used to open a file in a text mode (w, r, wt, rt, etc.), it returns a subclass of io.TextIOBase (specifically io.TextIOWrapper). When used
to open a file in a binary mode with buffering, the returned class is a subclass of `io.BufferedReader`. The exact class varies: in read binary mode, it returns an `io.BufferedReader`; in write binary and append binary modes, it returns an `io.BufferedWriter`, and in read/write mode, it returns an `io.BufferedRandom`. When buffering is disabled, the raw stream, a subclass of `io.RawIOBase`, `io.FileIO`, is returned.

See also the file handling modules, such as, `fileinput`, `io` (where `open()` is declared), `os`, `os.path`, `tempfile`, and `shutil`.

*Changed in version 3.3:* The `opener` parameter was added. The 'x' mode was added. `IOError` used to be raised, it is now an alias of `OSError`. `FileExistsError` is now raised if the file opened in exclusive creation mode ('x') already exists.

*Changed in version 3.4:* The file is now non-inheritable.

*Deprecated since version 3.4, will be removed in version 4.0:* The 'U' mode.

*Changed in version 3.5:* If the system call is interrupted and the signal handler does not raise an exception, the function now retries the system call instead of raising an `InterruptedError` exception (see PEP 475 for the rationale).

`ord(c)`

Given a string representing one Unicode character, return an integer representing the Unicode code point of that character. For example, `ord('a')` returns the integer 97 and `ord('ν')` returns 957. This is the inverse of `chr()`.
\texttt{pow(x, y[, z])}

Return $x$ to the power $y$; if $z$ is present, return $x$ to the power $y$, modulo $z$ (computed more efficiently than \texttt{pow(x, y) \% z}). The two-argument form \texttt{pow(x, y)} is equivalent to using the power operator: $x^{**}y$.

The arguments must have numeric types. With mixed operand types, the coercion rules for binary arithmetic operators apply. For \texttt{int} operands, the result has the same type as the operands (after coercion) unless the second argument is negative; in that case, all arguments are converted to float and a float result is delivered. For example, $10^{**}2$ returns 100, but $10^{**}-2$ returns 0.01. If the second argument is negative, the third argument must be omitted. If $z$ is present, $x$ and $y$ must be of integer types, and $y$ must be non-negative.

\texttt{print(*objects, sep='\ ', end='\n', file=sys.stdout, flush=False)}

Print \texttt{objects} to the text stream \texttt{file}, separated by \texttt{sep} and followed by \texttt{end}. \texttt{sep}, \texttt{end} and \texttt{file}, if present, must be given as keyword arguments.

All non-keyword arguments are converted to strings like \texttt{str()} does and written to the stream, separated by \texttt{sep} and followed by \texttt{end}. Both \texttt{sep} and \texttt{end} must be strings; they can also be None, which means to use the default values. If no \texttt{objects} are given, \texttt{print()} will just write \texttt{end}.

The \texttt{file} argument must be an object with a \texttt{write(string)} method; if it is not present or None, \texttt{sys.stdout} will be used. Since printed arguments are converted to text strings, \texttt{print()} cannot be used with binary mode file objects. For these, use
file.write(...) instead.

Whether output is buffered is usually determined by file, but if the flush keyword argument is true, the stream is forcibly flushed.

*Changed in version 3.3:* Added the flush keyword argument.

class **property**(fget=None, fset=None, fdel=None, doc=None)

Return a property attribute.

*fget* is a function for getting an attribute value. *fset* is a function for setting an attribute value. *fdel* is a function for deleting an attribute value. And *doc* creates a docstring for the attribute.

A typical use is to define a managed attribute x:

```python
class C:
    def __init__(self):
        self._x = None

    def getx(self):
        return self._x

    def setx(self, value):
        self._x = value

    def delx(self):
        del self._x

x = property(getx, setx, delx, "I'm the 'x' property.
```

If *c* is an instance of *C*, *c.x* will invoke the getter, *c.x = value* will invoke the setter and *del c.x* the deleter.

If given, *doc* will be the docstring of the property attribute.
Otherwise, the property will copy \texttt{fget}'s docstring (if it exists). This makes it possible to create read-only properties easily using \texttt{property()} as a \texttt{decorator}:

```python
class Parrot:
    def __init__(self):
        self._voltage = 100000

    @property
    def voltage(self):
        """Get the current voltage."""
        return self._voltage
```

The \texttt{@property} decorator turns the \texttt{voltage()} method into a “getter” for a read-only attribute with the same name, and it sets the docstring for \texttt{voltage} to “Get the current voltage.”

A property object has getter, setter, and deleter methods usable as decorators that create a copy of the property with the corresponding accessor function set to the decorated function. This is best explained with an example:

```python
class C:
    def __init__(self):
        self._x = None

    @property
    def x(self):
        """I'm the 'x' property."""
        return self._x

    @x.setter
    def x(self, value):
        self._x = value
```
This code is exactly equivalent to the first example. Be sure to give the additional functions the same name as the original property (x in this case.)

The returned property object also has the attributes fget, fset, and fdel corresponding to the constructor arguments.

*Changed in version 3.5:* The docstrings of property objects are now writeable.

```
@x.deleter
def x(self):
    del self._x
```

```
range(stop)
range(start, stop[, step])
```

Rather than being a function, `range` is actually an immutable sequence type, as documented in Ranges and Sequence Types — list, tuple, range.

```
repr(object)
```

Return a string containing a printable representation of an object. For many types, this function makes an attempt to return a string that would yield an object with the same value when passed to `eval()`, otherwise the representation is a string enclosed in angle brackets that contains the name of the type of the object together with additional information often including the name and address of the object. A class can control what this function returns for its instances by defining a `__repr__()` method.

```
reversed(seq)
```

Return a reverse iterator. `seq` must be an object which has a
__reversed__() method or supports the sequence protocol (the __len__() method and the __getitem__() method with integer arguments starting at 0).

round(number[, ndigits])

Return the floating point value number rounded to ndigits digits after the decimal point. If ndigits is omitted, it returns the nearest integer to its input. Delegates to number.__round__(ndigits).

For the built-in types supporting round(), values are rounded to the closest multiple of 10 to the power minus ndigits; if two multiples are equally close, rounding is done toward the even choice (so, for example, both round(0.5) and round(-0.5) are 0, and round(1.5) is 2). The return value is an integer if called with one argument, otherwise of the same type as number.

Note: The behavior of round() for floats can be surprising: for example, round(2.675, 2) gives 2.67 instead of the expected 2.68. This is not a bug: it’s a result of the fact that most decimal fractions can’t be represented exactly as a float. See Floating Point Arithmetic: Issues and Limitations for more information.

class set([iterable])

Return a new set object, optionally with elements taken from iterable. set is a built-in class. See set and Set Types — set, frozenset for documentation about this class.

For other containers see the built-in frozenset, list, tuple, and dict classes, as well as the collections module.
**setattr**(object, name, value)

This is the counterpart of `getattr()`. The arguments are an object, a string and an arbitrary value. The string may name an existing attribute or a new attribute. The function assigns the value to the attribute, provided the object allows it. For example, `setattr(x, 'foobar', 123)` is equivalent to `x.foobar = 123`.

**class slice**(stop)

**class slice**(start, stop[, step])

Return a slice object representing the set of indices specified by `range(start, stop, step)`. The start and step arguments default to None. Slice objects have read-only data attributes start, stop and step which merely return the argument values (or their default). They have no other explicit functionality; however they are used by Numerical Python and other third party extensions. Slice objects are also generated when extended indexing syntax is used. For example: `a[start:stop:step]` or `a[start:stop, i]`. See `itertools.islice()` for an alternate version that returns an iterator.

**sorted**(iterable[, key][, reverse])

Return a new sorted list from the items in iterable.

Has two optional arguments which must be specified as keyword arguments.

*key* specifies a function of one argument that is used to extract a comparison key from each list element: `key=str.lower`. The default value is None (compare the elements directly).

*reverse* is a boolean value. If set to True, then the list elements
are sorted as if each comparison were reversed.

Use `functools.cmp_to_key()` to convert an old-style `cmp` function to a `key` function.

The built-in `sorted()` function is guaranteed to be stable. A sort is stable if it guarantees not to change the relative order of elements that compare equal — this is helpful for sorting in multiple passes (for example, sort by department, then by salary grade).

For sorting examples and a brief sorting tutorial, see Sorting HowTo.

**classmethod(function)**

Return a static method for `function`.

A static method does not receive an implicit first argument. To declare a static method, use this idiom:

```python
@staticmethod
def f(arg1, arg2, ...):
...
```

The @staticmethod form is a function decorator – see the description of function definitions in Function definitions for details.

It can be called either on the class (such as `C.f()`) or on an instance (such as `C().f()`). The instance is ignored except for its class.

Static methods in Python are similar to those found in Java or C++. Also see `classmethod()` for a variant that is useful for creating alternate class constructors.
For more information on static methods, consult the documentation on the standard type hierarchy in The standard type hierarchy.

```python
class str(object='')
class str(object=b'', encoding='utf-8', errors='strict')
```

Return a `str` version of `object`. See `str()` for details.

`str` is the built-in string class. For general information about strings, see Text Sequence Type — `str`.

```python
def sum(iterable[, start])
```

Sums `start` and the items of an `iterable` from left to right and returns the total. `start` defaults to 0. The `iterable`'s items are normally numbers, and the start value is not allowed to be a string.

For some use cases, there are good alternatives to `sum()`. The preferred, fast way to concatenate a sequence of strings is by calling `''`.join(sequence). To add floating point values with extended precision, see `math.fsum()`. To concatenate a series of iterables, consider using `itertools.chain()`.

```python
def super([type[, object-or-type]])
```

Return a proxy object that delegates method calls to a parent or sibling class of `type`. This is useful for accessing inherited methods that have been overridden in a class. The search order is same as that used by `getattr()` except that the `type` itself is skipped.

The `__mro__` attribute of the `type` lists the method resolution search order used by both `getattr()` and `super()`. The attribute is dynamic and can change whenever the inheritance hierarchy is updated.
If the second argument is omitted, the super object returned is unbound. If the second argument is an object, `isinstance(obj, type)` must be true. If the second argument is a type, `issubclass(type2, type)` must be true (this is useful for classmethods).

There are two typical use cases for `super`. In a class hierarchy with single inheritance, `super` can be used to refer to parent classes without naming them explicitly, thus making the code more maintainable. This use closely parallels the use of `super` in other programming languages.

The second use case is to support cooperative multiple inheritance in a dynamic execution environment. This use case is unique to Python and is not found in statically compiled languages or languages that only support single inheritance. This makes it possible to implement “diamond diagrams” where multiple base classes implement the same method. Good design dictates that this method have the same calling signature in every case (because the order of calls is determined at runtime, because that order adapts to changes in the class hierarchy, and because that order can include sibling classes that are unknown prior to runtime).

For both use cases, a typical superclass call looks like this:

```python
class C(B):
    def method(self, arg):
        super().method(arg)  # This does the same as:
        # super(C, self).method(arg)
```

Note that `super()` is implemented as part of the binding process.
for explicit dotted attribute lookups such as `super().__getitem__(name)`. It does so by implementing its own `__getattr__()` method for searching classes in a predictable order that supports cooperative multiple inheritance. Accordingly, `super()` is undefined for implicit lookups using statements or operators such as `super()[name]`.

Also note that, aside from the zero argument form, `super()` is not limited to use inside methods. The two argument form specifies the arguments exactly and makes the appropriate references. The zero argument form only works inside a class definition, as the compiler fills in the necessary details to correctly retrieve the class being defined, as well as accessing the current instance for ordinary methods.

For practical suggestions on how to design cooperative classes using `super()`, see guide to using `super()`.

**tuple([iterable])**

Rather than being a function, `tuple` is actually an immutable sequence type, as documented in Tuples and Sequence Types — list, tuple, range.

**class type(object)**

**class type(name, bases, dict)**

With one argument, return the type of an `object`. The return value is a type object and generally the same object as returned by `object.__class__`.

The `isinstance()` built-in function is recommended for testing the type of an object, because it takes subclasses into account.
With three arguments, return a new type object. This is essentially a dynamic form of the `class` statement. The `name` string is the class name and becomes the `__name__` attribute; the `bases` tuple itemizes the base classes and becomes the `__bases__` attribute; and the `dict` dictionary is the namespace containing definitions for class body and becomes the `__dict__` attribute. For example, the following two statements create identical `type` objects:

```python
>>> class X:
...     a = 1
...
>>> X = type('X', (object,), dict(a=1))
```

See also `Type Objects`.

**`vars([object])`**

Return the `__dict__` attribute for a module, class, instance, or any other object with a `__dict__` attribute.

Objects such as modules and instances have an updateable `__dict__` attribute; however, other objects may have write restrictions on their `__dict__` attributes (for example, classes use a dictproxy to prevent direct dictionary updates).

Without an argument, `vars()` acts like `locals()`. Note, the locals dictionary is only useful for reads since updates to the locals dictionary are ignored.

**`zip(*iterables)`**

Make an iterator that aggregates elements from each of the iterables.

Returns an iterator of tuples, where the $i$-th tuple contains the $i$-th
element from each of the argument sequences or iterables. The iterator stops when the shortest input iterable is exhausted. With a single iterable argument, it returns an iterator of 1-tuples. With no arguments, it returns an empty iterator. Equivalent to:

```python
def zip(*iterables):
    # zip('ABCD', 'xy') --> Ax By
    sentinel = object()
    iterators = [iter(it) for it in iterables]
    while iterators:
        result = []
        for it in iterators:
            elem = next(it, sentinel)
            if elem is sentinel:
                return
            result.append(elem)
        yield tuple(result)
```

The left-to-right evaluation order of the iterables is guaranteed. This makes possible an idiom for clustering a data series into n-length groups using `zip(*[iter(s)]*n)`. This repeats the same iterator n times so that each output tuple has the result of n calls to the iterator. This has the effect of dividing the input into n-length chunks.

`zip()` should only be used with unequal length inputs when you don’t care about trailing, unmatched values from the longer iterables. If those values are important, use `itertools.zip_longest()` instead.

`zip()` in conjunction with the * operator can be used to unzip a list:

```python
>>> x = [1, 2, 3]
```
```python
globals = None
locals = None
fromlist = ()
level = 0

__import__(name, globals=None, locals=None, fromlist=(), level=0)

Note: This is an advanced function that is not needed in everyday Python programming, unlike importlib.import_module().

This function is invoked by the import statement. It can be replaced (by importing the builtins module and assigning to builtins.__import__) in order to change semantics of the import statement, but doing so is strongly discouraged as it is usually simpler to use import hooks (see PEP 302) to attain the same goals and does not cause issues with code which assumes the default import implementation is in use. Direct use of __import__() is also discouraged in favor of importlib.import_module().

The function imports the module name, potentially using the given globals and locals to determine how to interpret the name in a package context. The fromlist gives the names of objects or submodules that should be imported from the module given by name. The standard implementation does not use its locals argument at all, and uses its globals only to determine the package context of the import statement.
level specifies whether to use absolute or relative imports. 0 (the default) means only perform absolute imports. Positive values for level indicate the number of parent directories to search relative to the directory of the module calling __import__() (see PEP 328 for the details).

When the name variable is of the form package.module, normally, the top-level package (the name up till the first dot) is returned, not the module named by name. However, when a non-empty fromlist argument is given, the module named by name is returned.

For example, the statement import spam results in bytecode resembling the following code:

```python
spam = __import__('spam', globals(), locals(), [])
```

The statement import spam.ham results in this call:

```python
spam = __import__('spam.ham', globals(), locals())
```

Note how __import__() returns the toplevel module here because this is the object that is bound to a name by the import statement.

On the other hand, the statement from spam.ham import eggs, sausage as saus results in

```python
_temp = __import__('spam.ham', globals(), locals())
eggs = _temp.eggs
saus = _temp.sausage
```
Here, the spam.ham module is returned from __import__(). From this object, the names to import are retrieved and assigned to their respective names.

If you simply want to import a module (potentially within a package) by name, use importlib.import_module().

Changed in version 3.3: Negative values for level are no longer supported (which also changes the default value to 0).

Footnotes

[1] Note that the parser only accepts the Unix-style end of line convention. If you are reading the code from a file, make sure to use newline conversion mode to convert Windows or Mac-style newlines.
3. Built-in Constants

A small number of constants live in the built-in namespace. They are:

**False**

The false value of the `bool` type. Assignments to `False` are illegal and raise a `SyntaxError`.

**True**

The true value of the `bool` type. Assignments to `True` are illegal and raise a `SyntaxError`.

**None**

The sole value of the type `NoneType`. None is frequently used to represent the absence of a value, as when default arguments are not passed to a function. Assignments to `None` are illegal and raise a `SyntaxError`.

**NotImplemented**

Special value which should be returned by the binary special methods (e.g. `__eq__()`, `__lt__()`, `__add__()`, `__rsub__()`, etc.) to indicate that the operation is not implemented with respect to the other type; may be returned by the in-place binary special methods (e.g. `__imul__()`, `__iand__()`, etc.) for the same purpose. Its truth value is true.

**Note:** When `NotImplemented` is returned, the interpreter will then try the reflected operation on the other type, or some other fallback, depending on the operator. If all attempted operations return `NotImplemented`, the interpreter will raise an appropriate
exception.
See Implementing the arithmetic operations for more details.

**Ellipsis**

The same as .... Special value used mostly in conjunction with extended slicing syntax for user-defined container data types.

**__debug__**

This constant is true if Python was not started with an `-O` option. See also the `assert` statement.

**Note:** The names `None`, `False`, `True` and `__debug__` cannot be reassigned (assignments to them, even as an attribute name, raise `SyntaxError`), so they can be considered “true” constants.
3.1. Constants added by the site module

The site module (which is imported automatically during startup, except if the -S command-line option is given) adds several constants to the built-in namespace. They are useful for the interactive interpreter shell and should not be used in programs.

```python
quit(code=None)
exit(code=None)
```

Objects that when printed, print a message like “Use quit() or Ctrl-D (i.e. EOF) to exit”, and when called, raise SystemExit with the specified exit code.

```python
copyright
license
credits
```

Objects that when printed, print a message like “Type license() to see the full license text”, and when called, display the corresponding text in a pager-like fashion (one screen at a time).
4. Built-in Types

The following sections describe the standard types that are built into the interpreter.

The principal built-in types are numerics, sequences, mappings, classes, instances and exceptions.

Some collection classes are mutable. The methods that add, subtract, or rearrange their members in place, and don’t return a specific item, never return the collection instance itself but None.

Some operations are supported by several object types; in particular, practically all objects can be compared, tested for truth value, and converted to a string (with the `repr()` function or the slightly different `str()` function). The latter function is implicitly used when an object is written by the `print()` function.
4.1. Truth Value Testing

Any object can be tested for truth value, for use in an `if` or `while` condition or as operand of the Boolean operations below. The following values are considered false:

- None
- False
- zero of any numeric type, for example, 0, 0.0, 0j.
- any empty sequence, for example, '', (), [].
- any empty mapping, for example, {}.
- instances of user-defined classes, if the class defines a `__bool__()` or `__len__()` method, when that method returns the integer zero or bool value False. [1]

All other values are considered true — so objects of many types are always true.

Operations and built-in functions that have a Boolean result always return 0 or False for false and 1 or True for true, unless otherwise stated. (Important exception: the Boolean operations or and and always return one of their operands.)
4.2. Boolean Operations — and, or, not

These are the Boolean operations, ordered by ascending priority:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Result</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>x or y</td>
<td>if x is false, then y, else x</td>
<td>(1)</td>
</tr>
<tr>
<td>x and y</td>
<td>if x is false, then x, else y</td>
<td>(2)</td>
</tr>
<tr>
<td>not x</td>
<td>if x is false, then True, else False</td>
<td>(3)</td>
</tr>
</tbody>
</table>

Notes:

1. This is a short-circuit operator, so it only evaluates the second argument if the first one is False.
2. This is a short-circuit operator, so it only evaluates the second argument if the first one is True.
3. not has a lower priority than non-Boolean operators, so not a == b is interpreted as not (a == b), and a == not b is a syntax error.
4.3. Comparisons

There are eight comparison operations in Python. They all have the same priority (which is higher than that of the Boolean operations). Comparisons can be chained arbitrarily; for example, $x < y <= z$ is equivalent to $x < y$ and $y <= z$, except that $y$ is evaluated only once (but in both cases $z$ is not evaluated at all when $x < y$ is found to be false).

This table summarizes the comparison operations:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;</td>
<td>strictly less than</td>
</tr>
<tr>
<td>&lt;=</td>
<td>less than or equal</td>
</tr>
<tr>
<td>&gt;</td>
<td>strictly greater than</td>
</tr>
<tr>
<td>&gt;=</td>
<td>greater than or equal</td>
</tr>
<tr>
<td>==</td>
<td>equal</td>
</tr>
<tr>
<td>!=</td>
<td>not equal</td>
</tr>
<tr>
<td>is</td>
<td>object identity</td>
</tr>
<tr>
<td>is not</td>
<td>negated object identity</td>
</tr>
</tbody>
</table>

Objects of different types, except different numeric types, never compare equal. Furthermore, some types (for example, function objects) support only a degenerate notion of comparison where any two objects of that type are unequal. The <, <=, > and >= operators will raise a `TypeError` exception when comparing a complex number with another built-in numeric type, when the objects are of different types that cannot be compared, or in other cases where there is no defined ordering.
Non-identical instances of a class normally compare as non-equal unless the class defines the `__eq__()` method.

Instances of a class cannot be ordered with respect to other instances of the same class, or other types of object, unless the class defines enough of the methods `__lt__()`, `__le__()`, `__gt__()`, and `__ge__()` (in general, `__lt__()` and `__eq__()` are sufficient, if you want the conventional meanings of the comparison operators).

The behavior of the `is` and `is not` operators cannot be customized; also they can be applied to any two objects and never raise an exception.

Two more operations with the same syntactic priority, `in` and `not in`, are supported only by sequence types (below).
4.4. Numeric Types — int, float, complex

There are three distinct numeric types: integers, floating point numbers, and complex numbers. In addition, Booleans are a subtype of integers. Integers have unlimited precision. Floating point numbers are usually implemented using double in C; information about the precision and internal representation of floating point numbers for the machine on which your program is running is available in \texttt{sys.float_info}. Complex numbers have a real and imaginary part, which are each a floating point number. To extract these parts from a complex number \texttt{z}, use \texttt{z.real} and \texttt{z.imag}. (The standard library includes additional numeric types, \texttt{fractions} that hold rationals, and \texttt{decimal} that hold floating-point numbers with user-definable precision.)

Numbers are created by numeric literals or as the result of built-in functions and operators. Unadorned integer literals (including hex, octal and binary numbers) yield integers. Numeric literals containing a decimal point or an exponent sign yield floating point numbers.Appending \texttt{'}j\texttt{'} or \texttt{'}J\texttt{'} to a numeric literal yields an imaginary number (a complex number with a zero real part) which you can add to an integer or float to get a complex number with real and imaginary parts.

Python fully supports mixed arithmetic: when a binary arithmetic operator has operands of different numeric types, the operand with the “narrower” type is widened to that of the other, where integer is narrower than floating point, which is narrower than complex. Comparisons between numbers of mixed type use the same rule. [2] The constructors \texttt{int()}, \texttt{float()}, and \texttt{complex()} can be used to
produce numbers of a specific type.

All numeric types (except complex) support the following operations, sorted by ascending priority (all numeric operations have a higher priority than comparison operations):

<table>
<thead>
<tr>
<th>Operation</th>
<th>Result</th>
<th>Notes</th>
<th>Full documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>x + y</td>
<td>sum of x and y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x - y</td>
<td>difference of x and y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x * y</td>
<td>product of x and y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x / y</td>
<td>quotient of x and y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x // y</td>
<td>floored quotient of x and y</td>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>x % y</td>
<td>remainder of x / y</td>
<td>(2)</td>
<td></td>
</tr>
<tr>
<td>-x</td>
<td>x negated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+x</td>
<td>x unchanged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>abs(x)</td>
<td>absolute value or magnitude of x</td>
<td></td>
<td>abs()</td>
</tr>
<tr>
<td>int(x)</td>
<td>x converted to integer</td>
<td>(3)(6)</td>
<td>int()</td>
</tr>
<tr>
<td>float(x)</td>
<td>x converted to floating point</td>
<td>(4)(6)</td>
<td>float()</td>
</tr>
<tr>
<td>complex(re, im)</td>
<td>a complex number with real part re, imaginary part im. im defaults to zero.</td>
<td>(6)</td>
<td>complex()</td>
</tr>
<tr>
<td>c.conjugate()</td>
<td>conjugate of the complex number c</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
divmod(x, y)  the pair (x // y, x % y)  (2)  divmod()
pow(x, y)  x to the power y  (5)  pow()
x ** y  x to the power y  (5)

Notes:

1. Also referred to as integer division. The resultant value is a whole integer, though the result's type is not necessarily int. The result is always rounded towards minus infinity: 1//2 is 0, (-1)//2 is -1, 1//(-2) is -1, and (-1)//(-2) is 0.

2. Not for complex numbers. Instead convert to floats using abs() if appropriate.

3. Conversion from floating point to integer may round or truncate as in C; see functions math.floor() and math.ceil() for well-defined conversions.

4. float also accepts the strings “nan” and “inf” with an optional prefix “+” or “-” for Not a Number (NaN) and positive or negative infinity.

5. Python defines pow(0, 0) and 0 ** 0 to be 1, as is common for programming languages.

6. The numeric literals accepted include the digits 0 to 9 or any Unicode equivalent (code points with the Nd property).

See http://www.unicode.org/Public/8.0.0/ucd/extracted/DerivedNumeric for a complete list of code points with the Nd property.

All numbers.Real types (int and float) also include the following
operations:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Result</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>math.trunc(x)</code></td>
<td><code>x</code> truncated to Integral</td>
<td></td>
</tr>
<tr>
<td><code>round(x[, n])</code></td>
<td><code>x</code> rounded to n digits, rounding half to even. If n is omitted, it defaults to 0.</td>
<td></td>
</tr>
<tr>
<td><code>math.floor(x)</code></td>
<td>the greatest integral float &lt;= <code>x</code></td>
<td></td>
</tr>
<tr>
<td><code>math.ceil(x)</code></td>
<td>the least integral float &gt;= <code>x</code></td>
<td></td>
</tr>
</tbody>
</table>

For additional numeric operations see the `math` and `cmath` modules.

### 4.4.1. Bitwise Operations on Integer Types

Bitwise operations only make sense for integers. Negative numbers are treated as their 2’s complement value (this assumes a sufficiently large number of bits that no overflow occurs during the operation).

The priorities of the binary bitwise operations are all lower than the numeric operations and higher than the comparisons; the unary operation `~` has the same priority as the other unary numeric operations (+ and -).

This table lists the bitwise operations sorted in ascending priority:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Result</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>`x</td>
<td>y`</td>
<td>bitwise or of <code>x</code> and <code>y</code></td>
</tr>
<tr>
<td><code>x ^ y</code></td>
<td>bitwise exclusive or of <code>x</code> and <code>y</code></td>
<td></td>
</tr>
<tr>
<td><code>x &amp; y</code></td>
<td>bitwise and of <code>x</code> and <code>y</code></td>
<td></td>
</tr>
<tr>
<td><code>x &lt;&lt; n</code></td>
<td><code>x</code> shifted left by <code>n</code> bits</td>
<td></td>
</tr>
<tr>
<td><code>x &gt;&gt; n</code></td>
<td><code>x</code> shifted right by <code>n</code> bits</td>
<td></td>
</tr>
<tr>
<td>~x</td>
<td>the bits of x inverted</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>------------------------</td>
<td></td>
</tr>
</tbody>
</table>

Notes:

1. Negative shift counts are illegal and cause a `ValueError` to be raised.
2. A left shift by \( n \) bits is equivalent to multiplication by \( \text{pow}(2, n) \) without overflow check.
3. A right shift by \( n \) bits is equivalent to division by \( \text{pow}(2, n) \) without overflow check.

### 4.4.2. Additional Methods on Integer Types

The `int` type implements the `numbers.Integral` abstract base class. In addition, it provides a few more methods:

**int.bit_length()**

Return the number of bits necessary to represent an integer in binary, excluding the sign and leading zeros:

```python
>>> n = -37
>>> bin(n)
'-0b100101'
>>> n.bit_length()
6
```

More precisely, if \( x \) is nonzero, then \( x\text{.bit_length()} \) is the unique positive integer \( k \) such that \( 2^{(k-1)} \leq \text{abs}(x) < 2^k \). Equivalently, when \( \text{abs}(x) \) is small enough to have a correctly rounded logarithm, then \( k = 1 + \text{int}(\log(\text{abs}(x), 2)) \). If \( x \) is zero, then \( x\text{.bit_length()} \) returns 0.

Equivalent to:
def bit_length(self):
    s = bin(self)  # binary representation:
    s = s.lstrip('-0b')  # remove leading zeros and
    return len(s)  # len('100101') --> 6

New in version 3.1.

int.to_bytes(length, byteorder, *, signed=False)
Return an array of bytes representing an integer.

>>> (1024).to_bytes(2, byteorder='big')
b'\x04\x00'
>>> (1024).to_bytes(10, byteorder='big')
b'\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00'
>>> (-1024).to_bytes(10, byteorder='big', signed=True)
b'\xff\xff\xff\xff\xff\xff\xff\xff\xff\x00'
>>> x = 1000
>>> x.to_bytes((x.bit_length() // 8) + 1, byteorder='big')
b'\xe8\x03'

The integer is represented using length bytes. An OverflowError is raised if the integer is not representable with the given number of bytes.

The byteorder argument determines the byte order used to represent the integer. If byteorder is "big", the most significant byte is at the beginning of the byte array. If byteorder is "little", the most significant byte is at the end of the byte array. To request the native byte order of the host system, use sys.byteorder as the byte order value.

The signed argument determines whether two's complement is used to represent the integer. If signed is False and a negative
integer is given, an `OverflowError` is raised. The default value for `signed` is False.

*New in version 3.2.*

```python
classmethod int.from_bytes(bytes, byteorder, *, signed=False)
```

Return the integer represented by the given array of bytes.

```python
g>>> int.from_bytes(b'\x00\x10', byteorder='big')
16
g>>> int.from_bytes(b'\x00\x10', byteorder='little')
4096
g>>> int.from_bytes(b'\xfc\x00', byteorder='big', signed=True)
-1024
g>>> int.from_bytes(b'\xfc\x00', byteorder='big', signed=False)
64512
g>>> int.from_bytes([255, 0, 0], byteorder='big')
16711680
g```

The argument `bytes` must either be a `bytes-like object` or an iterable producing bytes.

The `byteorder` argument determines the byte order used to represent the integer. If `byteorder` is "big", the most significant byte is at the beginning of the byte array. If `byteorder` is "little", the most significant byte is at the end of the byte array. To request the native byte order of the host system, use `sys.byteorder` as the byte order value.

The `signed` argument indicates whether two's complement is used to represent the integer.

*New in version 3.2.*
4.4.3. Additional Methods on Float

The float type implements the numbers.Real abstract base class. float also has the following additional methods.

`float.as_integer_ratio()`
Return a pair of integers whose ratio is exactly equal to the original float and with a positive denominator. Raises OverflowError on infinities and a ValueError on NaNs.

`float.is_integer()`
Return True if the float instance is finite with integral value, and False otherwise:

```python
>>> (-2.0).is_integer()
True
>>> (3.2).is_integer()
False
```

Two methods support conversion to and from hexadecimal strings. Since Python’s floats are stored internally as binary numbers, converting a float to or from a decimal string usually involves a small rounding error. In contrast, hexadecimal strings allow exact representation and specification of floating-point numbers. This can be useful when debugging, and in numerical work.

`float.hex()`
Return a representation of a floating-point number as a hexadecimal string. For finite floating-point numbers, this representation will always include a leading 0x and a trailing p and exponent.
classmethod float.fromhex(s)

Class method to return the float represented by a hexadecimal string s. The string s may have leading and trailing whitespace.

Note that float.hex() is an instance method, while float.fromhex() is a class method.

A hexadecimal string takes the form:

```
[sign] ['0x'] integer ['.' fraction] ['p' exponent]
```

where the optional sign may by either + or -, integer and fraction are strings of hexadecimal digits, and exponent is a decimal integer with an optional leading sign. Case is not significant, and there must be at least one hexadecimal digit in either the integer or the fraction. This syntax is similar to the syntax specified in section 6.4.4.2 of the C99 standard, and also to the syntax used in Java 1.5 onwards. In particular, the output of float.hex() is usable as a hexadecimal floating-point literal in C or Java code, and hexadecimal strings produced by C's %a format character or Java's Double.toHexString are accepted by float.fromhex().

Note that the exponent is written in decimal rather than hexadecimal, and that it gives the power of 2 by which to multiply the coefficient. For example, the hexadecimal string 0x3.a7p10 represents the floating-point number (3 + 10./16 + 7./16**2) * 2.0**10, or 3740.0:

```python
>>> float.fromhex('0x3.a7p10')
3740.0
```

Applying the reverse conversion to 3740.0 gives a different
hexadecimal string representing the same number:

```python
>>> float.hex(3740.0)
'0x1.d380000000000p+11'
```

4.4.4. Hashing of numeric types

For numbers $x$ and $y$, possibly of different types, it’s a requirement that $\text{hash}(x) == \text{hash}(y)$ whenever $x == y$ (see the `__hash__` method documentation for more details). For ease of implementation and efficiency across a variety of numeric types (including `int`, `float`, `decimal.Decimal` and `fractions.Fraction`) Python’s hash for numeric types is based on a single mathematical function that’s defined for any rational number, and hence applies to all instances of `int` and `fractions.Fraction`, and all finite instances of `float` and `decimal.Decimal`. Essentially, this function is given by reduction modulo $P$ for a fixed prime $P$. The value of $P$ is made available to Python as the modulus attribute of `sys.hash_info`.

**CPython implementation detail:** Currently, the prime used is $P = 2^{31} - 1$ on machines with 32-bit C longs and $P = 2^{61} - 1$ on machines with 64-bit C longs.

Here are the rules in detail:

- If $x = \frac{m}{n}$ is a nonnegative rational number and $n$ is not divisible by $P$, define $\text{hash}(x)$ as $m \times \text{invmod}(n, P) \mod P$, where $\text{invmod}(n, P)$ gives the inverse of $n$ modulo $P$.
- If $x = \frac{m}{n}$ is a nonnegative rational number and $n$ is divisible by $P$ (but $m$ is not) then $n$ has no inverse modulo $P$ and the rule above doesn’t apply; in this case define $\text{hash}(x)$ to be the
constant value sys.hash_info.inf.

- If $x = m / n$ is a negative rational number define $\text{hash}(x)$ as $-\text{hash}(-x)$. If the resulting hash is $-1$, replace it with $-2$.
- The particular values sys.hash_info.inf, -sys.hash_info.inf and sys.hash_info.nan are used as hash values for positive infinity, negative infinity, or nans (respectively). (All hashable nans have the same hash value.)
- For a complex number $z$, the hash values of the real and imaginary parts are combined by computing $\text{hash}(z.\text{real}) + \text{sys.hash_info.imag} \times \text{hash}(z.\text{imag})$, reduced modulo $2^{\text{sys.hash_info.width}}$ so that it lies in range($-2^{\text{sys.hash_info.width} - 1}$, $2^{\text{sys.hash_info.width} - 1}$). Again, if the result is $-1$, it's replaced with $-2$.

To clarify the above rules, here's some example Python code, equivalent to the built-in hash, for computing the hash of a rational number, float, or complex:

```python
import sys, math

def hash_fraction(m, n):
    """Compute the hash of a rational number $m / n$.
    Assumes $m$ and $n$ are integers, with $n$ positive. Equivalent to hash(fractions.Fraction(m, n)).""
    
    P = sys.hash_info.modulus
    # Remove common factors of $P$. (Unnecessary if $m$ and $n$ are already coprime.)
    while m % P == n % P == 0:
        m, n = m // P, n // P

    if n % P == 0:
```
hash_ = sys.hash_info.inf

else:
    # Fermat's Little Theorem: \( \text{pow}(n, P-1, P) \) is
    # \( \text{pow}(n, P-2, P) \) gives the inverse of \( n \) mod \( P \)
    hash_ = (abs(m) % P) * \text{pow}(n, P - 2, P) % P

if m < 0:
    hash_ = -hash_
if hash_ == -1:
    hash_ = -2
return hash_

def hash_float(x):
    """Compute the hash of a float \( x \)."""

    if math.isnan(x):
        return sys.hash_info.nan
    elif math.isinf(x):
        return sys.hash_info.inf if x > 0 else -sys.
    else:
        return hash_fraction(*x.as_integer_ratio())

def hash_complex(z):
    """Compute the hash of a complex number \( z \)."""

    hash_ = hash_float(z.real) + sys.hash_info.imag
    # do a signed reduction modulo \( 2^{2\times\text{sys.hash_info.width}} \)
    M = 2**(sys.hash_info.width - 1)
    hash_ = (hash_ & (M - 1)) - (hash & M)

    if hash_ == -1:
        hash_ = -2
    return hash_
4.5. Iterator Types

Python supports a concept of iteration over containers. This is implemented using two distinct methods; these are used to allow user-defined classes to support iteration. Sequences, described below in more detail, always support the iteration methods.

One method needs to be defined for container objects to provide iteration support:

```python
container.__iter__()  
```

Return an iterator object. The object is required to support the iterator protocol described below. If a container supports different types of iteration, additional methods can be provided to specifically request iterators for those iteration types. (An example of an object supporting multiple forms of iteration would be a tree structure which supports both breadth-first and depth-first traversal.) This method corresponds to the `tp_iter` slot of the type structure for Python objects in the Python/C API.

The iterator objects themselves are required to support the following two methods, which together form the `iterator protocol`:

```python
iterator.__iter__()  
```

Return the iterator object itself. This is required to allow both containers and iterators to be used with the `for` and `in` statements. This method corresponds to the `tp_iter` slot of the type structure for Python objects in the Python/C API.

```python
iterator.__next__()  
```

Return the next item from the container. If there are no further items, raise the `StopIteration` exception. This method
corresponds to the `tp_iternext` slot of the type structure for Python objects in the Python/C API.

Python defines several iterator objects to support iteration over general and specific sequence types, dictionaries, and other more specialized forms. The specific types are not important beyond their implementation of the iterator protocol.

Once an iterator's `__next__() method raises `StopIteration`, it must continue to do so on subsequent calls. Implementations that do not obey this property are deemed broken.

### 4.5.1. Generator Types

Python's `generators` provide a convenient way to implement the iterator protocol. If a container object's `__iter__()` method is implemented as a generator, it will automatically return an iterator object (technically, a generator object) supplying the `__iter__()` and `__next__()` methods. More information about generators can be found in the documentation for the `yield` expression.
4.6. Sequence Types — list, tuple, range

There are three basic sequence types: lists, tuples, and range objects. Additional sequence types tailored for processing of binary data and text strings are described in dedicated sections.

4.6.1. Common Sequence Operations

The operations in the following table are supported by most sequence types, both mutable and immutable. The collections.abc.Sequence ABC is provided to make it easier to correctly implement these operations on custom sequence types.

This table lists the sequence operations sorted in ascending priority. In the table, s and t are sequences of the same type, n, i, j and k are integers and x is an arbitrary object that meets any type and value restrictions imposed by s.

The in and not in operations have the same priorities as the comparison operations. The + (concatenation) and * (repetition) operations have the same priority as the corresponding numeric operations.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Result</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>x in s</td>
<td>True if an item of s is equal to x, else False</td>
<td>(1)</td>
</tr>
<tr>
<td>x not in s</td>
<td>False if an item of s is equal to x, else True</td>
<td>(1)</td>
</tr>
<tr>
<td>s + t</td>
<td>the concatenation of s and t</td>
<td>(6)(7)</td>
</tr>
<tr>
<td>Expression</td>
<td>Description</td>
<td>Notes</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td><code>s * n or n * s</code></td>
<td>equivalent to adding <code>s</code> to itself <code>n</code> times</td>
<td>(2)(7)</td>
</tr>
<tr>
<td><code>s[i]</code></td>
<td><code>i</code>th item of <code>s</code>, origin 0</td>
<td>(3)</td>
</tr>
<tr>
<td><code>s[i:j]</code></td>
<td>slice of <code>s</code> from <code>i</code> to <code>j</code></td>
<td>(3)(4)</td>
</tr>
<tr>
<td><code>s[i:j:k]</code></td>
<td>slice of <code>s</code> from <code>i</code> to <code>j</code> with step <code>k</code></td>
<td>(3)(5)</td>
</tr>
<tr>
<td><code>len(s)</code></td>
<td>length of <code>s</code></td>
<td></td>
</tr>
<tr>
<td><code>min(s)</code></td>
<td>smallest item of <code>s</code></td>
<td></td>
</tr>
<tr>
<td><code>max(s)</code></td>
<td>largest item of <code>s</code></td>
<td></td>
</tr>
<tr>
<td><code>s.index(x[, i[, j]])</code></td>
<td>index of the first occurrence of <code>x</code> in <code>s</code> (at or after index <code>i</code> and before index <code>j</code>)</td>
<td>(8)</td>
</tr>
<tr>
<td><code>s.count(x)</code></td>
<td>total number of occurrences of <code>x</code> in <code>s</code></td>
<td></td>
</tr>
</tbody>
</table>

Sequences of the same type also support comparisons. In particular, tuples and lists are compared lexicographically by comparing corresponding elements. This means that to compare equal, every element must compare equal and the two sequences must be of the same type and have the same length. (For full details see `Comparisons` in the language reference.)

Notes:

1. While the `in` and `not in` operations are used only for simple containment testing in the general case, some specialised sequences (such as `str`, `bytes` and `bytearray`) also use them for subsequence testing:

```python
>>> "gg" in "eggs"
True
```
2. Values of \( n \) less than 0 are treated as 0 (which yields an empty sequence of the same type as \( s \)). Note that items in the sequence \( s \) are not copied; they are referenced multiple times. This often haunts new Python programmers; consider:

```python
>>> lists = [[]] * 3
>>> lists
[[], [], []]
>>> lists[0].append(3)
>>> lists
[[3], [3], [3]]
```

What has happened is that [[]] is a one-element list containing an empty list, so all three elements of [[]] * 3 are references to this single empty list. Modifying any of the elements of \( \text{lists} \) modifies this single list. You can create a list of different lists this way:

```python
>>> lists = [[] for i in range(3)]
>>> lists[0].append(3)
>>> lists[1].append(5)
>>> lists[2].append(7)
>>> lists
[[3], [5], [7]]
```

Further explanation is available in the FAQ entry How do I create a multidimensional list?.

3. If \( i \) or \( j \) is negative, the index is relative to the end of the string: \( \text{len}(s) + i \) or \( \text{len}(s) + j \) is substituted. But note that -0 is still 0.

4. The slice of \( s \) from \( i \) to \( j \) is defined as the sequence of items with index \( k \) such that \( i \leq k < j \). If \( i \) or \( j \) is greater than \( \text{len}(s) \),
5. The slice of $s$ from $i$ to $j$ with step $k$ is defined as the sequence of items with index $x = i + n \cdot k$ such that $0 \leq n < (j-i)/k$. In other words, the indices are $i$, $i+k$, $i+2k$, $i+3k$ and so on, stopping when $j$ is reached (but never including $j$). If $i$ or $j$ is greater than $\text{len}(s)$, use $\text{len}(s)$. If $i$ or $j$ are omitted or None, they become “end” values (which end depends on the sign of $k$). Note, $k$ cannot be zero. If $k$ is None, it is treated like 1.

6. Concatenating immutable sequences always results in a new object. This means that building up a sequence by repeated concatenation will have a quadratic runtime cost in the total sequence length. To get a linear runtime cost, you must switch to one of the alternatives below:

- if concatenating str objects, you can build a list and use \texttt{str.join()} at the end or else write to an \texttt{io.StringIO} instance and retrieve its value when complete
- if concatenating bytes objects, you can similarly use \texttt{bytes.join()} or \texttt{io.BytesIO}, or you can do in-place concatenation with a \texttt{bytearray} object. \texttt{bytearray} objects are mutable and have an efficient overallocation mechanism
- if concatenating tuple objects, extend a \texttt{list} instead
- for other types, investigate the relevant class documentation

7. Some sequence types (such as range) only support item sequences that follow specific patterns, and hence don’t support sequence concatenation or repetition.

8. \texttt{index} raises \texttt{ValueError} when $x$ is not found in $s$. When supported, the additional arguments to the index method allow
efficient searching of subsections of the sequence. Passing the extra arguments is roughly equivalent to using \texttt{s[i:j].index(x)}, only without copying any data and with the returned index being relative to the start of the sequence rather than the start of the slice.

4.6.2. Immutable Sequence Types

The only operation that immutable sequence types generally implement that is not also implemented by mutable sequence types is support for the \texttt{hash()} built-in.

This support allows immutable sequences, such as \texttt{tuple} instances, to be used as \texttt{dict} keys and stored in \texttt{set} and \texttt{frozenset} instances.

Attempting to hash an immutable sequence that contains unhashable values will result in \texttt{TypeError}.

4.6.3. Mutable Sequence Types

The operations in the following table are defined on mutable sequence types. The \texttt{collections.abc.MutableSequence} ABC is provided to make it easier to correctly implement these operations on custom sequence types.

In the table \texttt{s} is an instance of a mutable sequence type, \texttt{t} is any iterable object and \texttt{x} is an arbitrary object that meets any type and value restrictions imposed by \texttt{s} (for example, \texttt{bytearray} only accepts integers that meet the value restriction $0 \leq x \leq 255$).

<table>
<thead>
<tr>
<th>Operation</th>
<th>Result</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expression</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td><code>s[i] = x</code></td>
<td>item $i$ of $s$ is replaced by $x$</td>
<td></td>
</tr>
<tr>
<td><code>s[i:j] = t</code></td>
<td>slice of $s$ from $i$ to $j$ is replaced by the contents of the iterable $t$</td>
<td></td>
</tr>
<tr>
<td><code>del s[i:j]</code></td>
<td>same as $s[i:j] = []$</td>
<td></td>
</tr>
<tr>
<td><code>s[i:j:k] = t</code></td>
<td>the elements of $s[i:j:k]$ are replaced by those of $t$ (1)</td>
<td></td>
</tr>
<tr>
<td><code>del s[i:j:k]</code></td>
<td>removes the elements of $s[i:j:k]$ from the list</td>
<td></td>
</tr>
<tr>
<td><code>s.append(x)</code></td>
<td>appends $x$ to the end of the sequence (same as $s[len(s):len(s)] = [x]$)</td>
<td></td>
</tr>
<tr>
<td><code>s.clear()</code></td>
<td>removes all items from $s$ (same as <code>del s[:]</code>) (5)</td>
<td></td>
</tr>
<tr>
<td><code>s.copy()</code></td>
<td>creates a shallow copy of $s$ (same as $s[:]$) (5)</td>
<td></td>
</tr>
<tr>
<td><code>s.extend(t)</code> or <code>s += t</code></td>
<td>extends $s$ with the contents of $t$ (for the most part the same as $s[len(s):len(s)] = t$)</td>
<td></td>
</tr>
<tr>
<td><code>s *= n</code></td>
<td>updates $s$ with its contents repeated $n$ times (6)</td>
<td></td>
</tr>
<tr>
<td><code>s.insert(i, x)</code></td>
<td>inserts $x$ into $s$ at the index given by $i$ (same as $s[i:i] = [x]$)</td>
<td></td>
</tr>
<tr>
<td><code>s.pop(i)</code></td>
<td>retrieves the item at $i$ and also removes it from</td>
<td></td>
</tr>
<tr>
<td>Method</td>
<td>Description</td>
<td>Notes</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td><code>s.remove(x)</code></td>
<td>remove the first item from <code>s</code> where <code>s[i] == x</code></td>
<td>(3)</td>
</tr>
<tr>
<td><code>s.reverse()</code></td>
<td>reverses the items of <code>s</code> in place</td>
<td>(4)</td>
</tr>
</tbody>
</table>

Notes:

1. `t` must have the same length as the slice it is replacing.

2. The optional argument `i` defaults to `-1`, so that by default the last item is removed and returned.

3. `remove` raises `ValueError` when `x` is not found in `s`.

4. The `reverse()` method modifies the sequence in place for economy of space when reversing a large sequence. To remind users that it operates by side effect, it does not return the reversed sequence.

5. `clear()` and `copy()` are included for consistency with the interfaces of mutable containers that don't support slicing operations (such as `dict` and `set`)

   *New in version 3.3:* `clear()` and `copy()` methods.

6. The value `n` is an integer, or an object implementing `__index__()`. Zero and negative values of `n` clear the sequence. Items in the sequence are not copied; they are referenced multiple times, as explained for `s * n` under Common Sequence Operations.
4.6.4. Lists

Lists are mutable sequences, typically used to store collections of homogeneous items (where the precise degree of similarity will vary by application).

**class list([iterable])**

Lists may be constructed in several ways:

- Using a pair of square brackets to denote the empty list: `[]`
- Using square brackets, separating items with commas: `[a]`, `[a, b, c]`
- Using a list comprehension: `[x for x in iterable]`
- Using the type constructor: `list()` or `list(iterable)`

The constructor builds a list whose items are the same and in the same order as `iterable`'s items. `iterable` may be either a sequence, a container that supports iteration, or an iterator object. If `iterable` is already a list, a copy is made and returned, similar to `iterable[:]`. For example, `list('abc')` returns `['a', 'b', 'c']` and `list((1, 2, 3))` returns `[1, 2, 3]`. If no argument is given, the constructor creates a new empty list, `[]`.

Many other operations also produce lists, including the `sorted()` built-in.

Lists implement all of the common and mutable sequence operations. Lists also provide the following additional method:

**sort(*, key=None, reverse=None)**

This method sorts the list in place, using only `<` comparisons between items. Exceptions are not suppressed - if any
comparison operations fail, the entire sort operation will fail (and the list will likely be left in a partially modified state).

`sort()` accepts two arguments that can only be passed by keyword (**keyword-only arguments**):

* `key` specifies a function of one argument that is used to extract a comparison key from each list element (for example, `key=str.lower`). The key corresponding to each item in the list is calculated once and then used for the entire sorting process. The default value of `None` means that list items are sorted directly without calculating a separate key value.

The `functools.cmp_to_key()` utility is available to convert a 2.x style `cmp` function to a `key` function.

* `reverse` is a boolean value. If set to `True`, then the list elements are sorted as if each comparison were reversed.

This method modifies the sequence in place for economy of space when sorting a large sequence. To remind users that it operates by side effect, it does not return the sorted sequence (use `sorted()` to explicitly request a new sorted list instance).

The `sort()` method is guaranteed to be stable. A sort is stable if it guarantees not to change the relative order of elements that compare equal — this is helpful for sorting in multiple passes (for example, sort by department, then by salary grade).

**CPython implementation detail:** While a list is being sorted, the effect of attempting to mutate, or even inspect, the list is undefined. The C implementation of Python makes the list appear empty for the duration, and raises `ValueError` if it can
detect that the list has been mutated during a sort.

4.6.5. Tuples

Tuples are immutable sequences, typically used to store collections of heterogeneous data (such as the 2-tuples produced by the \texttt{enumerate()} built-in). Tuples are also used for cases where an immutable sequence of homogeneous data is needed (such as allowing storage in a \texttt{set} or \texttt{dict} instance).

\begin{verbatim}
class tuple(iterable)
    Tuples may be constructed in a number of ways:
    
    • Using a pair of parentheses to denote the empty tuple: ( )
    • Using a trailing comma for a singleton tuple: a, or (a, )
    • Separating items with commas: a, b, c or (a, b, c)
    • Using the \texttt{tuple()} built-in: tuple() or tuple(iterable)

    The constructor builds a tuple whose items are the same and in the same order as \texttt{iterable}'s items. \texttt{iterable} may be either a sequence, a container that supports iteration, or an iterator object. If \texttt{iterable} is already a tuple, it is returned unchanged. For example, tuple('abc') returns ('a', 'b', 'c') and tuple([1, 2, 3]) returns (1, 2, 3). If no argument is given, the constructor creates a new empty tuple, ()

    Note that it is actually the comma which makes a tuple, not the parentheses. The parentheses are optional, except in the empty tuple case, or when they are needed to avoid syntactic ambiguity. For example, f(a, b, c) is a function call with three arguments, while f((a, b, c)) is a function call with a 3-tuple as the sole argument.
\end{verbatim}
Tuples implement all of the common sequence operations.

For heterogeneous collections of data where access by name is clearer than access by index, collections.namedtuple() may be a more appropriate choice than a simple tuple object.

4.6.6. Ranges

The range type represents an immutable sequence of numbers and is commonly used for looping a specific number of times in for loops.

class range(stop)
class range(start, stop[, step])

The arguments to the range constructor must be integers (either built-in int or any object that implements the __index__ special method). If the step argument is omitted, it defaults to 1. If the start argument is omitted, it defaults to 0. If step is zero, ValueError is raised.

For a positive step, the contents of a range r are determined by the formula \( r[i] = start + step*i \) where \( i \geq 0 \) and \( r[i] < stop \).

For a negative step, the contents of the range are still determined by the formula \( r[i] = start + step*i \), but the constraints are \( i \geq 0 \) and \( r[i] > stop \).

A range object will be empty if \( r[0] \) does not meet the value constraint. Ranges do support negative indices, but these are interpreted as indexing from the end of the sequence determined by the positive indices.
Ranges containing absolute values larger than `sys.maxsize` are permitted but some features (such as `len()`) may raise `OverflowError`.

Range examples:

```python
>>> list(range(10))
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
>>> list(range(1, 11))
[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
>>> list(range(0, 30, 5))
[0, 5, 10, 15, 20, 25]
>>> list(range(0, 10, 3))
[0, 3, 6, 9]
>>> list(range(0, -10, -1))
[0, -1, -2, -3, -4, -5, -6, -7, -8, -9]
>>> list(range(0))
[]
>>> list(range(1, 0))
[]
```

Ranges implement all of the `common` sequence operations except concatenation and repetition (due to the fact that range objects can only represent sequences that follow a strict pattern and repetition and concatenation will usually violate that pattern).

The advantage of the `range` type over a regular `list` or `tuple` is that a `range` object will always take the same (small) amount of memory, no matter the size of the range it represents (as it only stores the start, stop and step values, calculating individual items and subranges as needed).

Range objects implement the `collections.abc.Sequence` ABC, and provide features such as containment tests, element index lookup,
slicing and support for negative indices (see Sequence Types — list, tuple, range):

```python
>>> r = range(0, 20, 2)
>>> r
range(0, 20, 2)
>>> 11 in r
False
>>> 10 in r
True
>>> r.index(10)
5
>>> r[5]
10
>>> r[:5]
range(0, 10, 2)
>>> r[-1]
18
```

Testing range objects for equality with == and != compares them as sequences. That is, two range objects are considered equal if they represent the same sequence of values. (Note that two range objects that compare equal might have different start, stop and step attributes, for example range(0) == range(2, 1, 3) or range(0, 3, 2) == range(0, 4, 2).)

*Changed in version 3.2:* Implement the Sequence ABC. Support slicing and negative indices. Test int objects for membership in constant time instead of iterating through all items.

*Changed in version 3.3:* Define ‘==’ and ‘!=’ to compare range objects based on the sequence of values they define (instead of comparing based on object identity).
New in version 3.3: The start, stop and step attributes.
4.7. Text Sequence Type — `str`

Textual data in Python is handled with `str` objects, or *strings*. Strings are immutable *sequences* of Unicode code points. String literals are written in a variety of ways:

- Single quotes: 'allows embedded "double" quotes'
- Double quotes: "allows embedded 'single' quotes".
- Triple quoted: '''Three single quotes''', '"""Three double quotes"""

Triple quoted strings may span multiple lines - all associated whitespace will be included in the string literal.

String literals that are part of a single expression and have only whitespace between them will be implicitly converted to a single string literal. That is, ("spam " "eggs") == "spam eggs".

See *String and Bytes literals* for more about the various forms of string literal, including supported escape sequences, and the r ("raw") prefix that disables most escape sequence processing.

Strings may also be created from other objects using the `str` constructor.

Since there is no separate “character” type, indexing a string produces strings of length 1. That is, for a non-empty string `s`, `s[0] == s[0:1]`.

There is also no mutable string type, but `str.join()` or `io.StringIO` can be used to efficiently construct strings from multiple fragments.
*Changed in version 3.3:* For backwards compatibility with the Python 2 series, the `u` prefix is once again permitted on string literals. It has no effect on the meaning of string literals and cannot be combined with the `r` prefix.

```python
class str(object=')
class str(object=b'', encoding='utf-8', errors='strict')
```

Return a string version of `object`. If `object` is not provided, returns the empty string. Otherwise, the behavior of `str()` depends on whether `encoding` or `errors` is given, as follows.

If neither `encoding` nor `errors` is given, `str(object)` returns `object.__str__()` which is the “informal” or nicely printable string representation of `object`. For string objects, this is the string itself. If `object` does not have a `__str__()` method, then `str()` falls back to returning `repr(object)`.

If at least one of `encoding` or `errors` is given, `object` should be a bytes-like object (e.g. `bytes` or `bytearray`). In this case, if `object` is a `bytes` (or `bytearray`) object, then `str(bytes, encoding, errors)` is equivalent to `bytes.decode(encoding, errors)`. Otherwise, the bytes object underlying the buffer object is obtained before calling `bytes.decode()`. See Binary Sequence Types — bytes, bytearray, memoryview and Buffer Protocol for information on buffer objects.

Passing a `bytes` object to `str()` without the `encoding` or `errors` arguments falls under the first case of returning the informal string representation (see also the `-b` command-line option to Python). For example:
For more information on the `str` class and its methods, see Text Sequence Type — `str` and the String Methods section below. To output formatted strings, see the String Formatting section. In addition, see the Text Processing Services section.

4.7.1. String Methods

Strings implement all of the common sequence operations, along with the additional methods described below.

Strings also support two styles of string formatting, one providing a large degree of flexibility and customization (see `str.format()`, Format String Syntax and String Formatting) and the other based on C printf style formatting that handles a narrower range of types and is slightly harder to use correctly, but is often faster for the cases it can handle (printf-style String Formatting).

The Text Processing Services section of the standard library covers a number of other modules that provide various text related utilities (including regular expression support in the `re` module).

**str.capitalize()**

Return a copy of the string with its first character capitalized and the rest lowercased.

**str.casefold()**

Return a casefolded copy of the string. Casefolded strings may be used for caseless matching.
Casefolding is similar to lowercasing but more aggressive because it is intended to remove all case distinctions in a string. For example, the German lowercase letter 'ß' is equivalent to "ss". Since it is already lowercase, `lower()` would do nothing to 'ß'; `casefold()` converts it to "ss".

The casefolding algorithm is described in section 3.13 of the Unicode Standard.

*New in version 3.3.*

```python
str.center(width[, fillchar])
```

Return centered in a string of length `width`. Padding is done using the specified `fillchar` (default is an ASCII space). The original string is returned if `width` is less than or equal to `len(s)`.

```python
str.count(sub[, start[, end]])
```

Return the number of non-overlapping occurrences of substring `sub` in the range `[start, end]`. Optional arguments `start` and `end` are interpreted as in slice notation.

```python
str.encode(encoding=“utf-8”, errors=“strict”)
```

Return an encoded version of the string as a bytes object. Default encoding is 'utf-8'. `errors` may be given to set a different error handling scheme. The default for `errors` is 'strict', meaning that encoding errors raise a `UnicodeError`. Other possible values are 'ignore', 'replace', 'xmlcharrefreplace', 'backslashreplace' and any other name registered via `codecs.register_error()`, see section *Error Handlers*. For a list of possible encodings, see section *Standard Encodings*.

*Changed in version 3.1:* Support for keyword arguments added.
str.\texttt{endswith}(\texttt{suffix[, start[, end]]})

Return True if the string ends with the specified \texttt{suffix}, otherwise return False. \texttt{suffix} can also be a tuple of suffixes to look for. With optional \texttt{start}, test beginning at that position. With optional \texttt{end}, stop comparing at that position.

str.\texttt{expandtabs}(\texttt{tabsize=8})

Return a copy of the string where all tab characters are replaced by one or more spaces, depending on the current column and the given tab size. Tab positions occur every \texttt{tabsize} characters (default is 8, giving tab positions at columns 0, 8, 16 and so on). To expand the string, the current column is set to zero and the string is examined character by character. If the character is a tab (\texttt{\t}), one or more space characters are inserted in the result until the current column is equal to the next tab position. (The tab character itself is not copied.) If the character is a newline (\texttt{\n}) or return (\texttt{\r}), it is copied and the current column is reset to zero. Any other character is copied unchanged and the current column is incremented by one regardless of how the character is represented when printed.

```
>>> '01\t012\t0123\t01234'.expandtabs()
'01 012 0123 01234'
>>> '01\t012\t0123\t01234'.expandtabs(4)
'01 012 0123 01234'
```

str.\texttt{find}(\texttt{sub[, start[, end]]})

Return the lowest index in the string where substring \texttt{sub} is found, such that \texttt{sub} is contained in the slice \texttt{s[start:end]}. Optional arguments \texttt{start} and \texttt{end} are interpreted as in slice notation. Return -1 if \texttt{sub} is not found.
Note: The `find()` method should be used only if you need to know the position of `sub`. To check if `sub` is a substring or not, use the `in` operator:

```python
>>> 'Py' in 'Python'
True
```

`str.format(*args, **kwargs)`

Perform a string formatting operation. The string on which this method is called can contain literal text or replacement fields delimited by braces `{}`. Each replacement field contains either the numeric index of a positional argument, or the name of a keyword argument. Returns a copy of the string where each replacement field is replaced with the string value of the corresponding argument.

```python
>>> "The sum of 1 + 2 is {0}".format(1+2)
'The sum of 1 + 2 is 3'
```

See [Format String Syntax](#) for a description of the various formatting options that can be specified in format strings.

`str.format_map(mapping)`

Similar to `str.format(**mapping)`, except that mapping is used directly and not copied to a `dict`. This is useful if for example mapping is a dict subclass:

```python
>>> class Default(dict):
...     def __missing__(self, key):
...         return key
... >>> '{name} was born in {country}'.format_map(Def
```
Guido was born in country

New in version 3.2.

str.index(sub[, start[, end]])
Like find(), but raise ValueError when the substring is not found.

str.isalnum()
Return true if all characters in the string are alphanumerics and there is at least one character, false otherwise. A character c is alphanumerics if one of the following returns True: c.isalpha(), c.isdecimal(), c.isdigit(), or c.isnumeric().

str.isalpha()
Return true if all characters in the string are alphabetic and there is at least one character, false otherwise. Alphabetic characters are those characters defined in the Unicode character database as “Letter”, i.e., those with general category property being one of “Lm”, “Lt”, “Lu”, “Ll”, or “Lo”. Note that this is different from the “Alphabetic” property defined in the Unicode Standard.

str.isdecimal()
Return true if all characters in the string are decimal characters and there is at least one character, false otherwise. Decimal characters are those from general category “Nd”. This category includes digit characters, and all characters that can be used to form decimal-radix numbers, e.g. U+0660, ARABIC-INDIC DIGIT ZERO.

str.isdigit()
Return true if all characters in the string are digits and there is at least one character, false otherwise. Digits include decimal
characters and digits that need special handling, such as the compatibility superscript digits. Formally, a digit is a character that has the property value Numeric_Type=Digit or Numeric_Type=Decimal.

str.isidentifier()
Return true if the string is a valid identifier according to the language definition, section Identifiers and keywords.

Use keyword.iskeyword() to test for reserved identifiers such as def and class.

str.islower()
Return true if all cased characters [4] in the string are lowercase and there is at least one cased character, false otherwise.

str.isnumeric()
Return true if all characters in the string are numeric characters, and there is at least one character, false otherwise. Numeric characters include digit characters, and all characters that have the Unicode numeric value property, e.g. U+2155, VULGAR FRACTION ONE FIFTH. Formally, numeric characters are those with the property value Numeric_Type=Digit, Numeric_Type=Decimal or Numeric_Type=Numeric.

str.isprintable()
Return true if all characters in the string are printable or the string is empty, false otherwise. Nonprintable characters are those characters defined in the Unicode character database as “Other” or “Separator”, excepting the ASCII space (0x20) which is considered printable. (Note that printable characters in this context are those which should not be escaped when repr() is invoked on a string.
It has no bearing on the handling of strings written to `sys.stdout` or `sys.stderr`.

**str.** `isspace()`  
Return true if there are only whitespace characters in the string and there is at least one character, false otherwise. Whitespace characters are those characters defined in the Unicode character database as “Other” or “Separator” and those with bidirectional property being one of “WS”, “B”, or “S”.

**str.** `istitle()`  
Return true if the string is a titlecased string and there is at least one character, for example uppercase characters may only follow uncased characters and lowercase characters only cased ones. Return false otherwise.

**str.** `isupper()`  
Return true if all cased characters [4] in the string are uppercase and there is at least one cased character, false otherwise.

**str.** `join(iterable)`  
Return a string which is the concatenation of the strings in the `iterable` `iterable`. A `TypeError` will be raised if there are any non-string values in `iterable`, including `bytes` objects. The separator between elements is the string providing this method.

**str.** `ljust(width[, fillchar])`  
Return the string left justified in a string of length `width`. Padding is done using the specified `fillchar` (default is an ASCII space). The original string is returned if `width` is less than or equal to `len(s)`.

**str.** `lower()`
Return a copy of the string with all the cased characters [4] converted to lowercase.

The lowercasing algorithm used is described in section 3.13 of the Unicode Standard.

```python
str.lstrip([chars])
```

Return a copy of the string with leading characters removed. The `chars` argument is a string specifying the set of characters to be removed. If omitted or None, the `chars` argument defaults to removing whitespace. The `chars` argument is not a prefix; rather, all combinations of its values are stripped:

```python
>>> ' spacious '.lstrip()
'spacious'
>>> 'www.example.com'.lstrip('cmowz.')
'exmaple.com'
```

```python
static str.maketrans(x[, y[, z]])
```

This static method returns a translation table usable for `str.translate()`.

If there is only one argument, it must be a dictionary mapping Unicode ordinals (integers) or characters (strings of length 1) to Unicode ordinals, strings (of arbitrary lengths) or None. Character keys will then be converted to ordinals.

If there are two arguments, they must be strings of equal length, and in the resulting dictionary, each character in `x` will be mapped to the character at the same position in `y`. If there is a third argument, it must be a string, whose characters will be mapped to None in the result.
str. **partition**(sep)
Split the string at the first occurrence of *sep*, and return a 3-tuple containing the part before the separator, the separator itself, and the part after the separator. If the separator is not found, return a 3-tuple containing the string itself, followed by two empty strings.

str. **replace**(old, new[, count])
Return a copy of the string with all occurrences of substring *old* replaced by *new*. If the optional argument *count* is given, only the first *count* occurrences are replaced.

str. **rfind**(sub[, start[, end]])
Return the highest index in the string where substring *sub* is found, such that *sub* is contained within *s*[start:end]. Optional arguments *start* and *end* are interpreted as in slice notation. Return -1 on failure.

str. **rindex**(sub[, start[, end]])
Like **rfind()** but raises **ValueError** when the substring *sub* is not found.

str. **rjust**(width[, fillchar])
Return the string right justified in a string of length *width*. Padding is done using the specified *fillchar* (default is an ASCII space). The original string is returned if *width* is less than or equal to len(*s*).

str. **rpartition**(sep)
Split the string at the last occurrence of *sep*, and return a 3-tuple containing the part before the separator, the separator itself, and the part after the separator. If the separator is not found, return a 3-tuple containing two empty strings, followed by the string itself.
str.rsplit(sep=None, maxsplit=-1)
Return a list of the words in the string, using sep as the delimiter string. If maxsplit is given, at most maxsplit splits are done, the rightmost ones. If sep is not specified or None, any whitespace string is a separator. Except for splitting from the right, rsplit() behaves like split() which is described in detail below.

str.rstrip([chars])
Return a copy of the string with trailing characters removed. The chars argument is a string specifying the set of characters to be removed. If omitted or None, the chars argument defaults to removing whitespace. The chars argument is not a suffix; rather, all combinations of its values are stripped:

```python
>>> ' spacious '.rstrip()
' spacious'
>>> 'mississippi'.rstrip('ipz')
'mississ'
```

str.split(sep=None, maxsplit=-1)
Return a list of the words in the string, using sep as the delimiter string. If maxsplit is given, at most maxsplit splits are done (thus, the list will have at most maxsplit+1 elements). If maxsplit is not specified or -1, then there is no limit on the number of splits (all possible splits are made).

If sep is given, consecutive delimiters are not grouped together and are deemed to delimit empty strings (for example, '1,,2'.split(',,')) returns ['1', '', '2']]. The sep argument may consist of multiple characters (for example, '1<>2<>3'.split('<>')) returns ['1', '2', '3']]. Splitting an empty string with a specified separator returns ['']].
For example:

```python
>>> '1,2,3'.split(',')
['1', '2', '3']
>>> '1,2,3'.split(',', maxsplit=1)
['1', '2,3']
>>> '1,2,,3,'.split(',')
['1', '2', '', '3', '']
```

If `sep` is not specified or is `None`, a different splitting algorithm is applied: runs of consecutive whitespace are regarded as a single separator, and the result will contain no empty strings at the start or end if the string has leading or trailing whitespace. Consequently, splitting an empty string or a string consisting of just whitespace with a `None` separator returns `[]`.

For example:

```python
>>> '1 2 3'.split()
['1', '2', '3']
>>> '1 2 3'.split(maxsplit=1)
['1', '2 3']
>>> '1 2 3 '.split()
['1', '2', '3']
```

```python
str.splitlines([keepends])
```

Return a list of the lines in the string, breaking at line boundaries. Line breaks are not included in the resulting list unless `keepends` is given and true.

This method splits on the following line boundaries. In particular, the boundaries are a superset of `universal newlines`.

<table>
<thead>
<tr>
<th>Representation</th>
<th>Description</th>
</tr>
</thead>
</table>

```
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\n</td>
<td>Line Feed</td>
</tr>
<tr>
<td>\r</td>
<td>Carriage Return</td>
</tr>
<tr>
<td>\r\n</td>
<td>Carriage Return + Line Feed</td>
</tr>
<tr>
<td>\v or \x0b</td>
<td>Line Tabulation</td>
</tr>
<tr>
<td>\f or \x0c</td>
<td>Form Feed</td>
</tr>
<tr>
<td>\x1c</td>
<td>File Separator</td>
</tr>
<tr>
<td>\x1d</td>
<td>Group Separator</td>
</tr>
<tr>
<td>\x1e</td>
<td>Record Separator</td>
</tr>
<tr>
<td>\x85</td>
<td>Next Line (C1 Control Code)</td>
</tr>
<tr>
<td>\u2028</td>
<td>Line Separator</td>
</tr>
<tr>
<td>\u2029</td>
<td>Paragraph Separator</td>
</tr>
</tbody>
</table>

*Changed in version 3.2:* \v and \f added to list of line boundaries.

For example:

```python
>>> 'ab c\n\nde fg\r\kl\r\n'.splitlines()
['ab c', '', 'de fg', 'kl']
>>> 'ab c\n\nde fg\r\kl\r\n'.splitlines(keepends=True)
['ab c\n', '\n', 'de fg\r', 'kl\r\n']
```

Unlike `split()` when a delimiter string `sep` is given, this method returns an empty list for the empty string, and a terminal line break does not result in an extra line:

```python
>>> ''.splitlines()
[]
>>> "One line\n".splitlines()
['One line']
```
For comparison, `split('\n')` gives:

```python
>>> ''.split('\n')
['']
>>> 'Two lines\n'.split('\n')
['Two lines', '']
```

**str.startwith**(prefix[, start[, end]])

Return True if string starts with the `prefix`, otherwise return False. `prefix` can also be a tuple of prefixes to look for. With optional `start`, test string beginning at that position. With optional `end`, stop comparing string at that position.

**str.strip**([chars])

Return a copy of the string with the leading and trailing characters removed. The `chars` argument is a string specifying the set of characters to be removed. If omitted or None, the `chars` argument defaults to removing whitespace. The `chars` argument is not a prefix or suffix; rather, all combinations of its values are stripped:

```python
>>> '    spacious    '.strip()
'spacious'
>>> 'www.example.com'.strip('cmowz.')
'exmaple'
```

The outermost leading and trailing `chars` argument values are stripped from the string. Characters are removed from the leading end until reaching a string character that is not contained in the set of characters in `chars`. A similar action takes place on the trailing end. For example:

```python
>>> comment_string = '#....... Section 3.2.1 Issue ' #!
>>> comment_string.strip('! #')
```
str. **swapcase()**

Return a copy of the string with uppercase characters converted to lowercase and vice versa. Note that it is not necessarily true that s.swapcase().swapcase() == s.

str. **title()**

Return a titlecased version of the string where words start with an uppercase character and the remaining characters are lowercase.

For example:

```python
>>> 'Hello world'.title()
'Hello World'
```

The algorithm uses a simple language-independent definition of a word as groups of consecutive letters. The definition works in many contexts but it means that apostrophes in contractions and possessives form word boundaries, which may not be the desired result:

```python
>>> "they're bill's friends from the UK".title()
'They'Re Bill'S Friends From The Uk'
```

A workaround for apostrophes can be constructed using regular expressions:

```python
>>> import re
>>> def titlecase(s):
...     return re.sub(r"[A-Za-z]+('[A-Za-z]+)?",
...                  lambda mo: mo.group(0)[0].upper() + mo.group(0)[1:],
...                  s)
```
str.translate(table)
Return a copy of the string in which each character has been mapped through the given translation table. The table must be an object that implements indexing via __getitem__(), typically a mapping or sequence. When indexed by a Unicode ordinal (an integer), the table object can do any of the following: return a Unicode ordinal or a string, to map the character to one or more other characters; return None, to delete the character from the return string; or raise a LookupError exception, to map the character to itself.

You can use str.maketrans() to create a translation map from character-to-character mappings in different formats.

See also the codecs module for a more flexible approach to custom character mappings.

str.upper()
Return a copy of the string with all the cased characters [4] converted to uppercase. Note that str.upper().isupper() might be False if s contains uncased characters or if the Unicode category of the resulting character(s) is not “Lu” (Letter, uppercase), but e.g. “Lt” (Letter, titlecase).

The uppercasing algorithm used is described in section 3.13 of the Unicode Standard.
str.zfill(width)

Return a copy of the string left filled with ASCII '0' digits to make a string of length width. A leading sign prefix ('+'/'-') is handled by inserting the padding after the sign character rather than before. The original string is returned if width is less than or equal to len(s).

For example:

```python
>>> "42".zfill(5)
'00042'
>>> "-42".zfill(5)
'-0042'
```

4.7.2. printf-style String Formatting

**Note:** The formatting operations described here exhibit a variety of quirks that lead to a number of common errors (such as failing to display tuples and dictionaries correctly). Using the newer `str.format()` interface helps avoid these errors, and also provides a generally more powerful, flexible and extensible approach to formatting text.

String objects have one unique built-in operation: the % operator (modulo). This is also known as the string formatting or interpolation operator. Given format % values (where format is a string), % conversion specifications in format are replaced with zero or more elements of values. The effect is similar to using the sprintf() in the C language.

If format requires a single argument, values may be a single non-tuple object. [5] Otherwise, values must be a tuple with exactly the number
of items specified by the format string, or a single mapping object (for example, a dictionary).

A conversion specifier contains two or more characters and has the following components, which must occur in this order:

1. The '%%' character, which marks the start of the specifier.
2. Mapping key (optional), consisting of a parenthesised sequence of characters (for example, (somename)).
3. Conversion flags (optional), which affect the result of some conversion types.
4. Minimum field width (optional). If specified as an '***' (asterisk), the actual width is read from the next element of the tuple in values, and the object to convert comes after the minimum field width and optional precision.
5. Precision (optional), given as a '.*' (dot) followed by the precision. If specified as '***' (an asterisk), the actual precision is read from the next element of the tuple in values, and the value to convert comes after the precision.
7. Conversion type.

When the right argument is a dictionary (or other mapping type), then the formats in the string must include a parenthesised mapping key into that dictionary inserted immediately after the '%%' character. The mapping key selects the value to be formatted from the mapping. For example:

```python
>>> print('%(language)s has %(number)03d quote types ...
       { 'language': "Python", "number": 2 })
Python has 002 quote types.
```

In this case no * specifiers may occur in a format (since they require a
sequential parameter list).

The conversion flag characters are:

<table>
<thead>
<tr>
<th>Flag</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'#'</td>
<td>The value conversion will use the “alternate form” (where defined below).</td>
</tr>
<tr>
<td>'0'</td>
<td>The conversion will be zero padded for numeric values.</td>
</tr>
<tr>
<td>'-'</td>
<td>The converted value is left adjusted (overrides the '0' conversion if both are given).</td>
</tr>
<tr>
<td></td>
<td>(a space) A blank should be left before a positive number (or empty string) produced by a signed conversion.</td>
</tr>
<tr>
<td>'+'</td>
<td>A sign character ('+' or '-' ) will precede the conversion (overrides a “space” flag).</td>
</tr>
</tbody>
</table>

A length modifier (h, l, or L) may be present, but is ignored as it is not necessary for Python – so e.g. %1d is identical to %d.

The conversion types are:

<table>
<thead>
<tr>
<th>Conversion</th>
<th>Meaning</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>'d'</td>
<td>Signed integer decimal.</td>
<td></td>
</tr>
<tr>
<td>'i'</td>
<td>Signed integer decimal.</td>
<td></td>
</tr>
<tr>
<td>'o'</td>
<td>Signed octal value.</td>
<td>(1)</td>
</tr>
<tr>
<td>'u'</td>
<td>Obsolete type – it is identical to 'd'.</td>
<td>(7)</td>
</tr>
<tr>
<td>'x'</td>
<td>Signed hexadecimal (lowercase).</td>
<td>(2)</td>
</tr>
<tr>
<td>'X'</td>
<td>Signed hexadecimal (uppercase).</td>
<td>(2)</td>
</tr>
<tr>
<td>'e'</td>
<td>Floating point exponential format (lowercase).</td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td>Floating point exponential format</td>
<td></td>
</tr>
<tr>
<td>Format</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>'E'</td>
<td>(uppercase). (3)</td>
<td></td>
</tr>
<tr>
<td>'f'</td>
<td>Floating point decimal format. (3)</td>
<td></td>
</tr>
<tr>
<td>'F'</td>
<td>Floating point decimal format. (3)</td>
<td></td>
</tr>
<tr>
<td>'g'</td>
<td>Floating point format. Uses lowercase exponential format if exponent is less than -4 or not less than precision, decimal format otherwise. (4)</td>
<td></td>
</tr>
<tr>
<td>'G'</td>
<td>Floating point format. Uses uppercase exponential format if exponent is less than -4 or not less than precision, decimal format otherwise. (4)</td>
<td></td>
</tr>
<tr>
<td>'c'</td>
<td>Single character (accepts integer or single character string).</td>
<td></td>
</tr>
<tr>
<td>'r'</td>
<td>String (converts any Python object using <code>repr()</code>). (5)</td>
<td></td>
</tr>
<tr>
<td>'s'</td>
<td>String (converts any Python object using <code>str()</code>). (5)</td>
<td></td>
</tr>
<tr>
<td>'a'</td>
<td>String (converts any Python object using <code>ascii()</code>). (5)</td>
<td></td>
</tr>
<tr>
<td>'%'</td>
<td>No argument is converted, results in a '%%' character in the result.</td>
<td></td>
</tr>
</tbody>
</table>

Notes:

1. The alternate form causes a leading zero ('0') to be inserted between left-hand padding and the formatting of the number if the leading character of the result is not already a zero.

2. The alternate form causes a leading '0x' or '0X' (depending on whether the 'x' or 'X' format was used) to be inserted between left-hand padding and the formatting of the number if the leading
character of the result is not already a zero.

3. The alternate form causes the result to always contain a decimal point, even if no digits follow it.

   The precision determines the number of digits after the decimal point and defaults to 6.

4. The alternate form causes the result to always contain a decimal point, and trailing zeroes are not removed as they would otherwise be.

   The precision determines the number of significant digits before and after the decimal point and defaults to 6.

5. If precision is N, the output is truncated to N characters.

7. See PEP 237.

Since Python strings have an explicit length, %s conversions do not assume that '\\0' is the end of the string.

_Changed in version 3.1:_ %f conversions for numbers whose absolute value is over 1e50 are no longer replaced by %g conversions.
4.8. Binary Sequence Types — bytes,
bytearray, memoryview
The core built-in types for manipulating binary data are bytes and
bytearray. They are supported by memoryview which uses the
buffer protocol to access the memory of other binary objects without
needing to make a copy.
The array module supports efficient storage of basic data types like
32-bit integers and IEEE754 double-precision floating values.

4.8.1. Bytes
Bytes objects are immutable sequences of single bytes. Since many
major binary protocols are based on the ASCII text encoding, bytes
objects offer several methods that are only valid when working with
ASCII compatible data and are closely related to string objects in a
variety of other ways.
Firstly, the syntax for bytes literals is largely the same as that for string
literals, except that a b prefix is added:
Single quotes: b'still allows embedded "double"
quotes'
Double quotes: b"still allows embedded 'single'
quotes".
Triple quoted: b'''3 single quotes''', b"""3 double
quotes"""
Only ASCII characters are permitted in bytes literals (regardless of the
declared source code encoding). Any binary values over 127 must be


entered into bytes literals using the appropriate escape sequence.

As with string literals, bytes literals may also use a r prefix to disable processing of escape sequences. See String and Bytes literals for more about the various forms of bytes literal, including supported escape sequences.

While bytes literals and representations are based on ASCII text, bytes objects actually behave like immutable sequences of integers, with each value in the sequence restricted such that 0 <= x < 256 (attempts to violate this restriction will trigger ValueError. This is done deliberately to emphasise that while many binary formats include ASCII based elements and can be usefully manipulated with some text-oriented algorithms, this is not generally the case for arbitrary binary data (blindly applying text processing algorithms to binary data formats that are not ASCII compatible will usually lead to data corruption).

In addition to the literal forms, bytes objects can be created in a number of other ways:

- A zero-filled bytes object of a specified length: `bytes(10)`
- From an iterable of integers: `bytes(range(20))`
- Copying existing binary data via the buffer protocol: `bytes(obj)`

Also see the bytes built-in.

Since 2 hexadecimal digits correspond precisely to a single byte, hexadecimal numbers are a commonly used format for describing binary data. Accordingly, the bytes type has an additional class method to read data in that format:

```
classmethod bytes.fromhex(string)
```
This `bytes` class method returns a bytes object, decoding the given string object. The string must contain two hexadecimal digits per byte, with ASCII spaces being ignored.

```python
>>> bytes.fromhex('2Ef0 F1f2 ')
'b'.xf0xf1xf2'
```

A reverse conversion function exists to transform a bytes object into its hexadecimal representation.

```python
bytes.hex()
```

Return a string object containing two hexadecimal digits for each byte in the instance.

```python
>>> b'\xf0\xf1\xf2'.hex()
'f0f1f2'
```

*New in version 3.5.*

Since bytes objects are sequences of integers (akin to a tuple), for a bytes object `b`, `b[0]` will be an integer, while `b[0:1]` will be a bytes object of length 1. (This contrasts with text strings, where both indexing and slicing will produce a string of length 1)

The representation of bytes objects uses the literal format (`b'...'`) since it is often more useful than e.g. `bytes([46, 46, 46])`. You can always convert a bytes object into a list of integers using `list(b)`. 

**Note:** For Python 2.x users: In the Python 2.x series, a variety of implicit conversions between 8-bit strings (the closest thing 2.x offers to a built-in binary data type) and Unicode strings were permitted. This was a backwards compatibility workaround to account for the
fact that Python originally only supported 8-bit text, and Unicode text was a later addition. In Python 3.x, those implicit conversions are gone - conversions between 8-bit binary data and Unicode text must be explicit, and bytes and string objects will always compare unequal.

4.8.2. Bytearray Objects

`bytearray` objects are a mutable counterpart to `bytes` objects. There is no dedicated literal syntax for `bytearray` objects, instead they are always created by calling the constructor:

- Creating an empty instance: `bytearray()`
- Creating a zero-filled instance with a given length: `bytearray(10)`
- From an iterable of integers: `bytearray(range(20))`
- Copying existing binary data via the buffer protocol: `bytearray(b'Hi!')`

As `bytearray` objects are mutable, they support the `mutable` sequence operations in addition to the common `bytes` and `bytearray` operations described in `Bytes and Bytearray Operations`.

Also see the `bytearray` built-in.

Since 2 hexadecimal digits correspond precisely to a single byte, hexadecimal numbers are a commonly used format for describing binary data. Accordingly, the `bytearray` type has an additional class method to read data in that format:

`classmethod bytearray.fromhex(string)`

This `bytearray` class method returns `bytearray` object, decoding the given string object. The string must contain two hexadecimal
digits per byte, with ASCII spaces being ignored.

```python
>>> bytearray.fromhex('2Ef0 F1f2')
bytearray(b'\xf0\xf1\xf2')
```

A reverse conversion function exists to transform a bytearray object into its hexadecimal representation.

`bytearray.hex()`

Return a string object containing two hexadecimal digits for each byte in the instance.

```python
>>> bytearray(b'\xf0\xf1\xf2').hex()
'f0f1f2'
```

*New in version 3.5.*

Since bytearray objects are sequences of integers (akin to a list), for a bytearray object \(b\), \(b[0]\) will be an integer, while \(b[0:1]\) will be a bytearray object of length 1. (This contrasts with text strings, where both indexing and slicing will produce a string of length 1)

The representation of bytearray objects uses the bytes literal format (`bytearray(b'...')`) since it is often more useful than e.g. `bytearray([46, 46, 46])`. You can always convert a bytearray object into a list of integers using `list(b)`.

### 4.8.3. Bytes and Bytearray Operations

Both bytes and bytearray objects support the common sequence operations. They interoperate not just with operands of the same type, but with any bytes-like object. Due to this flexibility, they can be freely mixed in operations without causing errors. However, the return type of
the result may depend on the order of operands.

**Note:** The methods on bytes and bytearray objects don’t accept strings as their arguments, just as the methods on strings don’t accept bytes as their arguments. For example, you have to write:

```python
a = "abc"
b = a.replace("a", "f")
```

and:

```python
a = b"abc"
b = a.replace(b"a", b"f")
```

Some bytes and bytearray operations assume the use of ASCII compatible binary formats, and hence should be avoided when working with arbitrary binary data. These restrictions are covered below.

**Note:** Using these ASCII based operations to manipulate binary data that is not stored in an ASCII based format may lead to data corruption.

The following methods on bytes and bytearray objects can be used with arbitrary binary data.

```python
bytes.count(sub[, start[, end]])
bytearray.count(sub[, start[, end]])
```

Return the number of non-overlapping occurrences of subsequence `sub` in the range `[start, end]`. Optional arguments `start` and `end` are interpreted as in slice notation.
The subsequence to search for may be any bytes-like object or an integer in the range 0 to 255.

*Changed in version 3.3:* Also accept an integer in the range 0 to 255 as the subsequence.

```python
bytes.decode(encoding="utf-8", errors="strict")
```

bytearray.decode(encoding="utf-8", errors="strict")

Return a string decoded from the given bytes. Default encoding is 'utf-8'. errors may be given to set a different error handling scheme. The default for errors is 'strict', meaning that encoding errors raise a UnicodeError. Other possible values are 'ignore', 'replace' and any other name registered via codecs.register_error(), see section Error Handlers. For a list of possible encodings, see section Standard Encodings.

**Note:** Passing the encoding argument to str allows decoding any bytes-like object directly, without needing to make a temporary bytes or bytearray object.

*Changed in version 3.1:* Added support for keyword arguments.

```python
bytes.endswith(suffix[, start[, end]])
bytearray.endswith(suffix[, start[, end]])
```

Return True if the binary data ends with the specified suffix, otherwise return False. suffix can also be a tuple of suffixes to look for. With optional start, test beginning at that position. With optional end, stop comparing at that position.

The suffix(es) to search for may be any bytes-like object.

```python
bytes.find(sub[, start[, end]])
```
bytearray.<code>find</code>(<em>sub</em>[<em>, start</em> [, <em>end</em> ]])

Return the lowest index in the data where the subsequence <em>sub</em> is found, such that <em>sub</em> is contained in the slice <em>s[start:end]</em>. Optional arguments <em>start</em> and <em>end</em> are interpreted as in slice notation. Return -1 if <em>sub</em> is not found.

The subsequence to search for may be any bytes-like object or an integer in the range 0 to 255.

Note: The <code>find()</code> method should be used only if you need to know the position of <em>sub</em>. To check if <em>sub</em> is a substring or not, use the <code>in</code> operator:

```python
>>> b'Py' in b'Python'
True
```

<em>Changed in version 3.3:</em> Also accept an integer in the range 0 to 255 as the subsequence.

<code>bytearray.<code>index</code>(<em>sub</em>[<em>, start</em> [, <em>end</em> ]])</code>
<code>bytes.<code>index</code>(<em>sub</em>[<em>, start</em> [, <em>end</em> ]])</code>

Like <code>find()</code>, but raise <code>ValueError</code> when the subsequence is not found.

The subsequence to search for may be any bytes-like object or an integer in the range 0 to 255.

<em>Changed in version 3.3:</em> Also accept an integer in the range 0 to 255 as the subsequence.

<code>bytearray.<code>join</code>(<code>iterable</code>)</code>
<code>bytes.<code>join</code>(<code>iterable</code>)</code>
Return a bytes or bytearray object which is the concatenation of the binary data sequences in the iterable iterable. A TypeError will be raised if there are any values in iterable that are not bytes-like objects, including str objects. The separator between elements is the contents of the bytes or bytearray object providing this method.

\[
\text{static bytes.} \text{maketrans}(\text{from, to}) \\
\text{static bytearray.} \text{maketrans}(\text{from, to})
\]

This static method returns a translation table usable for \text{bytes.translate(\text{)} that will map each character in from into the character at the same position in to; from and to must both be bytes-like objects and have the same length.}

\text{New in version 3.1.}

\[
\text{bytes.} \text{partition(}\text{sep)} \\
\text{bytearray.} \text{partition(}\text{sep)}
\]

Split the sequence at the first occurrence of sep, and return a 3-tuple containing the part before the separator, the separator, and the part after the separator. If the separator is not found, return a 3-tuple containing a copy of the original sequence, followed by two empty bytes or bytearray objects.

The separator to search for may be any bytes-like object.

\[
\text{bytes.} \text{replace}(\text{old, new[], count[])} \\
\text{bytearray.} \text{replace}(\text{old, new[], count[]})
\]

Return a copy of the sequence with all occurrences of subsequence old replaced by new. If the optional argument count is given, only the first count occurrences are replaced.
The subsequence to search for and its replacement may be any bytes-like object.

**Note:** The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

```python
bytes.rfind(sub[, start[, end]])
bytearray.rfind(sub[, start[, end]])
```

Return the highest index in the sequence where the subsequence `sub` is found, such that `sub` is contained within `s[start:end]`. Optional arguments `start` and `end` are interpreted as in slice notation. Return `-1` on failure.

The subsequence to search for may be any bytes-like object or an integer in the range 0 to 255.

*Changed in version 3.3:* Also accept an integer in the range 0 to 255 as the subsequence.

```python
bytes.rindex(sub[, start[, end]])
bytearray.rindex(sub[, start[, end]])
```

Like `rfind()` but raises `ValueError` when the subsequence `sub` is not found.

The subsequence to search for may be any bytes-like object or an integer in the range 0 to 255.

*Changed in version 3.3:* Also accept an integer in the range 0 to 255 as the subsequence.

```python
bytes.rpartition(sep)
```
bytearray.\texttt{rpartition}(sep)
Split the sequence at the last occurrence of \texttt{sep}, and return a 3-
tuple containing the part before the separator, the separator, and
the part after the separator. If the separator is not found, return a 3-
tuple containing a copy of the original sequence, followed by two
empty bytes or bytearray objects.

The separator to search for may be any \texttt{bytes-like object}.

\texttt{bytes.\texttt{startswith}(prefix[, start[, end]])}
\texttt{bytearray.\texttt{startswith}(prefix[, start[, end]])}
Return True if the binary data starts with the specified \texttt{prefix},
otherwise return False. \texttt{prefix} can also be a tuple of prefixes to
look for. With optional \texttt{start}, test beginning at that position. With
optional \texttt{end}, stop comparing at that position.

The prefix(es) to search for may be any \texttt{bytes-like object}.

\texttt{bytes.\texttt{translate}(table[, delete])}
\texttt{bytearray.\texttt{translate}(table[, delete])}
Return a copy of the bytes or bytearray object where all bytes
occurring in the optional argument \texttt{delete} are removed, and the
remaining bytes have been mapped through the given translation
table, which must be a bytes object of length 256.

You can use the \texttt{bytes.maketrans()} method to create a
translation table.

Set the \texttt{table} argument to \texttt{None} for translations that only delete
characters:

\texttt{>>> b'\texttt{read this short text}'.translate(\texttt{None, b'aei'})}
The following methods on bytes and bytearray objects have default behaviours that assume the use of ASCII compatible binary formats, but can still be used with arbitrary binary data by passing appropriate arguments. Note that all of the bytearray methods in this section do not operate in place, and instead produce new objects.

```
bytes.center(width[, fillbyte])
```
```
bytearray.center(width[, fillbyte])
```

Return a copy of the object centered in a sequence of length `width`. Padding is done using the specified `fillbyte` (default is an ASCII space). For `bytes` objects, the original sequence is returned if `width` is less than or equal to `len(s)`.

```
Note: The bytearray version of this method does not operate in place - it always produces a new object, even if no changes were made.
```

```
bytes.ljust(width[, fillbyte])
```
```
bytearray.ljust(width[, fillbyte])
```

Return a copy of the object left justified in a sequence of length `width`. Padding is done using the specified `fillbyte` (default is an ASCII space). For `bytes` objects, the original sequence is returned if `width` is less than or equal to `len(s)`.

```
Note: The bytearray version of this method does not operate in place - it always produces a new object, even if no changes were made.
```
bytes.\texttt{lstrip}([\texttt{chars}])
bytearray.\texttt{lstrip}([\texttt{chars}])

Return a copy of the sequence with specified leading bytes removed. The \texttt{chars} argument is a binary sequence specifying the set of byte values to be removed - the name refers to the fact this method is usually used with ASCII characters. If omitted or None, the \texttt{chars} argument defaults to removing ASCII whitespace. The \texttt{chars} argument is not a prefix; rather, all combinations of its values are stripped:

\begin{verbatim}
>>> b' spacious '.lstrip()
 b'spacious '
>>> b'www.example.com'.lstrip(b'cmowz.')
 b'example.com'
\end{verbatim}

The binary sequence of byte values to remove may be any \texttt{bytes}-like object.

\textbf{Note:} The bytearray version of this method does not operate in place - it always produces a new object, even if no changes were made.

bytes.\texttt{rjust}(\texttt{width[, fillbyte]})
bytearray.\texttt{rjust}(\texttt{width[, fillbyte]})

Return a copy of the object right justified in a sequence of length \texttt{width}. Padding is done using the specified \texttt{fillbyte} (default is an ASCII space). For \texttt{bytes} objects, the original sequence is returned if \texttt{width} is less than or equal to \texttt{len(s)}.

\textbf{Note:} The bytearray version of this method does not operate in place - it always produces a new object, even if no changes were made.
bytes.rsplit(sep=None, maxsplit=-1)
bytearray.rsplit(sep=None, maxsplit=-1)

Split the binary sequence into subsequences of the same type, using sep as the delimiter string. If maxsplit is given, at most maxsplit splits are done, the rightmost ones. If sep is not specified or None, any subsequence consisting solely of ASCII whitespace is a separator. Except for splitting from the right, rsplit() behaves like split() which is described in detail below.

bytes.rstrip([chars])
bytearray.rstrip([chars])

Return a copy of the sequence with specified trailing bytes removed. The chars argument is a binary sequence specifying the set of byte values to be removed - the name refers to the fact this method is usually used with ASCII characters. If omitted or None, the chars argument defaults to removing ASCII whitespace. The chars argument is not a suffix; rather, all combinations of its values are stripped:

```python
>>> b' spacious '.rstrip()
b' spacious'
>>> b'mississippi'.rstrip(b'ipz')
b'mississ'
```

The binary sequence of byte values to remove may be any bytes-like object.

**Note:** The bytearray version of this method does not operate in place - it always produces a new object, even if no changes were made.
Split the binary sequence into subsequences of the same type, using `sep` as the delimiter string. If `maxsplit` is given and non-negative, at most `maxsplit` splits are done (thus, the list will have at most `maxsplit+1` elements). If `maxsplit` is not specified or is `-1`, then there is no limit on the number of splits (all possible splits are made).

If `sep` is given, consecutive delimiters are not grouped together and are deemed to delimit empty subsequences (for example, `b'1,,2'.split(b',')` returns `[b'1', b'', b'2']`). The `sep` argument may consist of a multibyte sequence (for example, `b'1<>2<>3'.split(b'<>')` returns `[b'1', b'2', b'3']`).

Splitting an empty sequence with a specified separator returns `[b'']` or `[bytearray(b'')]` depending on the type of object being split. The `sep` argument may be any `bytes-like object`.

For example:

```python
>>> b'1,2,3'.split(b',')
[b'1', b'2', b'3']
>>> b'1,2,3'.split(b',', maxsplit=1)
[b'1', b'2,3']
>>> b'1,2,,3,'.split(b',')
[b'1', b'2', b'', b'3', b'']
```

If `sep` is not specified or is `None`, a different splitting algorithm is applied: runs of consecutive ASCII whitespace are regarded as a single separator, and the result will contain no empty strings at the start or end if the sequence has leading or trailing whitespace. Consequently, splitting an empty sequence or a sequence
consisting solely of ASCII whitespace without a specified separator returns `[]`.

For example:

```python
>>> b'1 2 3'.split()
[b'1', b'2', b'3']
>>> b'1 2 3'.split(maxsplit=1)
[b'1', b'2 3']
>>> b' 1 2 3 '.split()
[b'1', b'2', b'3']
```

**bytes**.strip([chars])

**bytearray**.strip([chars])

Return a copy of the sequence with specified leading and trailing bytes removed. The *chars* argument is a binary sequence specifying the set of byte values to be removed - the name refers to the fact this method is usually used with ASCII characters. If omitted or None, the *chars* argument defaults to removing ASCII whitespace. The *chars* argument is not a prefix or suffix; rather, all combinations of its values are stripped:

```python
>>> b' spacious '.strip()
'b spacious'
>>> b'www.example.com'.strip(b'cmowz.')
b'exmaple'
```

The binary sequence of byte values to remove may be any bytes-like object.

**Note:** The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.
The following methods on bytes and bytearray objects assume the use of ASCII compatible binary formats and should not be applied to arbitrary binary data. Note that all of the bytearray methods in this section do not operate in place, and instead produce new objects.

`bytes.capitalize()`
`bytearray.capitalize()`

Return a copy of the sequence with each byte interpreted as an ASCII character, and the first byte capitalized and the rest lowercased. Non-ASCII byte values are passed through unchanged.

**Note:** The bytearray version of this method does not operate in place - it always produces a new object, even if no changes were made.

`bytes.expandtabs(tabsize=8)`
`bytearray.expandtabs(tabsize=8)`

Return a copy of the sequence where all ASCII tab characters are replaced by one or more ASCII spaces, depending on the current column and the given tab size. Tab positions occur every `tabsize` bytes (default is 8, giving tab positions at columns 0, 8, 16 and so on). To expand the sequence, the current column is set to zero and the sequence is examined byte by byte. If the byte is an ASCII tab character (b'\t'), one or more space characters are inserted in the result until the current column is equal to the next tab position. (The tab character itself is not copied.) If the current byte is an ASCII newline (b'\n') or carriage return (b'\r'), it is copied and the current column is reset to zero. Any other byte value is copied unchanged and the current column is incremented by one regardless of how the byte value is represented when printed:
Note: The bytearray version of this method does not operate in place - it always produces a new object, even if no changes were made.

bytes.isalnum()
bytestring.isalnum()

Return true if all bytes in the sequence are alphabetical ASCII characters or ASCII decimal digits and the sequence is not empty, false otherwise. Alphabetic ASCII characters are those byte values in the sequence b'abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ'
ASCII decimal digits are those byte values in the sequence b'0123456789'.

For example:

```python
>>> b'ABCabc1'.isalnum()
True
>>> b'ABC abc1'.isalnum()
False
```

bytes.isalpha()
bytestring.isalpha()

Return true if all bytes in the sequence are alphabetic ASCII characters and the sequence is not empty, false otherwise. Alphabetic ASCII characters are those byte values in the sequence b'abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ'
For example:

```python
>>> b'ABCabc'.isalpha()
True
>>> b'ABCabc1'.isalpha()
False
```

**bytes.isdigit()**

**bytearray.isdigit()**

Return true if all bytes in the sequence are ASCII decimal digits and the sequence is not empty, false otherwise. ASCII decimal digits are those byte values in the sequence `b'0123456789'`.

For example:

```python
>>> b'1234'.isdigit()
True
>>> b'1.23'.isdigit()
False
```

**bytes.islower()**

**bytearray.islower()**

Return true if there is at least one lowercase ASCII character in the sequence and no uppercase ASCII characters, false otherwise.

For example:

```python
>>> b'hello world'.islower()
True
>>> b'Hello world'.islower()
False
```

Lowercase ASCII characters are those byte values in the sequence `b'abcdefghijklmnopqrstuvwxyz'`. Uppercase ASCII
characters are those byte values in the sequence b'ABCDEFGHIJKLMNOPQRSTUVWXYZ'.

bytes.isspace()
bytearray.isspace()

Return true if all bytes in the sequence are ASCII whitespace and the sequence is not empty, false otherwise. ASCII whitespace characters are those byte values in the sequence b'\x09\x0a\x0b\x0c\x0d\x0e\x0f\n' (space, tab, newline, carriage return, vertical tab, form feed).

bytes.istitle()
bytearray.istitle()

Return true if the sequence is ASCII titlecase and the sequence is not empty, false otherwise. See bytes.title() for more details on the definition of “titlecase”.

For example:

```python
>>> b'Hello World'.istitle()
True
>>> b'Hello world'.istitle()
False
```

bytes.isupper()
bytearray.isupper()

Return true if there is at least one uppercase alphabetic ASCII character in the sequence and no lowercase ASCII characters, false otherwise.

For example:

```python
>>> b'HELLO WORLD'.isupper()
True
```
>>> b'Hello world'.isupper()
False

Lowercase ASCII characters are those byte values in the sequence b'abcdefghijklmnopqrstuvwxyz'. Uppercase ASCII characters are those byte values in the sequence b'ABCDEFGHIJKLMNOPQRSTUVWXYZ'.

bytes.lower()
byterarray.lower()

Return a copy of the sequence with all the uppercase ASCII characters converted to their corresponding lowercase counterpart.

For example:

>>> b'Hello World'.lower()
b'hello world'

Lowercase ASCII characters are those byte values in the sequence b'abcdefghijklmnopqrstuvwxyz'. Uppercase ASCII characters are those byte values in the sequence b'ABCDEFGHIJKLMNOPQRSTUVWXYZ'.

Note: The bytarray version of this method does not operate in place - it always produces a new object, even if no changes were made.

bytes.splitlines(keepends=False)
byterarray.splitlines(keepends=False)

Return a list of the lines in the binary sequence, breaking at ASCII line boundaries. This method uses the universal newlines approach to splitting lines. Line breaks are not included in the resulting list
unless `keepends` is given and true.

For example:

```python
>>> b'ab c\nde fg\rkl\r\n'.splitlines()
[b'ab c', b'', b'de fg', b'kl']
>>> b'ab c\nde fg\rkl\r\n'.splitlines(keepends=True)
[b'ab c\n', b'\n', b'de fg\r', b'kl\r\n']
```

Unlike `split()` when a delimiter string `sep` is given, this method returns an empty list for the empty string, and a terminal line break does not result in an extra line:

```python
>>> b''.split(b'\n'), b'Two lines\n'.split(b'\n')
([b''], [b'Two lines', b''])
>>> b''.splitlines(), b'One line\n'.splitlines()
([], [b'One line'])
```

`bytes.swapcase()`

`bytearray.swapcase()`

Return a copy of the sequence with all the lowercase ASCII characters converted to their corresponding uppercase counterpart and vice-versa.

For example:

```python
>>> b'Hello World'.swapcase()
'b'hELLO wORLD'
```

Lowercase ASCII characters are those byte values in the sequence `b'abcdefghijklmnopqrstuvwxyz'`. Uppercase ASCII characters are those byte values in the sequence `b'ABCDEFGHIJKLMNOPQRSTUVWXYZ'`. 
Unlike `str.swapcase()`, it is always the case that `bin.swapcase().swapcase() == bin` for the binary versions. Case conversions are symmetrical in ASCII, even though that is not generally true for arbitrary Unicode code points.

**Note:** The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

`bytes.title()`  
`bytearray.title()`

Return a titlecased version of the binary sequence where words start with an uppercase ASCII character and the remaining characters are lowercase. Uncased byte values are left unmodified.

For example:

```python
>>> b'Hello world'.title()
b'Hello Hello World'
```

Lowercase ASCII characters are those byte values in the sequence `b'abcdefghijklmnopqrstuvwxyz'`. Uppercase ASCII characters are those byte values in the sequence `b'ABCDEFGHIJKLMNOPQRSTUVWXYZ'`. All other byte values are uncased.

The algorithm uses a simple language-independent definition of a word as groups of consecutive letters. The definition works in many contexts but it means that apostrophes in contractions and possessives form word boundaries, which may not be the desired result:
A workaround for apostrophes can be constructed using regular expressions:

```python
>>> import re
>>> def titlecase(s):
...    return re.sub(rb"[A-Za-z]+('[A-Za-z]+)?", lambda mo: mo.group(0)[0:1] + mo.group(0)[1:], s)
...    
>>> titlecase(b"they're bill's friends."
b"They're Bill's Friends.
```

**Note:** The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

`bytes.upper()`

`bytearray.upper()`

Return a copy of the sequence with all the lowercase ASCII characters converted to their corresponding uppercase counterpart.

For example:

```python
>>> b'Hello World'.upper()
'HELLO WORLD'
```

Lowercase ASCII characters are those byte values in the sequence...
\texttt{b'abcdefghijklmnopqrstuvwxyz'.} Uppercase ASCII characters are those byte values in the sequence \texttt{b'ABCDEFGHIJKLMNOPQRSTUVWXYZ'}.

\textbf{Note:} The bytearray version of this method does \textit{not} operate in place - it always produces a new object, even if no changes were made.

\texttt{bytes.\textbf{zfill}(width)}
\texttt{bytearray.\textbf{zfill}(width)}

Return a copy of the sequence left filled with ASCII \texttt{b'0'} digits to make a sequence of length \texttt{width}. A leading sign prefix (\texttt{b'+'} / \texttt{b'-'} is handled by inserting the padding \textit{after} the sign character rather than before. For \texttt{bytes} objects, the original sequence is returned if \texttt{width} is less than or equal to \texttt{len(seq)}.

For example:

\begin{verbatim}
>>> b"42".zfill(5)
b'00042'
>>> b"-42".zfill(5)
b'-0042'
\end{verbatim}

\textbf{Note:} The bytearray version of this method does \textit{not} operate in place - it always produces a new object, even if no changes were made.

4.8.4. \texttt{printf}-style Bytes Formatting

\textbf{Note:} The formatting operations described here exhibit a variety of quirks that lead to a number of common errors (such as failing to
display tuples and dictionaries correctly). If the value being printed may be a tuple or dictionary, wrap it in a tuple.

Bytes objects (bytes/bytearray) have one unique built-in operation: the % operator (modulo). This is also known as the bytes formatting or interpolation operator. Given format % values (where format is a bytes object), % conversion specifications in format are replaced with zero or more elements of values. The effect is similar to using the sprintf() in the C language.

If format requires a single argument, values may be a single non-tuple object. Otherwise, values must be a tuple with exactly the number of items specified by the format bytes object, or a single mapping object (for example, a dictionary).

A conversion specifier contains two or more characters and has the following components, which must occur in this order:

1. The '%', which marks the start of the specifier.
2. Mapping key (optional), consisting of a parenthesised sequence of characters (for example, (somename)).
3. Conversion flags (optional), which affect the result of some conversion types.
4. Minimum field width (optional). If specified as an '*' (asterisk), the actual width is read from the next element of the tuple in values, and the object to convert comes after the minimum field width and optional precision.
5. Precision (optional), given as a '.' (dot) followed by the precision. If specified as '*' (an asterisk), the actual precision is read from the next element of the tuple in values, and the value to convert comes after the precision.
7. Conversion type.
When the right argument is a dictionary (or other mapping type), then the formats in the bytes object must include a parenthesised mapping key into that dictionary inserted immediately after the '%' character. The mapping key selects the value to be formatted from the mapping. For example:

```python
>>> print(b'%(language)s has %(number)03d quote types.
... {b'language': b'Python', b'number': 2})
b'Python has 002 quote types.'
```

In this case no * specifiers may occur in a format (since they require a sequential parameter list).

The conversion flag characters are:

<table>
<thead>
<tr>
<th>Flag</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'# '</td>
<td>The value conversion will use the “alternate form” (where defined below).</td>
</tr>
<tr>
<td>'0 '</td>
<td>The conversion will be zero padded for numeric values.</td>
</tr>
<tr>
<td>'-'</td>
<td>The converted value is left adjusted (overrides the '0' conversion if both are given).</td>
</tr>
<tr>
<td>' '</td>
<td>(a space) A blank should be left before a positive number (or empty string) produced by a signed conversion.</td>
</tr>
<tr>
<td>'+ '</td>
<td>A sign character ('+' or '-') will precede the conversion (overrides a “space” flag).</td>
</tr>
</tbody>
</table>

A length modifier (h, l, or L) may be present, but is ignored as it is not necessary for Python – so e.g. %1d is identical to %d.

The conversion types are:

<table>
<thead>
<tr>
<th>Conversion</th>
<th>Meaning</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>'d'</td>
<td>Signed integer decimal.</td>
</tr>
<tr>
<td>'i'</td>
<td>Signed integer decimal.</td>
</tr>
<tr>
<td>'o'</td>
<td>Signed octal value.</td>
</tr>
<tr>
<td>'u'</td>
<td>Obsolete type – it is identical to 'd'.</td>
</tr>
<tr>
<td>'x'</td>
<td>Signed hexadecimal (lowercase).</td>
</tr>
<tr>
<td>'X'</td>
<td>Signed hexadecimal (uppercase).</td>
</tr>
<tr>
<td>'e'</td>
<td>Floating point exponential format (lowercase).</td>
</tr>
<tr>
<td>'E'</td>
<td>Floating point exponential format (uppercase).</td>
</tr>
<tr>
<td>'f'</td>
<td>Floating point decimal format.</td>
</tr>
<tr>
<td>'F'</td>
<td>Floating point decimal format.</td>
</tr>
<tr>
<td>'g'</td>
<td>Floating point format. Uses lowercase exponential format if exponent is less than -4 or not less than precision, decimal format otherwise.</td>
</tr>
<tr>
<td>'G'</td>
<td>Floating point format. Uses uppercase exponential format if exponent is less than -4 or not less than precision, decimal format otherwise.</td>
</tr>
<tr>
<td>'c'</td>
<td>Single byte (accepts integer or single byte objects).</td>
</tr>
<tr>
<td>'b'</td>
<td>Bytes (any object that follows the buffer protocol or has <code>__bytes__()</code>).</td>
</tr>
<tr>
<td>'s'</td>
<td>'s' is an alias for 'b' and should only be used for Python2/3 code bases.</td>
</tr>
<tr>
<td>'a'</td>
<td>Bytes (converts any Python object using <code>repr(obj).encode('ascii','backslashreplace</code>)}.</td>
</tr>
<tr>
<td>'r'</td>
<td>'r' is an alias for 'a' and should only be used for Python2/3 code bases.</td>
</tr>
<tr>
<td>'%'</td>
<td>No argument is converted, results in a '%' character in the result.</td>
</tr>
</tbody>
</table>
Notes:

1. The alternate form causes a leading zero ('0') to be inserted between left-hand padding and the formatting of the number if the leading character of the result is not already a zero.

2. The alternate form causes a leading '0x' or '0X' (depending on whether the 'x' or 'X' format was used) to be inserted between left-hand padding and the formatting of the number if the leading character of the result is not already a zero.

3. The alternate form causes the result to always contain a decimal point, even if no digits follow it.

   The precision determines the number of digits after the decimal point and defaults to 6.

4. The alternate form causes the result to always contain a decimal point, and trailing zeroes are not removed as they would otherwise be.

   The precision determines the number of significant digits before and after the decimal point and defaults to 6.

5. If precision is N, the output is truncated to N characters.

6. b'%s' is deprecated, but will not be removed during the 3.x series.

7. b'%r' is deprecated, but will not be removed during the 3.x series.

8. See PEP 237.
Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

See also: PEP 461.

New in version 3.5.

4.8.5. Memory Views

memoryview objects allow Python code to access the internal data of an object that supports the buffer protocol without copying.

```python
class memoryview(obj)
    Create a memoryview that references obj. obj must support the buffer protocol. Built-in objects that support the buffer protocol include bytes and bytearray.
```

A memoryview has the notion of an element, which is the atomic memory unit handled by the originating object obj. For many simple types such as bytes and bytearray, an element is a single byte, but other types such as array.array may have bigger elements.

```python
len(view) is equal to the length of tolist. If view.ndim = 0, the length is 1. If view.ndim = 1, the length is equal to the number of elements in the view. For higher dimensions, the length is equal to the length of the nested list representation of the view. The itemsize attribute will give you the number of bytes in a single element.
```

A memoryview supports slicing and indexing to expose its data. One-dimensional slicing will result in a subview:
If `format` is one of the native format specifiers from the `struct` module, indexing with an integer or a tuple of integers is also supported and returns a single element with the correct type. One-dimensional memoryviews can be indexed with an integer or a one-integer tuple. Multi-dimensional memoryviews can be indexed with tuples of exactly \texttt{ndim} integers where \texttt{ndim} is the number of dimensions. Zero-dimensional memoryviews can be indexed with the empty tuple.

Here is an example with a non-byte format:

```python
>>> import array
>>> a = array.array('l', [-11111111, 22222222, -3
>>> m = memoryview(a)
>>> m[0]
-11111111
>>> m[-1]
44444444
>>> m[:2].tolist()
[-11111111, -33333333]
```

If the underlying object is writable, the memoryview supports one-dimensional slice assignment. Resizing is not allowed:
```python
>>> data = bytearray(b'abcefg')
>>> v = memoryview(data)
>>> v.readonly
False
>>> v[0] = ord(b'z')
>>> data
bytearray(b'zbcefg')
>>> v[1:4] = b'123'
>>> data
bytearray(b'z123fg')
>>> v[2:3] = b'spam'
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: memoryview assignment: lvalue and rvalue have different structures
>>> v[2:6] = b'spam'
>>> data
bytearray(b'z1spam')
```

One-dimensional memoryviews of hashable (read-only) types with formats ‘B’, ‘b’ or ‘c’ are also hashable. The hash is defined as hash(m) == hash(m.tobytes()):

```python
>>> v = memoryview(b'abcefg')
>>> hash(v) == hash(b'abcefg')
True
>>> hash(v[2:4]) == hash(b'ce')
True
>>> hash(v[:2]) == hash(b'abcefg'[:2])
True
```

*Changed in version 3.3:* One-dimensional memoryviews can now be sliced. One-dimensional memoryviews with formats ‘B’, ‘b’ or ‘c’ are now hashable.

*Changed in version 3.4:* memoryview is now registered
automatically with `collections.abc.Sequence`

*Changed in version 3.5:* memoryviews can now be indexed with tuple of integers.

`memoryview` has several methods:

```python
___eq___(exporter)
```

A memoryview and a [PEP 3118](https://www.python.org/dev/peps/pep-0318/) exporter are equal if their shapes are equivalent and if all corresponding values are equal when the operands’ respective format codes are interpreted using `struct` syntax.

For the subset of `struct` format strings currently supported by `tolist()`, `v` and `w` are equal if `v.tolist() == w.tolist()`:

```python
>>> import array
>>> a = array.array('I', [1, 2, 3, 4, 5])
>>> b = array.array('d', [1.0, 2.0, 3.0, 4.0, 5.0])
>>> c = array.array('b', [5, 3, 1])
>>> x = memoryview(a)
>>> y = memoryview(b)
>>> x == a == y == b
True
>>> x.tolist() == a.tolist() == y.tolist() == b.tolist()
True
>>> z = y[:,-2]
>>> z == c
True
>>> z.tolist() == c.tolist()
True
```

If either format string is not supported by the `struct` module,
then the objects will always compare as unequal (even if the format strings and buffer contents are identical):

```python
>>> from ctypes import BigEndianStructure, c_long
>>> class BEPoint(BigEndianStructure):
...     _fields_ = [("x", c_long), ("y", c_long)]
...
>>> point = BEPoint(100, 200)
>>> a = memoryview(point)
>>> b = memoryview(point)
>>> a == point
False
>>> a == b
False
```

Note that, as with floating point numbers, \( v \) is \( w \) does not imply \( v \ == \ w \) for memoryview objects.

*Changed in version 3.3:* Previous versions compared the raw memory disregarding the item format and the logical array structure.

**tobytes()**

Return the data in the buffer as a bytestring. This is equivalent to calling the `bytes` constructor on the memoryview.

```python
>>> m = memoryview(b"abc")
>>> m.tobytes()
'b\text{\'}abc\text{\'}
>>> bytes(m)
b'abc'
```

For non-contiguous arrays the result is equal to the flattened list representation with all elements converted to bytes.
tobytes() supports all format strings, including those that are not in struct module syntax.

hex()

Return a string object containing two hexadecimal digits for each byte in the buffer.

```
>>> m = memoryview(b"abc")
>>> m.hex()
'616263'
```

New in version 3.5.

tolist()

Return the data in the buffer as a list of elements.

```
>>> memoryview(b'abc').tolist()
[97, 98, 99]
>>> import array
>>> a = array.array('d', [1.1, 2.2, 3.3])
>>> m = memoryview(a)
>>> m.tolist()
[1.1, 2.2, 3.3]
```

Changed in version 3.3: tolist() now supports all single character native formats in struct module syntax as well as multi-dimensional representations.

release()

Release the underlying buffer exposed by the memoryview object. Many objects take special actions when a view is held on them (for example, a bytearray would temporarily forbid resizing); therefore, calling release() is handy to remove these
restrictions (and free any dangling resources) as soon as possible.

After this method has been called, any further operation on the view raises a `ValueError` (except `release()` itself which can be called multiple times):

```python
>>> m = memoryview(b'abc')
>>> m.release()
>>> m[0]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: operation forbidden on released memoryview object
```

The context management protocol can be used for a similar effect, using the `with` statement:

```python
>>> with memoryview(b'abc') as m:
...    m[0]
... 97
>>> m[0]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: operation forbidden on released memoryview object
```

`New in version 3.2.`

`cast(format[, shape])`

Cast a memoryview to a new format or shape. `shape` defaults to `[byte_length//new_itemsize]`, which means that the result view will be one-dimensional. The return value is a new memoryview, but the buffer itself is not copied. Supported casts
are 1D -> C-contiguous and C-contiguous -> 1D.

The destination format is restricted to a single element native format in struct syntax. One of the formats must be a byte format ('B', 'b' or 'c'). The byte length of the result must be the same as the original length.

Cast 1D/long to 1D/unsigned bytes:

```python
>>> import array
>>> a = array.array('l', [1, 2, 3])
>>> x = memoryview(a)
>>> x.format
'l'
>>> x.itemsize
8
>>> len(x)
3
>>> x.nbytes
24
>>> y = x.cast('B')
>>> y.format
'B'
>>> y.itemsize
1
>>> len(y)
24
>>> y.nbytes
24
```

Cast 1D/unsigned bytes to 1D/char:

```python
>>> b = bytearray(b'zyz')
>>> x = memoryview(b)
>>> x[0] = b'a'
Traceback (most recent call last):
```
File "<stdin>", line 1, in <module>
ValueError: memoryview: invalid value for format

```python
>>> y = x.cast('c')
>>> y[0] = b'a'

bytearray(b'ayz')
```  

Cast 1D/bytes to 3D/int to 1D/singed char:

```python
>>> import struct
>>> buf = struct.pack("i"*12, *list(range(12)))
>>> x = memoryview(buf)
>>> y = x.cast('i', shape=[2,2,3])
>>> y.tolist()
[[[0, 1, 2], [3, 4, 5]], [[6, 7, 8], [9, 10, 11]]

```  

```python
>>> y.format
'i'
>>> y.itemsize
4
>>> len(y)
2
>>> y.nbytes
48

```  

```python
>>> z = y.cast('b')
>>> z.format
'b'
>>> z.itemsize
1
>>> len(z)
48
>>> z.nbytes
48
```  

Cast 1D/unsigned char to 2D/unsigned long:
```python
>>> buf = struct.pack("L"*6, *list(range(6)))
>>> x = memoryview(buf)
>>> y = x.cast('L', shape=[2,3])
>>> len(y)
2
>>> y.nbytes
48
>>> y.tolist()
[[0, 1, 2], [3, 4, 5]]
```

*New in version 3.3.*

*Changed in version 3.5:* The source format is no longer restricted when casting to a byte view.

There are also several readonly attributes available:

**obj**

The underlying object of the memoryview:

```python
>>> b = bytearray(b'xyz')
>>> m = memoryview(b)
>>> m.obj is b
True
```

*New in version 3.3.*

**nbytes**

\[
\text{nbytes} = \text{product(shape)} \times \text{itemsize} = \text{len(m.tobytes())}.
\]

This is the amount of space in bytes that the array would use in a contiguous representation. It is not necessarily equal to `len(m)`:  

```python
>>> import array
>>> a = array.array('i', [1,2,3,4,5])
```
>>> m = memoryview(a)
>>> len(m)
5
>>> m.nbytes
20
>>> y = m[::2]
>>> len(y)
3
>>> y.nbytes
12
>>> len(y.tobytes())
12

Multi-dimensional arrays:

>>> import struct
>>> buf = struct.pack("d"*12, *[1.5]*x for x in
>>> x = memoryview(buf)
>>> y = x.cast('d', shape=[3,4])
>>> y.tolist()
[[0.0, 1.5, 3.0, 4.5], [6.0, 7.5, 9.0, 10.5], [
>>> len(y)
3
>>> y.nbytes
96

*New in version 3.3.*

**readonly**

A bool indicating whether the memory is read only.

**format**

A string containing the format (in `struct` module style) for each element in the view. A memoryview can be created from exporters with arbitrary format strings, but some methods (e.g.
tolist()) are restricted to native single element formats.

Changed in version 3.3: format 'B' is now handled according to the struct module syntax. This means that memoryview(b'abc')[0] == b'abc'[0] == 97.

**itemsize**
The size in bytes of each element of the memoryview:

```python
>>> import array, struct
>>> m = memoryview(array.array('H', [32000, 32001])
>>> m.itemsize
2
>>> m[0]
32000
>>> struct.calcsize('H') == m.itemsize
True
```

**ndim**
An integer indicating how many dimensions of a multi-dimensional array the memory represents.

**shape**
A tuple of integers the length of ndim giving the shape of the memory as an N-dimensional array.

Changed in version 3.3: An empty tuple instead of None when ndim = 0.

**strides**
A tuple of integers the length of ndim giving the size in bytes to access each element for each dimension of the array.
Changed in version 3.3: An empty tuple instead of None when ndim = 0.

**suboffsets**
Used internally for PIL-style arrays. The value is informational only.

**c_contiguous**
A bool indicating whether the memory is C-contiguous.

*New in version 3.3.*

**f_contiguous**
A bool indicating whether the memory is Fortran contiguous.

*New in version 3.3.*

**contiguous**
A bool indicating whether the memory is contiguous.

*New in version 3.3.*
4.9. Set Types — *set*, *frozenset*

A set object is an unordered collection of distinct hashable objects. Common uses include membership testing, removing duplicates from a sequence, and computing mathematical operations such as intersection, union, difference, and symmetric difference. (For other containers see the built-in *dict*, *list*, and *tuple* classes, and the *collections* module.)

Like other collections, sets support `x in set`, `len(set)`, and `for x in set`. Being an unordered collection, sets do not record element position or order of insertion. Accordingly, sets do not support indexing, slicing, or other sequence-like behavior.

There are currently two built-in set types, *set* and *frozenset*. The *set* type is mutable — the contents can be changed using methods like `add()` and `remove()`. Since it is mutable, it has no hash value and cannot be used as either a dictionary key or as an element of another set. The *frozenset* type is immutable and hashable — its contents cannot be altered after it is created; it can therefore be used as a dictionary key or as an element of another set.

Non-empty sets (not frozensets) can be created by placing a comma-separated list of elements within braces, for example: `{'jack', 'sjoerd'}`, in addition to the *set* constructor.

The constructors for both classes work the same:

```python
class set([iterable])
class frozenset([iterable])
```

Return a new set or frozenset object whose elements are taken
from iterable. The elements of a set must be hashable. To represent sets of sets, the inner sets must be frozenset objects. If iterable is not specified, a new empty set is returned.

Instances of set and frozenset provide the following operations:

len(s)
Return the cardinality of set s.

x in s
Test x for membership in s.

x not in s
Test x for non-membership in s.

isdisjoint(other)
Return True if the set has no elements in common with other. Sets are disjoint if and only if their intersection is the empty set.

issubset(other)
set <= other
Test whether every element in the set is in other.

set < other
Test whether the set is a proper subset of other, that is, set <= other and set != other.

issuperset(other)
set >= other
Test whether every element in other is in the set.

set > other
Test whether the set is a proper superset of other, that is, set
\[ \geq \text{ other and set } \neq \text{ other.} \]

**union**(*other, ...*)

\[
\text{set } \mid \text{ other } \mid \ldots
\]

Return a new set with elements from the set and all others.

**intersection**(*other, ...*)

\[
\text{set } \& \text{ other } \& \ldots
\]

Return a new set with elements common to the set and all others.

**difference**(*other, ...*)

\[
\text{set } - \text{ other } - \ldots
\]

Return a new set with elements in the set that are not in the others.

**symmetric_difference**(*other*)

\[
\text{set } \wedge \text{ other}
\]

Return a new set with elements in either the set or other but not both.

**copy**()

Return a new set with a shallow copy of s.

Note, the non-operator versions of **union**, **intersection**, **difference**, and **symmetric_difference**, **issubset**, and **issuperset** methods will accept any iterable as an argument. In contrast, their operator based counterparts require their arguments to be sets. This precludes error-prone constructions like `set('abc') & 'cbs'` in favor of the more readable `set('abc').intersection('cbs')`.

Both **set** and **frozenset** support set to set comparisons. Two
sets are equal if and only if every element of each set is contained in the other (each is a subset of the other). A set is less than another set if and only if the first set is a proper subset of the second set (is a subset, but is not equal). A set is greater than another set if and only if the first set is a proper superset of the second set (is a superset, but is not equal).

Instances of `set` are compared to instances of `frozenset` based on their members. For example, `set('abc') == frozenset('abc')` returns `True` and so does `set('abc') in set([frozenset('abc')])`.

The subset and equality comparisons do not generalize to a total ordering function. For example, any two nonempty disjoint sets are not equal and are not subsets of each other, so all of the following return `False`: `a<b, a==b, or a>b`.

Since sets only define partial ordering (subset relationships), the output of the `list.sort()` method is undefined for lists of sets.

Set elements, like dictionary keys, must be `hashable`.

Binary operations that mix `set` instances with `frozenset` return the type of the first operand. For example: `frozenset('ab') | set('bc')` returns an instance of `frozenset`.

The following table lists operations available for `set` that do not apply to immutable instances of `frozenset`:

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>update(other, ...)</td>
<td>Update the set, adding elements from all others.</td>
</tr>
</tbody>
</table>
**intersection_update**(other,...)
set &= other & ...

Update the set, keeping only elements found in it and all others.

**difference_update**(other,...)
set -= other | ...

Update the set, removing elements found in others.

**symmetric_difference_update**(other)
set ^= other

Update the set, keeping only elements found in either set, but not in both.

**add**(elem)

Add element *elem* to the set.

**remove**(elem)

Remove element *elem* from the set. Raises * KeyError* if *elem* is not contained in the set.

**discard**(elem)

Remove element *elem* from the set if it is present.

**pop()**

Remove and return an arbitrary element from the set. Raises * KeyError* if the set is empty.

**clear()**

Remove all elements from the set.

Note, the non-operator versions of the *update()*,
**intersection_update()**, **difference_update()**, and
**symmetric_difference_update()** methods will accept any
iterable as an argument.

Note, the *elem* argument to the *__contains__()*, *remove()*, and *discard()* methods may be a set. To support searching for an equivalent frozenset, the *elem* set is temporarily mutated during the search and then restored. During the search, the *elem* set should not be read or mutated since it does not have a meaningful value.
4.10. Mapping Types — dict

A mapping object maps hashable values to arbitrary objects. Mappings are mutable objects. There is currently only one standard mapping type, the dictionary. (For other containers see the built-in list, set, and tuple classes, and the collections module.)

A dictionary’s keys are almost arbitrary values. Values that are not hashable, that is, values containing lists, dictionaries or other mutable types (that are compared by value rather than by object identity) may not be used as keys. Numeric types used for keys obey the normal rules for numeric comparison: if two numbers compare equal (such as 1 and 1.0) then they can be used interchangeably to index the same dictionary entry. (Note however, that since computers store floating-point numbers as approximations it is usually unwise to use them as dictionary keys.)

Dictionaries can be created by placing a comma-separated list of key: value pairs within braces, for example: {'jack': 4098, 'sjoerd': 4127} or {4098: 'jack', 4127: 'sjoerd'}, or by the dict constructor.

```python
class dict(**kwarg)
class dict(mapping, **kwarg)
class dict(iterable, **kwarg)
```

Return a new dictionary initialized from an optional positional argument and a possibly empty set of keyword arguments.

If no positional argument is given, an empty dictionary is created. If a positional argument is given and it is a mapping object, a dictionary is created with the same key-value pairs as the mapping
object. Otherwise, the positional argument must be an iterable object. Each item in the iterable must itself be an iterable with exactly two objects. The first object of each item becomes a key in the new dictionary, and the second object the corresponding value. If a key occurs more than once, the last value for that key becomes the corresponding value in the new dictionary.

If keyword arguments are given, the keyword arguments and their values are added to the dictionary created from the positional argument. If a key being added is already present, the value from the keyword argument replaces the value from the positional argument.

To illustrate, the following examples all return a dictionary equal to \{"one": 1, "two": 2, "three": 3\}:

```python
given:
>>> a = dict(one=1, two=2, three=3)
>>> b = {'one': 1, 'two': 2, 'three': 3}
>>> c = dict(zip(['one', 'two', 'three'], [1, 2, 3]))
>>> d = dict([('two', 2), ('one', 1), ('three', 3)])
>>> e = dict({'three': 3, 'one': 1, 'two': 2})
>>> a == b == c == d == e
True
```

Providing keyword arguments as in the first example only works for keys that are valid Python identifiers. Otherwise, any valid keys can be used.

These are the operations that dictionaries support (and therefore, custom mapping types should support too):

- `len(d)`
  Return the number of items in the dictionary \(d\).
**d[key]**

Return the item of *d* with key *key*. Raises a `KeyError` if *key* is not in the map.

If a subclass of `dict` defines a method `__missing__()`, and *key* is not present, the `d[key]` operation calls that method with the key *key* as argument. The `d[key]` operation then returns or raises whatever is returned or raised by the `__missing__(key)` call. No other operations or methods invoke `__missing__()`. If `__missing__()` is not defined, `KeyError` is raised. `__missing__()` must be a method; it cannot be an instance variable.

```python
>>> class Counter(dict):
...     def __missing__(self, key):
...         return 0
>>> c = Counter()
>>> c['red']
0
>>> c['red'] += 1
>>> c['red']
1
```

The example above shows part of the implementation of `collections.Counter`. A different `__missing__` method is used by `collections.defaultdict`.

**d[key] = value**

Set `d[key]` to `value`.

**del d[key]**

Remove `d[key]` from *d*. Raises a `KeyError` if *key* is not in the map.
**key in d**
Return True if \(d\) has a key \(key\), else False.

**key not in d**
Equivalent to not key in d.

**iter(d)**
Return an iterator over the keys of the dictionary. This is a shortcut for iter(d.keys()).

**clear()**
Remove all items from the dictionary.

**copy()**
Return a shallow copy of the dictionary.

**classmethod fromkeys(seq[, value])**
Create a new dictionary with keys from \(seq\) and values set to \(value\).

**fromkeys()** is a class method that returns a new dictionary. \(value\) defaults to None.

**get(key[, default])**
Return the value for \(key\) if \(key\) is in the dictionary, else \(default\). If \(default\) is not given, it defaults to None, so that this method never raises a **KeyError**.

**items()**
Return a new view of the dictionary’s items ((key, value) pairs). See the documentation of view objects.
keys()
Return a new view of the dictionary's keys. See the documentation of view objects.

pop(key[, default])
If key is in the dictionary, remove it and return its value, else return default. If default is not given and key is not in the dictionary, a KeyError is raised.

popitem()
Remove and return an arbitrary (key, value) pair from the dictionary.

popitem() is useful to destructively iterate over a dictionary, as often used in set algorithms. If the dictionary is empty, calling popitem() raises a KeyError.

setdefault(key[, default])
If key is in the dictionary, return its value. If not, insert key with a value of default and return default. default defaults to None.

update([other])
Update the dictionary with the key/value pairs from other, overwriting existing keys. Return None.

update() accepts either another dictionary object or an iterable of key/value pairs (as tuples or other iterables of length two). If keyword arguments are specified, the dictionary is then updated with those key/value pairs: d.update(red=1, blue=2).

values()
Return a new view of the dictionary’s values. See the documentation of view objects.

Dictionaries compare equal if and only if they have the same (key, value) pairs. Order comparisons (‘<’, ‘<=’, ‘>’, ‘>=’) raise TypeError.

See also: types.MappingProxyType can be used to create a read-only view of a dict.

4.10.1. Dictionary view objects

The objects returned by dict.keys(), dict.values() and dict.items() are view objects. They provide a dynamic view on the dictionary’s entries, which means that when the dictionary changes, the view reflects these changes.

Dictionary views can be iterated over to yield their respective data, and support membership tests:

**len(dictview)**

Return the number of entries in the dictionary.

**iter(dictview)**

Return an iterator over the keys, values or items (represented as tuples of (key, value)) in the dictionary.

Keys and values are iterated over in an arbitrary order which is non-random, varies across Python implementations, and depends on the dictionary’s history of insertions and deletions. If keys, values and items views are iterated over with no intervening modifications to the dictionary, the order of items will directly
correspond. This allows the creation of (value, key) pairs using `zip()`: `pairs = zip(d.values(), d.keys())`. Another way to create the same list is `pairs = [(v, k) for (k, v) in d.items()]`.

Iterating views while adding or deleting entries in the dictionary may raise a `RuntimeError` or fail to iterate over all entries.

**x in dictview**

Return True if `x` is in the underlying dictionary's keys, values or items (in the latter case, `x` should be a (key, value) tuple).

Keys views are set-like since their entries are unique and hashable. If all values are hashable, so that (key, value) pairs are unique and hashable, then the items view is also set-like. (Values views are not treated as set-like since the entries are generally not unique.) For set-like views, all of the operations defined for the abstract base class `collections.abc.Set` are available (for example, `==`, `<`, or `^`).

An example of dictionary view usage:

```python
>>> dishes = {'eggs': 2, 'sausage': 1, 'bacon': 1, 'spam': 1}
>>> keys = dishes.keys()
>>> values = dishes.values()

>>> # iteration
>>> n = 0
>>> for val in values:
...    n += val
>>> print(n)
504

>>> # keys and values are iterated over in the same
>>> list(keys)
```
['eggs', 'bacon', 'sausage', 'spam']

>>> list(values)
[2, 1, 1, 500]

>>> # view objects are dynamic and reflect dict changes
>>> del dishes['eggs']
>>> del dishes['sausage']

>>> list(keys)
['spam', 'bacon']

>>> # set operations
>>> keys & {'eggs', 'bacon', 'salad'}
{'bacon'}

>>> keys ^ {'sausage', 'juice'}
{'juice', 'sausage', 'bacon', 'spam'}
4.11. Context Manager Types

Python’s `with` statement supports the concept of a runtime context defined by a context manager. This is implemented using a pair of methods that allow user-defined classes to define a runtime context that is entered before the statement body is executed and exited when the statement ends:

```python
class contextmanager:
    def __enter__(self):
        # Enter the runtime context and return either this object or another object related to the runtime context. The value returned by this method is bound to the identifier in the `as` clause of `with` statements using this context manager.
        # An example of a context manager that returns itself is a file object. File objects return themselves from `__enter__()` to allow `open()` to be used as the context expression in a `with` statement.
        # An example of a context manager that returns a related object is the one returned by `decimal.localcontext()`. These managers set the active decimal context to a copy of the original decimal context and then return the copy. This allows changes to be made to the current decimal context in the body of the `with` statement without affecting code outside the `with` statement.

    def __exit__(self, exc_type, exc_val, exc_tb):
        # Exit the runtime context and return a Boolean flag indicating if any exception occurred that occurred should be suppressed. If an exception occurred while executing the body of the `with` statement, the arguments contain the exception type, value and traceback information. Otherwise, all three arguments are None.
```

```
Returning a true value from this method will cause the `with` statement to suppress the exception and continue execution with the statement immediately following the `with` statement. Otherwise the exception continues propagating after this method has finished executing. Exceptions that occur during execution of this method will replace any exception that occurred in the body of the `with` statement.

The exception passed in should never be reraised explicitly - instead, this method should return a false value to indicate that the method completed successfully and does not want to suppress the raised exception. This allows context management code to easily detect whether or not an `__exit__()` method has actually failed.

Python defines several context managers to support easy thread synchronisation, prompt closure of files or other objects, and simpler manipulation of the active decimal arithmetic context. The specific types are not treated specially beyond their implementation of the context management protocol. See the `contextlib` module for some examples.

Python's generators and the `contextlib.contextmanager` decorator provide a convenient way to implement these protocols. If a generator function is decorated with the `contextlib.contextmanager` decorator, it will return a context manager implementing the necessary `__enter__()` and `__exit__()` methods, rather than the iterator produced by an undecorated generator function.

Note that there is no specific slot for any of these methods in the type structure for Python objects in the Python/C API. Extension types wanting to define these methods must provide them as a normal
Python accessible method. Compared to the overhead of setting up the runtime context, the overhead of a single class dictionary lookup is negligible.
4.12. Other Built-in Types

The interpreter supports several other kinds of objects. Most of these support only one or two operations.

4.12.1. Modules

The only special operation on a module is attribute access: \texttt{m.name}, where \texttt{m} is a module and \texttt{name} accesses a name defined in \texttt{m}'s symbol table. Module attributes can be assigned to. (Note that the \texttt{import} statement is not, strictly speaking, an operation on a module object; \texttt{import foo} does not require a module object named \texttt{foo} to exist, rather it requires an (external) \textit{definition} for a module named \texttt{foo} somewhere.)

A special attribute of every module is \texttt{__dict__}. This is the dictionary containing the module's symbol table. Modifying this dictionary will actually change the module's symbol table, but direct assignment to the \texttt{__dict__} attribute is not possible (you can write \texttt{m.__dict__['a'] = 1}, which defines \texttt{m.a} to be 1, but you can't write \texttt{m.__dict__ = {}}). Modifying \texttt{__dict__} directly is not recommended.

Modules built into the interpreter are written like this: \texttt{<module 'sys' (built-in)>}. If loaded from a file, they are written as \texttt{<module 'os' from '/usr/local/lib/pythonX.Y/os.pyc'>}.

4.12.2. Classes and Class Instances

See \textit{Objects, values and types} and \textit{Class definitions} for these.
4.12.3. Functions

Function objects are created by function definitions. The only operation on a function object is to call it: `func(argument-list).

There are really two flavors of function objects: built-in functions and user-defined functions. Both support the same operation (to call the function), but the implementation is different, hence the different object types.

See Function definitions for more information.

4.12.4. Methods

Methods are functions that are called using the attribute notation. There are two flavors: built-in methods (such as `append()` on lists) and class instance methods. Built-in methods are described with the types that support them.

If you access a method (a function defined in a class namespace) through an instance, you get a special object: a bound method (also called instance method) object. When called, it will add the self argument to the argument list. Bound methods have two special read-only attributes: `m.__self__` is the object on which the method operates, and `m.__func__` is the function implementing the method. Calling `m(arg-1, arg-2, ..., arg-n)` is completely equivalent to calling `m.__func__(m.__self__, arg-1, arg-2, ..., arg-n).

Like function objects, bound method objects support getting arbitrary attributes. However, since method attributes are actually stored on the
underlying function object (meth.__func__), setting method attributes on bound methods is disallowed. Attempting to set an attribute on a method results in an AttributeError being raised. In order to set a method attribute, you need to explicitly set it on the underlying function object:

```python
>>> class C:
...     def method(self):
...         pass
...
>>> c = C()
>>> c.method.whoami = 'my name is method'  # can't set an attribute on a method
Traceback (most recent call last):
  File "<stdin>" , line 1, in <module>
AttributeError: 'method' object has no attribute 'whoami'
>>> c.method.__func__.whoami = 'my name is method'
>>> c.method.whoami
'my name is method'
```

See The standard type hierarchy for more information.

### 4.12.5. Code Objects

Code objects are used by the implementation to represent “pseudo-compiled” executable Python code such as a function body. They differ from function objects because they don’t contain a reference to their global execution environment. Code objects are returned by the built-in `compile()` function and can be extracted from function objects through their `__code__` attribute. See also the `code` module.

A code object can be executed or evaluated by passing it (instead of a source string) to the `exec()` or `eval()` built-in functions.
See The standard type hierarchy for more information.

4.12.6. Type Objects

Type objects represent the various object types. An object’s type is accessed by the built-in function type(). There are no special operations on types. The standard module types defines names for all standard built-in types.

Types are written like this: <class 'int'>.

4.12.7. The Null Object

This object is returned by functions that don’t explicitly return a value. It supports no special operations. There is exactly one null object, named None (a built-in name). type(None)() produces the same singleton.

It is written as None.

4.12.8. The Ellipsis Object

This object is commonly used by slicing (see Slicings). It supports no special operations. There is exactly one ellipsis object, named Ellipsis (a built-in name). type(Ellipsis)() produces the Ellipsis singleton.

It is written as Ellipsis or ....

4.12.9. The NotImplemented Object
This object is returned from comparisons and binary operations when they are asked to operate on types they don't support. See `Comparisons` for more information. There is exactly one `NotImplemented` object. `type(NotImplemented)()` produces the singleton instance.

It is written as `NotImplemented`.

### 4.12.10. Boolean Values

Boolean values are the two constant objects `False` and `True`. They are used to represent truth values (although other values can also be considered false or true). In numeric contexts (for example when used as the argument to an arithmetic operator), they behave like the integers 0 and 1, respectively. The built-in function `bool()` can be used to convert any value to a Boolean, if the value can be interpreted as a truth value (see section `Truth Value Testing` above).

They are written as `False` and `True`, respectively.

### 4.12.11. Internal Objects

See `The standard type hierarchy` for this information. It describes stack frame objects, traceback objects, and slice objects.
4.13. Special Attributes

The implementation adds a few special read-only attributes to several object types, where they are relevant. Some of these are not reported by the `dir()` built-in function.

- **object.__dict__**
  A dictionary or other mapping object used to store an object's (writable) attributes.

- **instance.__class__**
  The class to which a class instance belongs.

- **class.__bases__**
  The tuple of base classes of a class object.

- **class.__name__**
  The name of the class or type.

- **class.__qualname__**
  The qualified name of the class or type.

  _New in version 3.3._

- **class.__mro__**
  This attribute is a tuple of classes that are considered when looking for base classes during method resolution.

- **class.mro()**
  This method can be overridden by a metaclass to customize the method resolution order for its instances. It is called at class instantiation, and its result is stored in **__mro__**.
class.__subclasses__()  
Each class keeps a list of weak references to its immediate subclasses. This method returns a list of all those references still alive. Example:

```python
>>> int.__subclasses__()
[<class 'bool'>]
```

Footnotes

[1] Additional information on these special methods may be found in the Python Reference Manual (Basic customization).

[2] As a consequence, the list [1, 2] is considered equal to [1.0, 2.0], and similarly for tuples.

[3] They must have since the parser can’t tell the type of the operands.

[4] (1, 2, 3, 4) Cased characters are those with general category property being one of “Lu” (Letter, uppercase), “Ll” (Letter, lowercase), or “Lt” (Letter, titlecase).

[5] (1, 2) To format only a tuple you should therefore provide a singleton tuple whose only element is the tuple to be formatted.
5. Built-in Exceptions

In Python, all exceptions must be instances of a class that derives from `BaseException`. In a `try` statement with an `except` clause that mentions a particular class, that clause also handles any exception classes derived from that class (but not exception classes from which it is derived). Two exception classes that are not related via subclassing are never equivalent, even if they have the same name.

The built-in exceptions listed below can be generated by the interpreter or built-in functions. Except where mentioned, they have an “associated value” indicating the detailed cause of the error. This may be a string or a tuple of several items of information (e.g., an error code and a string explaining the code). The associated value is usually passed as arguments to the exception class’s constructor.

User code can raise built-in exceptions. This can be used to test an exception handler or to report an error condition “just like” the situation in which the interpreter raises the same exception; but beware that there is nothing to prevent user code from raising an inappropriate error.

The built-in exception classes can be subclassed to define new exceptions; programmers are encouraged to derive new exceptions from the `Exception` class or one of its subclasses, and not from `BaseException`. More information on defining exceptions is available in the Python Tutorial under User-defined Exceptions.

When raising (or re-raising) an exception in an `except` or `finally` clause `__context__` is automatically set to the last exception caught; if the new exception is not handled the traceback that is eventually
displayed will include the originating exception(s) and the final exception.

When raising a new exception (rather than using a bare `raise` to re-raise the exception currently being handled), the implicit exception context can be supplemented with an explicit cause by using `from` with `raise`:

```
raise new_exc from original_exc
```

The expression following `from` must be an exception or `None`. It will be set as `__cause__` on the raised exception. Setting `__cause__` also implicitly sets the `__suppress_context__` attribute to `True`, so that using `raise new_exc from None` effectively replaces the old exception with the new one for display purposes (e.g. converting `KeyError` to `AttributeError`, while leaving the old exception available in `__context__` for introspection when debugging.

The default traceback display code shows these chained exceptions in addition to the traceback for the exception itself. An explicitly chained exception in `__cause__` is always shown when present. An implicitly chained exception in `__context__` is shown only if `__cause__` is `None` and `__suppress_context__` is `false`.

In either case, the exception itself is always shown after any chained exceptions so that the final line of the traceback always shows the last exception that was raised.
5.1. Base classes

The following exceptions are used mostly as base classes for other exceptions.

**exception BaseException**

The base class for all built-in exceptions. It is not meant to be directly inherited by user-defined classes (for that, use Exception). If `str()` is called on an instance of this class, the representation of the argument(s) to the instance are returned, or the empty string when there were no arguments.

**args**

The tuple of arguments given to the exception constructor. Some built-in exceptions (like OSError) expect a certain number of arguments and assign a special meaning to the elements of this tuple, while others are usually called only with a single string giving an error message.

**with_traceback**(tb)

This method sets `tb` as the new traceback for the exception and returns the exception object. It is usually used in exception handling code like this:

```python
try:
    ...
except SomeException:
    tb = sys.exc_info()[2]
    raise OtherException(...).with_traceback(tb)
```

**exception Exception**
All built-in, non-system-exiting exceptions are derived from this class. All user-defined exceptions should also be derived from this class.

**exception** `ArithmeticError`

The base class for those built-in exceptions that are raised for various arithmetic errors: `OverflowError`, `ZeroDivisionError`, `FloatingPointError`.

**exception** `BufferError`

Raised when a buffer related operation cannot be performed.

**exception** `LookupError`

The base class for the exceptions that are raised when a key or index used on a mapping or sequence is invalid: `IndexError`, `KeyError`. This can be raised directly by `codecs.lookup()`.
5.2. Concrete exceptions

The following exceptions are the exceptions that are usually raised.

**exception AssertionError**

Raised when an `assert` statement fails.

**exception AttributeError**

Raised when an attribute reference (see `Attribute references`) or assignment fails. (When an object does not support attribute references or attribute assignments at all, `TypeError` is raised.)

**exception EOFError**

Raised when the `input()` function hits an end-of-file condition (EOF) without reading any data. (N.B.: the `io.IOBase.read()` and `io.IOBase.readline()` methods return an empty string when they hit EOF.)

**exception FloatingPointError**

Raised when a floating point operation fails. This exception is always defined, but can only be raised when Python is configured with the `--with-fpectl` option, or the `WANT_SIGFPE_HANDLER` symbol is defined in the `pyconfig.h` file.

**exception GeneratorExit**

Raised when a generator or coroutine is closed; see `generator.close()` and `coroutine.close()`. It directly inherits from `BaseException` instead of `Exception` since it is technically not an error.

**exception ImportError**
Raised when an `import` statement fails to find the module definition or when a `from ... import` fails to find a name that is to be imported.

The name and path attributes can be set using keyword-only arguments to the constructor. When set they represent the name of the module that was attempted to be imported and the path to any file which triggered the exception, respectively.

*Changed in version 3.3:* Added the name and path attributes.

**exception IndexError**

Raised when a sequence subscript is out of range. (Slice indices are silently truncated to fall in the allowed range; if an index is not an integer, `TypeError` is raised.)

**exception KeyError**

Raised when a mapping (dictionary) key is not found in the set of existing keys.

**exception KeyboardInterrupt**

Raised when the user hits the interrupt key (normally Control-C or Delete). During execution, a check for interrupts is made regularly. The exception inherits from `BaseException` so as to not be accidentally caught by code that catches `Exception` and thus prevent the interpreter from exiting.

**exception MemoryError**

Raised when an operation runs out of memory but the situation may still be rescued (by deleting some objects). The associated value is a string indicating what kind of (internal) operation ran out of memory. Note that because of the underlying memory
management architecture (C's malloc() function), the interpreter may not always be able to completely recover from this situation; it nevertheless raises an exception so that a stack traceback can be printed, in case a run-away program was the cause.

**exception NameError**

Raised when a local or global name is not found. This applies only to unqualified names. The associated value is an error message that includes the name that could not be found.

**exception NotImplementedException**

This exception is derived from RuntimeError. In user defined base classes, abstract methods should raise this exception when they require derived classes to override the method.

**exception OSError([[arg]])**

This exception is raised when a system function returns a system-related error, including I/O failures such as “file not found” or “disk full” (not for illegal argument types or other incidental errors).

The second form of the constructor sets the corresponding attributes, described below. The attributes default to None if not specified. For backwards compatibility, if three arguments are passed, the args attribute contains only a 2-tuple of the first two constructor arguments.

The constructor often actually returns a subclass of OSError, as described in OS exceptions below. The particular subclass depends on the final errno value. This behaviour only occurs when constructing OSError directly or via an alias, and is not
inherited when subclassing.

**errno**

A numeric error code from the C variable `errno`.

**winerror**

Under Windows, this gives you the native Windows error code. The `errno` attribute is then an approximate translation, in POSIX terms, of that native error code.

Under Windows, if the `winerror` constructor argument is an integer, the `errno` attribute is determined from the Windows error code, and the `errno` argument is ignored. On other platforms, the `winerror` argument is ignored, and the `winerror` attribute does not exist.

**strerror**

The corresponding error message, as provided by the operating system. It is formatted by the C functions `perror()` under POSIX, and `FormatMessage()` under Windows.

**filename**

**filename2**

For exceptions that involve a file system path (such as `open()` or `os.unlink()`), `filename` is the file name passed to the function. For functions that involve two file system paths (such as `os.rename()`), `filename2` corresponds to the second file name passed to the function.

*Changed in version 3.3:* `EnvironmentError`, `IOError`, `WindowsError`, `VMSError`, `socket.error`, `select.error` and `mmap.error` have been merged into `OSError`, and the
constructor may return a subclass.

*Changed in version 3.4:* The `filename` attribute is now the original file name passed to the function, instead of the name encoded to or decoded from the filesystem encoding. Also, the `filename2` constructor argument and attribute was added.

**exception OverflowError**

Raised when the result of an arithmetic operation is too large to be represented. This cannot occur for integers (which would rather raise `MemoryError` than give up). However, for historical reasons, `OverflowError` is sometimes raised for integers that are outside a required range. Because of the lack of standardization of floating point exception handling in C, most floating point operations are not checked.

**exception RecursionError**

This exception is derived from `RuntimeError`. It is raised when the interpreter detects that the maximum recursion depth (see `sys.getrecursionlimit()`) is exceeded.

*New in version 3.5:* Previously, a plain `RuntimeError` was raised.

**exception ReferenceError**

This exception is raised when a weak reference proxy, created by the `weakref.proxy()` function, is used to access an attribute of the referent after it has been garbage collected. For more information on weak references, see the `weakref` module.

**exception RuntimeError**

Raised when an error is detected that doesn’t fall in any of the other categories. The associated value is a string indicating what precisely went wrong.
\textit{exception} \textbf{StopIteration}

Raised by built-in function \texttt{next()} and an \texttt{iteror}'s \texttt{\_\_next\_\_()} method to signal that there are no further items produced by the iterator.

The exception object has a single attribute \texttt{value}, which is given as an argument when constructing the exception, and defaults to \texttt{None}.

When a \texttt{generator} or \texttt{coroutine} function returns, a new \texttt{StopIteration} instance is raised, and the value returned by the function is used as the value parameter to the constructor of the exception.

If a generator function defined in the presence of a from \texttt{\_\_future\_\_ import generator\_stop} directive raises \texttt{StopIteration}, it will be converted into a \texttt{RuntimeError} (retaining the \texttt{StopIteration} as the new exception's cause).

\textit{Changed in version 3.3:} Added value attribute and the ability for generator functions to use it to return a value.

\textit{Changed in version 3.5:} Introduced the RuntimeError transformation.

\textit{exception} \textbf{StopAsyncIteration}

Must be raised by \texttt{\_\_anext\_\_()} method of an \texttt{asynchronous iterator} object to stop the iteration.

\textit{New in version 3.5}.

\textit{exception} \textbf{SyntaxError}

Raised when the parser encounters a syntax error. This may occur
in an `import` statement, in a call to the built-in functions `exec()` or `eval()`, or when reading the initial script or standard input (also interactively).

Instances of this class have attributes `filename`, `lineno`, `offset` and `text` for easier access to the details. `str()` of the exception instance returns only the message.

**exception** *IndentationError*

Base class for syntax errors related to incorrect indentation. This is a subclass of `SyntaxError`.

**exception** *TabError*

Raised when indentation contains an inconsistent use of tabs and spaces. This is a subclass of `IndentationError`.

**exception** *SystemError*

Raised when the interpreter finds an internal error, but the situation does not look so serious to cause it to abandon all hope. The associated value is a string indicating what went wrong (in low-level terms).

You should report this to the author or maintainer of your Python interpreter. Be sure to report the version of the Python interpreter (`sys.version`; it is also printed at the start of an interactive Python session), the exact error message (the exception's associated value) and if possible the source of the program that triggered the error.

**exception** *SystemExit*

This exception is raised by the `sys.exit()` function. It inherits from `BaseException` instead of `Exception` so that it is not
accidentally caught by code that catches Exception. This allows the exception to properly propagate up and cause the interpreter to exit. When it is not handled, the Python interpreter exits; no stack traceback is printed. The constructor accepts the same optional argument passed to sys.exit(). If the value is an integer, it specifies the system exit status (passed to C’s exit() function); if it is None, the exit status is zero; if it has another type (such as a string), the object's value is printed and the exit status is one.

A call to sys.exit() is translated into an exception so that clean-up handlers (finally clauses of try statements) can be executed, and so that a debugger can execute a script without running the risk of losing control. The os._exit() function can be used if it is absolutely positively necessary to exit immediately (for example, in the child process after a call to os.fork()).

code

The exit status or error message that is passed to the constructor. (Defaults to None.)

exception TypeError

Raised when an operation or function is applied to an object of inappropriate type. The associated value is a string giving details about the type mismatch.

exception UnboundLocalError

Raised when a reference is made to a local variable in a function or method, but no value has been bound to that variable. This is a subclass of NameError.

exception UnicodeError

Raised when a Unicode-related encoding or decoding error occurs.
It is a subclass of `ValueError`.

`UnicodeError` has attributes that describe the encoding or decoding error. For example, `err.object[err.start:err.end]` gives the particular invalid input that the codec failed on.

**encoding**

The name of the encoding that raised the error.

**reason**

A string describing the specific codec error.

**object**

The object the codec was attempting to encode or decode.

**start**

The first index of invalid data in `object`.

**end**

The index after the last invalid data in `object`.

*exception* `UnicodeEncodeError`

Raised when a Unicode-related error occurs during encoding. It is a subclass of `UnicodeError`.

*exception* `UnicodeDecodeError`

Raised when a Unicode-related error occurs during decoding. It is a subclass of `UnicodeError`.

*exception* `UnicodeTranslateError`

Raised when a Unicode-related error occurs during translating. It is a subclass of `UnicodeError`. 
exception **ValueError**

Raised when a built-in operation or function receives an argument that has the right type but an inappropriate value, and the situation is not described by a more precise exception such as **IndexError**.

exception **ZeroDivisionError**

Raised when the second argument of a division or modulo operation is zero. The associated value is a string indicating the type of the operands and the operation.

The following exceptions are kept for compatibility with previous versions; starting from Python 3.3, they are aliases of **OSError**.

exception **EnvironmentError**

exception **IOError**

exception **WindowsError**

Only available on Windows.

5.2.1. OS exceptions

The following exceptions are subclasses of **OSError**, they get raised depending on the system error code.

exception **BlockingIOError**

Raised when an operation would block on an object (e.g. socket) set for non-blocking operation. Corresponds to errno EAGAIN, EALREADY, EWOULDBLOCK and EINPROGRESS.

In addition to those of **OSError**, **BlockingIOError** can have one more attribute:
characters_written

An integer containing the number of characters written to the stream before it blocked. This attribute is available when using the buffered I/O classes from the io module.

exception ChildProcessError

Raised when an operation on a child process failed. Corresponds to errno ECHILD.

exception ConnectionError

A base class for connection-related issues.

Subclasses are BrokenPipeError, ConnectionAbortedError, ConnectionRefusedError and ConnectionResetError.

exception BrokenPipeError

A subclass of ConnectionError, raised when trying to write on a pipe while the other end has been closed, or trying to write on a socket which has been shutdown for writing. Corresponds to errno EPIPE and ESHUTDOWN.

exception ConnectionAbortedError

A subclass of ConnectionError, raised when a connection attempt is aborted by the peer. Corresponds to errno ECONNABORTED.

exception ConnectionRefusedError

A subclass of ConnectionError, raised when a connection attempt is refused by the peer. Corresponds to errno ECONNREFUSED.
**exception** **ConnectionResetError**
A subclass of **ConnectionError**, raised when a connection is reset by the peer. Corresponds to errno ECONNRESET.

**exception** **FileExistsError**
Raised when trying to create a file or directory which already exists. Corresponds to errno EEXIST.

**exception** **FileNotFoundError**
Raised when a file or directory is requested but doesn’t exist. Corresponds to errno ENOENT.

**exception** **InterruptedError**
Raised when a system call is interrupted by an incoming signal. Corresponds to errno EINTR.

*Changed in version 3.5:* Python now retries system calls when a syscall is interrupted by a signal, except if the signal handler raises an exception (see PEP 475 for the rationale), instead of raising **InterruptedError**.

**exception** **IsADirectoryError**
Raised when a file operation (such as `os.remove()`) is requested on a directory. Corresponds to errno EISDIR.

**exception** **NotADirectoryError**
Raised when a directory operation (such as `os.listdir()`) is requested on something which is not a directory. Corresponds to errno ENOTDIR.

**exception** **PermissionError**
Raised when trying to run an operation without the adequate
access rights - for example filesystem permissions. Corresponds to errno EACCES and EPERM.

exception **ProcessLookupError**
Raised when a given process doesn’t exist. Corresponds to errno ESRCH.

exception **TimeoutError**
Raised when a system function timed out at the system level. Corresponds to errno ETIMEDOUT.

*New in version 3.3*: All the above OSError subclasses were added.

**See also:** [PEP 3151](https://www.python.org/dev/peps/pep-03151/) - Reworking the OS and IO exception hierarchy
5.3. Warnings

The following exceptions are used as warning categories; see the warnings module for more information.

exception **Warning**
   Base class for warning categories.

exception **UserWarning**
   Base class for warnings generated by user code.

exception **DeprecationWarning**
   Base class for warnings about deprecated features.

exception **PendingDeprecationWarning**
   Base class for warnings about features which will be deprecated in the future.

exception **SyntaxWarning**
   Base class for warnings about dubious syntax.

exception **RuntimeWarning**
   Base class for warnings about dubious runtime behavior.

exception **FutureWarning**
   Base class for warnings about constructs that will change semantically in the future.

exception **ImportWarning**
   Base class for warnings about probable mistakes in module imports.

exception **UnicodeWarning**
Base class for warnings related to Unicode.

exception **BytesWarning**
Base class for warnings related to `bytes` and `bytearray`.

exception **ResourceWarning**
Base class for warnings related to resource usage.

*New in version 3.2.*
5.4. Exception hierarchy

The class hierarchy for built-in exceptions is:

```
BaseException
 | -- SystemExit
 | -- KeyboardInterrupt
 | -- GeneratorExit
 | -- Exception
 | | -- StopIteration
 | | -- StopAsyncIteration
 | | -- ArithmeticError
 | | | -- FloatingPointError
 | | | -- OverflowError
 | | | -- ZeroDivisionError
 | | -- AssertionError
 | | -- AttributeError
 | | -- BufferError
 | | -- EOFError
 | | -- ImportError
 | | -- LookupError
 | | | -- IndexError
 | | | -- KeyError
 | | -- MemoryError
 | | -- NameError
 | | | -- UnboundLocalError
 | | -- OSError
 | | | -- BlockingIOError
 | | | -- ChildProcessError
 | | | -- ConnectionError
 | | | | -- BrokenPipeError
 | | | | -- ConnectionAbortedError
 | | | | -- ConnectionRefusedError
 | | | | -- ConnectionResetError
 | | | -- FileExistsError
```
The Python Software Foundation is a non-profit corporation. Please donate.
Last updated on Dec 06, 2015. Found a bug?
Created using Sphinx 1.3.1.
6. Text Processing Services

The modules described in this chapter provide a wide range of string manipulation operations and other text processing services.

The `codecs` module described under Binary Data Services is also highly relevant to text processing. In addition, see the documentation for Python’s built-in string type in Text Sequence Type — `str`.

- **6.1. string — Common string operations**
  - 6.1.1. String constants
  - 6.1.2. String Formatting
  - 6.1.3. Format String Syntax
    - 6.1.3.1. Format Specification Mini-Language
    - 6.1.3.2. Format examples
  - 6.1.4. Template strings
  - 6.1.5. Helper functions
- **6.2. re — Regular expression operations**
  - 6.2.1. Regular Expression Syntax
  - 6.2.2. Module Contents
  - 6.2.3. Regular Expression Objects
  - 6.2.4. Match Objects
  - 6.2.5. Regular Expression Examples
    - 6.2.5.1. Checking for a Pair
    - 6.2.5.2. Simulating `scanf()`
    - 6.2.5.3. `search()` vs. `match()`
    - 6.2.5.4. Making a Phonebook
    - 6.2.5.5. Text Munging
    - 6.2.5.6. Finding all Adverbs
    - 6.2.5.7. Finding all Adverbs and their Positions
    - 6.2.5.8. Raw String Notation
    - 6.2.5.9. Writing a Tokenizer
6.3. difflib — Helpers for computing deltas
   6.3.1. SequenceMatcher Objects
   6.3.2. SequenceMatcher Examples
   6.3.3. Differ Objects
   6.3.4. Differ Example
   6.3.5. A command-line interface to difflib
6.4. textwrap — Text wrapping and filling
6.5. unicodedata — Unicode Database
6.6. stringprep — Internet String Preparation
6.7. readline — GNU readline interface
   6.7.1. Example
6.8. rlcompleter — Completion function for GNU readline
   6.8.1. Completer Objects
6.1. **string** — Common string operations

**Source code:** `Lib/string.py`

**See also:**  
- Text Sequence Type — `str`
- String Methods
6.1.1. String constants

The constants defined in this module are:

string.\texttt{ascii\_letters}
The concatenation of the \texttt{ascii\_lowercase} and \texttt{ascii\_uppercase} constants described below. This value is not locale-dependent.

string.\texttt{ascii\_lowercase}
The lowercase letters 'abcdefghijklmnopqrstuvwxyz'. This value is not locale-dependent and will not change.

string.\texttt{ascii\_uppercase}
The uppercase letters 'ABCDEFGHIJKLMNOPQRSTUVWXYZ'. This value is not locale-dependent and will not change.

string.\texttt{digits}
The string '0123456789'.

string.\texttt{hexdigits}
The string '0123456789abcdefABCDEF'.

string.\texttt{octdigits}
The string '01234567'.

string.\texttt{punctuation}
String of ASCII characters which are considered punctuation characters in the C locale.

string.\texttt{printable}
String of ASCII characters which are considered printable. This is a
combination of digits, ascii_letters, punctuation, and whitespace.

**string.whitespace**

A string containing all ASCII characters that are considered whitespace. This includes the characters space, tab, linefeed, return, formfeed, and vertical tab.
### 6.1.2. String Formatting

The built-in string class provides the ability to do complex variable substitutions and value formatting via the `format()` method described in [PEP 3101](https://www.python.org/dev/peps/pep-03101/). The `Formatter` class in the `string` module allows you to create and customize your own string formatting behaviors using the same implementation as the built-in `format()` method.

```python
class string.Formatter
    The Formatter class has the following public methods:

    **format**(*format_string, *args, **kwargs)*
    
    `format()` is the primary API method. It takes a format string and an arbitrary set of positional and keyword arguments. `format()` is just a wrapper that calls `vformat()`.

    *Deprecated since version 3.5:* Passing a format string as keyword argument `format_string` has been deprecated.

    **vformat**(*format_string, args, kwargs)*
    
    This function does the actual work of formatting. It is exposed as a separate function for cases where you want to pass in a predefined dictionary of arguments, rather than unpacking and repacking the dictionary as individual arguments using the `*args` and `**kwargs` syntax. `vformat()` does the work of breaking up the format string into character data and replacement fields. It calls the various methods described below.

    In addition, the `Formatter` defines a number of methods that are
intended to be replaced by subclasses:

**parse(format_string)**
Loop over the format_string and return an iterable of tuples (`literal_text`, `field_name`, `format_spec`, `conversion`). This is used by `vformat()` to break the string into either literal text, or replacement fields.

The values in the tuple conceptually represent a span of literal text followed by a single replacement field. If there is no literal text (which can happen if two replacement fields occur consecutively), then `literal_text` will be a zero-length string. If there is no replacement field, then the values of `field_name`, `format_spec` and `conversion` will be None.

**get_field(field_name, args, kwargs)**
Given `field_name` as returned by `parse()` (see above), convert it to an object to be formatted. Returns a tuple (obj, used_key). The default version takes strings of the form defined in PEP 3101, such as “0[name]” or “label.title”. `args` and `kwargs` are as passed in to `vformat()`. The return value `used_key` has the same meaning as the `key` parameter to `get_value()`.

**get_value(key, args, kwargs)**
Retrieve a given field value. The `key` argument will be either an integer or a string. If it is an integer, it represents the index of the positional argument in `args`; if it is a string, then it represents a named argument in `kwargs`.

The `args` parameter is set to the list of positional arguments to `vformat()`, and the `kwargs` parameter is set to the dictionary of keyword arguments.
For compound field names, these functions are only called for the first component of the field name; Subsequent components are handled through normal attribute and indexing operations.

So for example, the field expression '0.name' would cause get_value() to be called with a key argument of 0. The name attribute will be looked up after get_value() returns by calling the built-in getattr() function.

If the index or keyword refers to an item that does not exist, then an IndexError or KeyError should be raised.

**check_unused_args**(used_args, args, kwargs)
Implement checking for unused arguments if desired. The arguments to this function is the set of all argument keys that were actually referred to in the format string (integers for positional arguments, and strings for named arguments), and a reference to the args and kwargs that was passed to vformat. The set of unused args can be calculated from these parameters. check_unused_args() is assumed to raise an exception if the check fails.

**format_field**(value, format_spec)
format_field() simply calls the global format() built-in. The method is provided so that subclasses can override it.

**convert_field**(value, conversion)
Converts the value (returned by get_field()) given a conversion type (as in the tuple returned by the parse() method). The default version understands ‘s’ (str), ‘r’ (repr) and ‘a’ (ascii) conversion types.
6.1.3. Format String Syntax

The `str.format()` method and the `Formatter` class share the same syntax for format strings (although in the case of `Formatter`, subclasses can define their own format string syntax).

Format strings contain “replacement fields” surrounded by curly braces `{}`. Anything that is not contained in braces is considered literal text, which is copied unchanged to the output. If you need to include a brace character in the literal text, it can be escaped by doubling: `{ { and } }`.

The grammar for a replacement field is as follows:

```
replacement_field ::= "{" [field_name] ["!" conversion] "}"
field_name ::= arg_name ("." attribute_name)
arg_name ::= [identifier | integer]
attribute_name ::= identifier
element_index ::= integer | index_string
index_string ::= <any source character except "]"> +
conversion ::= "r" | "s" | "a"
format_spec ::= <described in the next section>
```

In less formal terms, the replacement field can start with a `field_name` that specifies the object whose value is to be formatted and inserted into the output instead of the replacement field. The `field_name` is optionally followed by a `conversion` field, which is preceded by an exclamation point '!', and a `format_spec`, which is preceded by a colon ':'. These specify a non-default format for the replacement value.

See also the Format Specification Mini-Language section.
The field_name itself begins with an arg_name that is either a number or a keyword. If it's a number, it refers to a positional argument, and if it's a keyword, it refers to a named keyword argument. If the numerical arg_names in a format string are 0, 1, 2, ... in sequence, they can all be omitted (not just some) and the numbers 0, 1, 2, ... will be automatically inserted in that order. Because arg_name is not quote-delimited, it is not possible to specify arbitrary dictionary keys (e.g., the strings '10' or ': -]') within a format string. The arg_name can be followed by any number of index or attribute expressions. An expression of the form '.name' selects the named attribute using getattr(), while an expression of the form '[index]' does an index lookup using __getitem__().

Changed in version 3.1: The positional argument specifiers can be omitted, so '{} {}' is equivalent to '{0} {1}'.

Some simple format string examples:

"First, thou shalt count to {0}" # References first positional argument
"Bring me a {}" # Implicitly references the first positional argument
"From {} to {}" # Same as "From {0} to {1}
"My quest is {name}" # References keyword argument's value
"Weight in tons {0.weight}" # 'weight' attribute of first positional arg
"Units destroyed: {players[0]}" # First element of keyword argument

The conversion field causes a type coercion before formatting. Normally, the job of formatting a value is done by the __format__() method of the value itself. However, in some cases it is desirable to force a type to be formatted as a string, overriding its own definition of formatting. By converting the value to a string before calling __format__(), the normal formatting logic is bypassed.
Three conversion flags are currently supported: '!s' which calls \texttt{str()} on the value, '!r' which calls \texttt{repr()} and '!a' which calls \texttt{ascii()}.

Some examples:

\begin{verbatim}
"Harold's a clever {0!s}"  # Calls \texttt{str()} on the argument first
"Bring out the holy {name!r}"  # Calls \texttt{repr()} on the argument first
"More {!a}"  # Calls \texttt{ascii()} on the argument first
\end{verbatim}

The \texttt{format_spec} field contains a specification of how the value should be presented, including such details as field width, alignment, padding, decimal precision and so on. Each value type can define its own “formatting mini-language” or interpretation of the \texttt{format_spec}.

Most built-in types support a common formatting mini-language, which is described in the next section.

A \texttt{format_spec} field can also include nested replacement fields within it. These nested replacement fields can contain only a field name; conversion flags and format specifications are not allowed. The replacement fields within the \texttt{format_spec} are substituted before the \texttt{format_spec} string is interpreted. This allows the formatting of a value to be dynamically specified.

See the \texttt{Format examples} section for some examples.

\textbf{6.1.3.1. Format Specification Mini-Language}

“Format specifications” are used within replacement fields contained within a format string to define how individual values are presented (see \texttt{Format String Syntax}). They can also be passed directly to the
built-in `format()` function. Each formattable type may define how the format specification is to be interpreted.

Most built-in types implement the following options for format specifications, although some of the formatting options are only supported by the numeric types.

A general convention is that an empty format string (""") produces the same result as if you had called `str()` on the value. A non-empty format string typically modifies the result.

The general form of a standard format specifier is:

```
format_spec ::= [[fill]align][sign][#][0][width][,][.]
fill ::= <any character>
align ::= "<" | ">" | ":" | "^"
sign ::= "+" | "-" | " "
width ::= integer
precision ::= integer
type ::= "b" | "c" | "d" | "e" | "E" | "f" | "g" | "G" | "n" | "o" | "s" | "x" | "X" | "%"
```

If a valid `align` value is specified, it can be preceded by a `fill` character that can be any character and defaults to a space if omitted. Note that it is not possible to use `{` and `}` as `fill` char while using the `str.format()` method; this limitation however doesn’t affect the `format()` function.

The meaning of the various alignment options is as follows:

<table>
<thead>
<tr>
<th>Option</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'&lt;'</td>
<td>Forces the field to be left-aligned within the available space (this is the default for most objects).</td>
</tr>
<tr>
<td>'&gt;'</td>
<td>Forces the field to be right-aligned within the available</td>
</tr>
</tbody>
</table>
Forces the padding to be placed after the sign (if any) but before the digits. This is used for printing fields in the form ‘+000000120’. This alignment option is only valid for numeric types.

Forces the field to be centered within the available space.

Note that unless a minimum field width is defined, the field width will always be the same size as the data to fill it, so that the alignment option has no meaning in this case.

The sign option is only valid for number types, and can be one of the following:

<table>
<thead>
<tr>
<th>Option</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>' '</td>
<td>indicates that a sign should be used for both positive as well as negative numbers.</td>
</tr>
<tr>
<td>' - '</td>
<td>indicates that a sign should be used only for negative numbers (this is the default behavior).</td>
</tr>
<tr>
<td>space</td>
<td>indicates that a leading space should be used on positive numbers, and a minus sign on negative numbers.</td>
</tr>
</tbody>
</table>

The '#' option causes the “alternate form” to be used for the conversion. The alternate form is defined differently for different types. This option is only valid for integer, float, complex and Decimal types. For integers, when binary, octal, or hexadecimal output is used, this option adds the prefix respective '0b', '0o', or '0x' to the output value. For floats, complex and Decimal the alternate form causes the result of the conversion to always contain a decimal-point character, even if no digits follow it. Normally, a decimal-point character appears
in the result of these conversions only if a digit follows it. In addition, for 'g' and 'G' conversions, trailing zeros are not removed from the result.

The ', ' option signals the use of a comma for a thousands separator. For a locale aware separator, use the 'n' integer presentation type instead.

*Changed in version 3.1:* Added the ', ' option (see also PEP 378).

`width` is a decimal integer defining the minimum field width. If not specified, then the field width will be determined by the content.

Preceding the `width` field by a zero ('0') character enables sign-aware zero-padding for numeric types. This is equivalent to a *fill* character of '0' with an *alignment* type of '='.

The `precision` is a decimal number indicating how many digits should be displayed after the decimal point for a floating point value formatted with 'f' and 'F', or before and after the decimal point for a floating point value formatted with 'g' or 'G'. For non-number types the field indicates the maximum field size - in other words, how many characters will be used from the field content. The `precision` is not allowed for integer values.

Finally, the `type` determines how the data should be presented.

The available string presentation types are:

<table>
<thead>
<tr>
<th>Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'s'</td>
<td>String format. This is the default type for strings and may be omitted.</td>
</tr>
<tr>
<td>None</td>
<td>The same as 's'.</td>
</tr>
</tbody>
</table>
The available integer presentation types are:

<table>
<thead>
<tr>
<th>Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'b'</td>
<td>Binary format. Outputs the number in base 2.</td>
</tr>
<tr>
<td>'c'</td>
<td>Character. Converts the integer to the corresponding unicode character before printing.</td>
</tr>
<tr>
<td>'d'</td>
<td>Decimal Integer. Outputs the number in base 10.</td>
</tr>
<tr>
<td>'o'</td>
<td>Octal format. Outputs the number in base 8.</td>
</tr>
<tr>
<td>'x'</td>
<td>Hex format. Outputs the number in base 16, using lower-case letters for the digits above 9.</td>
</tr>
<tr>
<td>'X'</td>
<td>Hex format. Outputs the number in base 16, using upper-case letters for the digits above 9.</td>
</tr>
<tr>
<td>'n'</td>
<td>Number. This is the same as 'd', except that it uses the current locale setting to insert the appropriate number separator characters.</td>
</tr>
<tr>
<td>None</td>
<td>The same as 'd'.</td>
</tr>
</tbody>
</table>

In addition to the above presentation types, integers can be formatted with the floating point presentation types listed below (except 'n' and None). When doing so, `float()` is used to convert the integer to a floating point number before formatting.

The available presentation types for floating point and decimal values are:

<table>
<thead>
<tr>
<th>Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'e'</td>
<td>Exponent notation. Prints the number in scientific notation using the letter ‘e’ to indicate the exponent. The default precision is 6.</td>
</tr>
<tr>
<td>'E'</td>
<td>Exponent notation. Same as 'e' except it uses an upper case ‘E’ as the separator character.</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>'f'</td>
<td>Fixed point. Displays the number as a fixed-point number. The default precision is 6.</td>
</tr>
<tr>
<td>'F'</td>
<td>Fixed point. Same as 'f', but converts nan to NAN and inf to INF.</td>
</tr>
<tr>
<td>'g'</td>
<td>General format. For a given precision p ( \geq 1 ), this rounds the number to p significant digits and then formats the result in either fixed-point format or in scientific notation, depending on its magnitude. The precise rules are as follows: suppose that the result formatted with presentation type 'e' and precision p-1 would have exponent exp. Then if -4 ( \leq ) exp &lt; p, the number is formatted with presentation type 'f' and precision p-1-exp. Otherwise, the number is formatted with presentation type 'e' and precision p-1. In both cases insignificant trailing zeros are removed from the significand, and the decimal point is also removed if there are no remaining digits following it. Positive and negative infinity, positive and negative zero, and nans, are formatted as inf, -inf, 0, -0 and nan respectively, regardless of the precision. A precision of 0 is treated as equivalent to a precision of 1. The default precision is 6.</td>
</tr>
<tr>
<td>'G'</td>
<td>General format. Same as 'g' except switches to 'E' if the number gets too large. The representations of infinity and NaN are uppercased, too.</td>
</tr>
<tr>
<td>Number</td>
<td>This is the same as 'g', except that it uses</td>
</tr>
<tr>
<td>'n'</td>
<td>the current locale setting to insert the appropriate number separator characters.</td>
</tr>
<tr>
<td>'%'</td>
<td>Percentage. Multiplies the number by 100 and displays in fixed ('f') format, followed by a percent sign.</td>
</tr>
<tr>
<td>None</td>
<td>Similar to 'g', except that fixed-point notation, when used, has at least one digit past the decimal point. The default precision is as high as needed to represent the particular value. The overall effect is to match the output of str() as altered by the other format modifiers.</td>
</tr>
</tbody>
</table>

6.1.3.2. Format examples

This section contains examples of the new format syntax and comparison with the old %-formatting.

In most of the cases the syntax is similar to the old %-formatting, with the addition of the {} and with : used instead of %. For example, '%03.2f' can be translated to '{:03.2f}'.

The new format syntax also supports new and different options, shown in the follow examples.

Accessing arguments by position:

```python
>>> '{0}, {1}, {2}'.format('a', 'b', 'c')
'a, b, c'
>>> '{}, {}, {}'.format('a', 'b', 'c')  # 3.1+ only
'a, b, c'
>>> '{2}, {1}, {0}'.format('a', 'b', 'c')
'c, b, a'
>>> '{2}, {1}, {0}'.format(*'abc')  # unpacking
'c, b, a'
>>> '{0}{1}{0}'.format('abra', 'cad')  # arguments
```
Accessing arguments by name:

```python
>>> 'Coordinates: {latitude}, {longitude}'.format(latitude=37.24, longitude=-115.81)
'Coordinates: 37.24N, -115.81W'
>>> coord = {'latitude': '37.24N', 'longitude': '-115.81W'}
>>> 'Coordinates: {latitude}, {longitude}'.format(**coord)
'Coordinates: 37.24N, -115.81W'
```

Accessing arguments' attributes:

```python
>>> c = 3-5j
>>> ('The complex number {0} is formed from the real part {0.real} ' +
... 'and the imaginary part {0.imag}.').format(c)
'The complex number (3-5j) is formed from the real part 3.0 and the imaginary part -5.0.'
>>> class Point:
...     def __init__(self, x, y):
...         self.x, self.y = x, y
...     def __str__(self):
...         return 'Point({self.x}, {self.y})'.format(s=self)
...
>>> str(Point(4, 2))
'Point(4, 2)'
```

Accessing arguments' items:

```python
>>> coord = (3, 5)
>>> 'X: {0[0]}; Y: {0[1]}'.format(coord)
'X: 3; Y: 5'
```

Replacing %s and %r:

```python
>>> "repr() shows quotes: {!r}; str() doesn't: {!s}""repr() shows quotes: {!r}; str() doesn't: {!s}"```
"repr() shows quotes: 'test1'; str() doesn't: test2"
>>> '{:,}'.format(1234567890)
'1,234,567,890'

Expressing a percentage:

>>> points = 19
>>> total = 22
>>> 'Correct answers: {:.2%}'.format(points/total)
'Correct answers: 86.36%

Using type-specific formatting:

```python
>>> import datetime
>>> d = datetime.datetime(2010, 7, 4, 12, 15, 58)
>>> '{:%Y-%m-%d %H:%M:%S}'.format(d)
'2010-07-04 12:15:58'
```

Nesting arguments and more complex examples:

```python
>>> for align, text in zip('<^>', ['left', 'center', 'right', 'left', 'center', 'right', 'left', 'center', 'right', 'left', 'center', 'right', 'left', 'center', 'right', 'left', 'center', 'right', 'left', 'center', 'right', 'left', 'center', 'right'], '
...
  '{0:{fill}{align}16}'.format(text, fill=align)
...
'left<<<<<<<<<<<<
'^^^^^center^^^^^'
'>>>>>>>>>>>right'
>>> octets = [192, 168, 0, 1]
>>> '{:02X}{:02X}{:02X}{:02X}'.format(*octets)
'C0A80001'
>>> int(_, 16)
3232235521
>>> width = 5
>>> for num in range(5,12):
...    for base in 'dXob':
...        print('{0:{width}{base}}'.format(num, ba
... print() ...

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
<td>101</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>6</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>7</td>
<td>111</td>
<td></td>
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<tr>
<td>8</td>
<td>8</td>
<td>10</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>11</td>
<td>1001</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>A</td>
<td>12</td>
<td>1010</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>B</td>
<td>13</td>
<td>1011</td>
<td></td>
</tr>
</tbody>
</table>
6.1.4. Template strings

Templates provide simpler string substitutions as described in PEP 292. Instead of the normal %-based substitutions, Templates support $-based substitutions, using the following rules:

- $$ is an escape; it is replaced with a single $.
- $identifier names a substitution placeholder matching a mapping key of "identifier". By default, "identifier" is restricted to any case-insensitive ASCII alphanumeric string (including underscores) that starts with an underscore or ASCII letter. The first non-identifier character after the $ character terminates this placeholder specification.
- $\{identifier\}$ is equivalent to $identifier$. It is required when valid identifier characters follow the placeholder but are not part of the placeholder, such as "$\{noun\}ification".

Any other appearance of $ in the string will result in a ValueError being raised.

The string module provides a Template class that implements these rules. The methods of Template are:

\hspace{10pt} \texttt{class \texttt{string.Templat}}e(\texttt{template})

The constructor takes a single argument which is the template string.

\hspace{10pt} \texttt{substitute}(\texttt{mapping}, **\texttt{kwds})

Performs the template substitution, returning a new string. \texttt{mapping} is any dictionary-like object with keys that match the placeholders in the template. Alternatively, you can provide keyword arguments, where the keywords are the placeholders.
When both \textit{mapping} and \textit{kwds} are given and there are duplicates, the placeholders from \textit{kwds} take precedence.

\textbf{safe\_substitute}(mapping, **kwds)

Like \textbf{substitute()}, except that if placeholders are missing from \textit{mapping} and \textit{kwds}, instead of raising a \texttt{KeyError} exception, the original placeholder will appear in the resulting string intact. Also, unlike with \textbf{substitute()}, any other appearances of the $ will simply return $ instead of raising \texttt{ValueError}.

While other exceptions may still occur, this method is called “safe” because substitutions always tries to return a usable string instead of raising an exception. In another sense, \textbf{safe\_substitute()} may be anything other than safe, since it will silently ignore malformed templates containing dangling delimiters, unmatched braces, or placeholders that are not valid Python identifiers.

\texttt{Template} instances also provide one public data attribute:

\texttt{template}

This is the object passed to the constructor’s \texttt{template} argument. In general, you shouldn’t change it, but read-only access is not enforced.

Here is an example of how to use a Template:

```python
>>> from string import Template
>>> s = Template('$who likes $what')
>>> s.substitute(who='tim', what='kung pao')
'tim likes kung pao'
>>> d = dict(who='tim')
```
Advanced usage: you can derive subclasses of `Template` to customize the placeholder syntax, delimiter character, or the entire regular expression used to parse template strings. To do this, you can override these class attributes:

- **delimiter** – This is the literal string describing a placeholder introducing delimiter. The default value is $. Note that this should *not* be a regular expression, as the implementation will call `re.escape()` on this string as needed.

- **idpattern** – This is the regular expression describing the pattern for non-braced placeholders (the braces will be added automatically as appropriate). The default value is the regular expression `[_a-z][_a-z0-9]*`.

- **flags** – The regular expression flags that will be applied when compiling the regular expression used for recognizing substitutions. The default value is `re.IGNORECASE`. Note that `re.VERBOSE` will always be added to the flags, so custom `idpatterns` must follow conventions for verbose regular expressions.
New in version 3.2.

Alternatively, you can provide the entire regular expression pattern by overriding the class attribute `pattern`. If you do this, the value must be a regular expression object with four named capturing groups. The capturing groups correspond to the rules given above, along with the invalid placeholder rule:

- **escaped** – This group matches the escape sequence, e.g. $$, in the default pattern.
- **named** – This group matches the unbraced placeholder name; it should not include the delimiter in capturing group.
- **braced** – This group matches the brace enclosed placeholder name; it should not include either the delimiter or braces in the capturing group.
- **invalid** – This group matches any other delimiter pattern (usually a single delimiter), and it should appear last in the regular expression.
6.1.5. Helper functions

`string.capwords(s, sep=None)`

Split the argument into words using `str.split()`, capitalize each word using `str.capitalize()`, and join the capitalized words using `str.join()`. If the optional second argument `sep` is absent or `None`, runs of whitespace characters are replaced by a single space and leading and trailing whitespace are removed, otherwise `sep` is used to split and join the words.
6.2. \texttt{re} — Regular expression operations

This module provides regular expression matching operations similar to those found in Perl.

Both patterns and strings to be searched can be Unicode strings as well as 8-bit strings. However, Unicode strings and 8-bit strings cannot be mixed: that is, you cannot match an Unicode string with a byte pattern or vice-versa; similarly, when asking for a substitution, the replacement string must be of the same type as both the pattern and the search string.

Regular expressions use the backslash character ('\') to indicate special forms or to allow special characters to be used without invoking their special meaning. This collides with Python's usage of the same character for the same purpose in string literals; for example, to match a literal backslash, one might have to write '\\\' as the pattern string, because the regular expression must be \, and each backslash must be expressed as \ inside a regular Python string literal.

The solution is to use Python's raw string notation for regular expression patterns; backslashes are not handled in any special way in a string literal prefixed with 'r'. So r"\n" is a two-character string containing '\' and 'n', while "\n" is a one-character string containing a newline. Usually patterns will be expressed in Python code using this raw string notation.

It is important to note that most regular expression operations are
available as module-level functions and methods on compiled regular expressions. The functions are shortcuts that don’t require you to compile a regex object first, but miss some fine-tuning parameters.
6.2.1. Regular Expression Syntax

A regular expression (or RE) specifies a set of strings that matches it; the functions in this module let you check if a particular string matches a given regular expression (or if a given regular expression matches a particular string, which comes down to the same thing).

Regular expressions can be concatenated to form new regular expressions; if $A$ and $B$ are both regular expressions, then $AB$ is also a regular expression. In general, if a string $p$ matches $A$ and another string $q$ matches $B$, the string $pq$ will match $AB$. This holds unless $A$ or $B$ contain low precedence operations; boundary conditions between $A$ and $B$; or have numbered group references. Thus, complex expressions can easily be constructed from simpler primitive expressions like the ones described here. For details of the theory and implementation of regular expressions, consult the Friedl book referenced above, or almost any textbook about compiler construction.

A brief explanation of the format of regular expressions follows. For further information and a gentler presentation, consult the Regular Expression HOWTO.

Regular expressions can contain both special and ordinary characters. Most ordinary characters, like 'A', 'a', or '0', are the simplest regular expressions; they simply match themselves. You can concatenate ordinary characters, so last matches the string 'last'. (In the rest of this section, we'll write RE's in this special style, usually without quotes, and strings to be matched 'in single quotes'.)

Some characters, like '|' or '(', are special. Special characters either stand for classes of ordinary characters, or affect how the
regular expressions around them are interpreted. Regular expression pattern strings may not contain null bytes, but can specify the null byte using a \number notation such as '\\x00'.

The special characters are:

'.'
(Dot.) In the default mode, this matches any character except a newline. If the DOTALL flag has been specified, this matches any character including a newline.

'^'
(Caret.) Matches the start of the string, and in MULTILINE mode also matches immediately after each newline.

'$$'
Matches the end of the string or just before the newline at the end of the string, and in MULTILINE mode also matches before a newline. foo matches both ‘foo’ and ‘foobar’, while the regular expression foo$ matches only ‘foo’. More interestingly, searching for foo.$$ in 'foo1\nfoo2\n' matches ‘foo2’ normally, but ‘foo1’ in MULTILINE mode; searching for a single $ in 'foo\n' will find two (empty) matches: one just before the newline, and one at the end of the string.

'*'
Causes the resulting RE to match 0 or more repetitions of the preceding RE, as many repetitions as are possible. ab* will match ‘a’, ‘ab’, or ‘a’ followed by any number of ‘b’s.

'+'
Causes the resulting RE to match 1 or more repetitions of the preceding RE. ab+ will match ‘a’ followed by any non-zero number of ‘b’s; it will not match just ‘a’.

'?'
Causes the resulting RE to match 0 or 1 repetitions of the
preceding RE. $ab?$ will match either ‘a’ or ‘ab’.

$*?, +?, ??$

The '*', '+', and '?' qualifiers are all greedy; they match as much text as possible. Sometimes this behaviour isn't desired; if the RE <.*> is matched against '<H1>title</H1>', it will match the entire string, and not just '<H1>'. Adding '?' after the qualifier makes it perform the match in non-greedy or minimal fashion; as few characters as possible will be matched. Using .*? in the previous expression will match only '<H1>'.

$$\{m\}$$

Specifies that exactly $m$ copies of the previous RE should be matched; fewer matches cause the entire RE not to match. For example, $a\{6\}$ will match exactly six 'a' characters, but not five.

$$\{m, n\}$$

Causes the resulting RE to match from $m$ to $n$ repetitions of the preceding RE, attempting to match as many repetitions as possible. For example, $a\{3, 5\}$ will match from 3 to 5 'a' characters. Omitting $m$ specifies a lower bound of zero, and omitting $n$ specifies an infinite upper bound. As an example, $a\{4, \}b$ will match aaaaab or a thousand 'a' characters followed by a b, but not aaab. The comma may not be omitted or the modifier would be confused with the previously described form.

$$\{m, n\}?$$

Causes the resulting RE to match from $m$ to $n$ repetitions of the preceding RE, attempting to match as few repetitions as possible. This is the non-greedy version of the previous qualifier. For example, on the 6-character string 'aaaaaa', $a\{3, 5\}$ will match 5 'a' characters, while $a\{3, 5\}?\text{will only match 3 characters.}$

\'\'\'

Either escapes special characters (permitting you to match characters like '*', '?', and so forth), or signals a special
sequence; special sequences are discussed below.

If you're not using a raw string to express the pattern, remember that Python also uses the backslash as an escape sequence in string literals; if the escape sequence isn't recognized by Python's parser, the backslash and subsequent character are included in the resulting string. However, if Python would recognize the resulting sequence, the backslash should be repeated twice. This is complicated and hard to understand, so it's highly recommended that you use raw strings for all but the simplest expressions.

[]
Used to indicate a set of characters. In a set:

- Characters can be listed individually, e.g. [amk] will match 'a', 'm', or 'k'.
- Ranges of characters can be indicated by giving two characters and separating them by a '-', for example [a-z] will match any lowercase ASCII letter, [\-5][\-9] will match all the two-digits numbers from 00 to 59, and [\-9A-Fa-f] will match any hexadecimal digit. If - is escaped (e.g. [a\-z]) or if it's placed as the first or last character (e.g. [a-]), it will match a literal '-'.
- Special characters lose their special meaning inside sets. For example, [(\*+)] will match any of the literal characters '(', '+', '*', or ')'.
- Character classes such as \w or \S (defined below) are also accepted inside a set, although the characters they match depends on whether ASCII or LOCALE mode is in force.
- Characters that are not within a range can be matched by complementing the set. If the first character of the set is '^', all the characters that are not in the set will be matched. For example,[^5] will match any character except '5', and
[^\^] will match any character except '^'. ^ has no special meaning if it's not the first character in the set.

- To match a literal ']' inside a set, precede it with a backslash, or place it at the beginning of the set. For example, both [ ( ) \{\} ] and [ ]( )[{} ] will both match a parenthesis.

'|'
A|B, where A and B can be arbitrary REs, creates a regular expression that will match either A or B. An arbitrary number of REs can be separated by the '|' in this way. This can be used inside groups (see below) as well. As the target string is scanned, REs separated by '|' are tried from left to right. When one pattern completely matches, that branch is accepted. This means that once A matches, B will not be tested further, even if it would produce a longer overall match. In other words, the '|' operator is never greedy. To match a literal '|', use \|, or enclose it inside a character class, as in [ | ].

(...)
Matches whatever regular expression is inside the parentheses, and indicates the start and end of a group; the contents of a group can be retrieved after a match has been performed, and can be matched later in the string with the \number special sequence, described below. To match the literals '(', or ')', use \( or \), or enclose them inside a character class: [ ( ) ].

(?...)
This is an extension notation (a '?' following a '(' is not meaningful otherwise). The first character after the '?' determines what the meaning and further syntax of the construct is. Extensions usually do not create a new group; (?P<name>...) is the only exception to this rule. Following are the currently supported extensions.

(?ailmsux)
(One or more letters from the set 'a', 'i', 'L', 'm', 's', 'u', 'x'.) The group matches the empty string; the letters set the corresponding flags: \texttt{re.A} (ASCII-only matching), \texttt{re.I} (ignore case), \texttt{re.L} (locale dependent), \texttt{re.M} (multi-line), \texttt{re.S} (dot matches all), and \texttt{re.X} (verbose), for the entire regular expression. (The flags are described in \texttt{Module Contents}.) This is useful if you wish to include the flags as part of the regular expression, instead of passing a \texttt{flag} argument to the \texttt{re.compile()} function.

Note that the \texttt{(?x)} flag changes how the expression is parsed. It should be used first in the expression string, or after one or more whitespace characters. If there are non-whitespace characters before the flag, the results are undefined.

\texttt{(?:...)}
A non-capturing version of regular parentheses. Matches whatever regular expression is inside the parentheses, but the substring matched by the group \texttt{cannot} be retrieved after performing a match or referenced later in the pattern.

\texttt{(\?P<name>...)}
Similar to regular parentheses, but the substring matched by the group is accessible via the symbolic group name \texttt{name}. Group names must be valid Python identifiers, and each group name must be defined only once within a regular expression. A symbolic group is also a numbered group, just as if the group were not named.

Named groups can be referenced in three contexts. If the pattern is \texttt{(?P<quote>['"]).*?(?P=quote)} (i.e. matching a string quoted with either single or double quotes):

<table>
<thead>
<tr>
<th>Context of reference to group</th>
</tr>
</thead>
</table>


<table>
<thead>
<tr>
<th>&quot;quote&quot;</th>
<th>Ways to reference it</th>
</tr>
</thead>
</table>
| in the same pattern itself | • (?P=quote) (as shown)  
• \1 |
| when processing match object m | • m.group('quote')  
• m.end('quote') (etc.) |
| in a string passed to the repl argument of re.sub() | • \g<quote>  
• \g<1>  
• \1 |

(?P=name)
A backreference to a named group; it matches whatever text was matched by the earlier group named *name*.

(?#...)  
A comment; the contents of the parentheses are simply ignored.

(?)
Matches if ... matches next, but doesn’t consume any of the string. This is called a lookahead assertion. For example, Isaac (?=Asimov) will match 'Isaac ' only if it’s followed by 'Asimov'.

(?!...)
Matches if ... doesn’t match next. This is a negative lookahead assertion. For example, Isaac (?!Asimov) will match 'Isaac ' only if it's *not* followed by 'Asimov'.

(?!<=...)
Matches if the current position in the string is preceded by a match for ... that ends at the current position. This is called a *positive*
**lookbehind assertion.** (?<=abc)def will find a match in abcdef, since the lookbehind will back up 3 characters and check if the contained pattern matches. The contained pattern must only match strings of some fixed length, meaning that abc or a|b are allowed, but a* and a{3,4} are not. Note that patterns which start with positive lookbehind assertions will not match at the beginning of the string being searched; you will most likely want to use the `search()` function rather than the `match()` function:

```python
>>> import re
>>> m = re.search('(?<=abc)def', 'abcdef')
>>> m.group(0)
'def'
```

This example looks for a word following a hyphen:

```python
>>> m = re.search('(?<=-)\w+', 'spam-egg')
>>> m.group(0)
'egg'
```

(?<!...) Matches if the current position in the string is not preceded by a match for .... This is called a **negative lookbehind assertion**. Similar to positive lookbehind assertions, the contained pattern must only match strings of some fixed length. Patterns which start with negative lookbehind assertions may match at the beginning of the string being searched.

(?(id/name)yes-pattern|no-pattern) Will try to match with yes-pattern if the group with given id or name exists, and with no-pattern if it doesn't. no-pattern is optional and can be omitted. For example, (<)?(\w+@\w+ (?:\.\w+)+)(?(1)>|$) is a poor email matching pattern, which will match with '<user@host.com>' as well as
'user@host.com', but not with '<user@host.com' nor 'user@host.com>'.

The special sequences consist of '\' and a character from the list below. If the ordinary character is not on the list, then the resulting RE will match the second character. For example, \$ matches the character '$'.

\number
  Matches the contents of the group of the same number. Groups are numbered starting from 1. For example, (.+) \1 matches 'the the' or '55 55', but not 'the the' (note the space after the group). This special sequence can only be used to match one of the first 99 groups. If the first digit of number is 0, or number is 3 octal digits long, it will not be interpreted as a group match, but as the character with octal value number. Inside the ' [ ' and ' ] ' of a character class, all numeric escapes are treated as characters.

\A
  Matches only at the start of the string.

\b
  Matches the empty string, but only at the beginning or end of a word. A word is defined as a sequence of Unicode alphanumeric or underscore characters, so the end of a word is indicated by whitespace or a non-alphanumeric, non-underscore Unicode character. Note that formally, \b is defined as the boundary between a \w and a \W character (or vice versa), or between \w and the beginning/end of the string. This means that r'\bfoo\b' matches 'foo', 'foo.', '(foo)', 'bar foo baz' but not 'foobar' or 'foo3'.

By default Unicode alphanumerics are the ones used, but this can be changed by using the ASCII flag. Inside a character range, \b
represents the backspace character, for compatibility with Python’s string literals.

\B
Matches the empty string, but only when it is not at the beginning or end of a word. This means that r'py\B' matches 'python', 'py3', 'py2', but not 'py', 'py.', or 'py!'. \B is just the opposite of \b, so word characters are Unicode alphanumerics or the underscore, although this can be changed by using the ASCII flag.

\d
For Unicode (str) patterns:
Matches any Unicode decimal digit (that is, any character in Unicode character category [Nd]). This includes [0-9], and also many other digit characters. If the ASCII flag is used only [0-9] is matched (but the flag affects the entire regular expression, so in such cases using an explicit [0-9] may be a better choice).

For 8-bit (bytes) patterns:
Matches any decimal digit; this is equivalent to [0-9].

\D
Matches any character which is not a Unicode decimal digit. This is the opposite of \d. If the ASCII flag is used this becomes the equivalent of [^0-9] (but the flag affects the entire regular expression, so in such cases using an explicit [^0-9] may be a better choice).

\s
For Unicode (str) patterns:
Matches Unicode whitespace characters (which includes [\t\n\r\f\v], and also many other characters, for example the non-breaking spaces mandated by typography rules in
many languages). If the ASCII flag is used, only [\t\n\r\f\v] is matched (but the flag affects the entire regular expression, so in such cases using an explicit [\t\n\r\f\v] may be a better choice).

For 8-bit (bytes) patterns:
Matches characters considered whitespace in the ASCII character set; this is equivalent to [\t\n\r\f\v].

\S
Matches any character which is not a Unicode whitespace character. This is the opposite of \s. If the ASCII flag is used this becomes the equivalent of [^\t\n\r\f\v] (but the flag affects the entire regular expression, so in such cases using an explicit [^\t\n\r\f\v] may be a better choice).

\w
For Unicode (str) patterns:
Matches Unicode word characters; this includes most characters that can be part of a word in any language, as well as numbers and the underscore. If the ASCII flag is used, only [a-zA-Z0-9_] is matched (but the flag affects the entire regular expression, so in such cases using an explicit [a-zA-Z0-9_] may be a better choice).

For 8-bit (bytes) patterns:
Matches characters considered alphanumeric in the ASCII character set; this is equivalent to [a-zA-Z0-9_].
\Z

Matches only at the end of the string.

Most of the standard escapes supported by Python string literals are also accepted by the regular expression parser:

\a \b \f \n \r \t \u \U  \\
v \x \\ \\

(Note that \b is used to represent word boundaries, and means “backspace” only inside character classes.)

'\u' and '\U' escape sequences are only recognized in Unicode patterns. In bytes patterns they are not treated specially.

Octal escapes are included in a limited form. If the first digit is a 0, or if there are three octal digits, it is considered an octal escape. Otherwise, it is a group reference. As for string literals, octal escapes are always at most three digits in length.

*Changed in version 3.3:* The '\u' and '\U' escape sequences have been added.

*Deprecated since version 3.5, will be removed in version 3.6:* Unknown escapes consist of '\' and ASCII letter now raise a deprecation warning and will be forbidden in Python 3.6.

**See also:**

**Mastering Regular Expressions**

Book on regular expressions by Jeffrey Friedl, published by O'Reilly. The second edition of the book no longer covers Python at all, but the first edition covered writing good regular expression
patterns in great detail.
6.2.2. Module Contents

The module defines several functions, constants, and an exception. Some of the functions are simplified versions of the full featured methods for compiled regular expressions. Most non-trivial applications always use the compiled form.

\texttt{re.compile(pattern, flags=0)}

Compile a regular expression pattern into a regular expression object, which can be used for matching using its \texttt{match()} and \texttt{search()} methods, described below.

The expression’s behaviour can be modified by specifying a \texttt{flags} value. Values can be any of the following variables, combined using bitwise OR (the | operator).

The sequence

\begin{verbatim}
prog = re.compile(pattern)
result = prog.match(string)
\end{verbatim}

is equivalent to

\begin{verbatim}
result = re.match(pattern, string)
\end{verbatim}

but using \texttt{re.compile()} and saving the resulting regular expression object for reuse is more efficient when the expression will be used several times in a single program.

\textbf{Note:} The compiled versions of the most recent patterns passed to \texttt{re.compile()} and the module-level matching functions are cached, so programs that use only a few regular expressions at a
time needn’t worry about compiling regular expressions.

re.A
re.ASCII
Make \w, \W, \b, \B, \d, \D, \s and \S perform ASCII-only matching instead of full Unicode matching. This is only meaningful for Unicode patterns, and is ignored for byte patterns.

Note that for backward compatibility, the re.U flag still exists (as well as its synonym re.UNICODE and its embedded counterpart (?u)), but these are redundant in Python 3 since matches are Unicode by default for strings (and Unicode matching isn’t allowed for bytes).

re.DEBUG
Display debug information about compiled expression.

re.I
re.IGNORECASE
Perform case-insensitive matching; expressions like [A-Z] will match lowercase letters, too. This is not affected by the current locale and works for Unicode characters as expected.

re.L
re.LOCALE
Make \w, \W, \b, \B, \s and \S dependent on the current locale. The use of this flag is discouraged as the locale mechanism is very unreliable, and it only handles one “culture” at a time anyway; you should use Unicode matching instead, which is the default in Python 3 for Unicode (str) patterns. This flag makes sense only with bytes patterns.
Deprecated since version 3.5, will be removed in version 3.6: Deprecated the use of `re.LOCALE` with string patterns or `re.ASCII`.

`re.M`  
`re.MULTILINE`

When specified, the pattern character `'^'` matches at the beginning of the string and at the beginning of each line (immediately following each newline); and the pattern character `'$'` matches at the end of the string and at the end of each line (immediately preceding each newline). By default, `'^'` matches only at the beginning of the string, and `'$'` only at the end of the string and immediately before the newline (if any) at the end of the string.

`re.S`  
`re.DOTALL`

Make the `.'` special character match any character at all, including a newline; without this flag, `.'` will match anything except a newline.

`re.X`  
`re.VERBOSE`

This flag allows you to write regular expressions that look nicer and are more readable by allowing you to visually separate logical sections of the pattern and add comments. Whitespace within the pattern is ignored, except when in a character class or when preceded by an unescaped backslash. When a line contains a `#` that is not in a character class and is not preceded by an unescaped backslash, all characters from the leftmost such `#` through the end of the line are ignored.
This means that the two following regular expression objects that match a decimal number are functionally equal:

```python
a = re.compile(r"\"\"\d + # the integral part \\.. # the decimal point \d * # some fractional digits
b = re.compile(r"\d+/.\d*"
```

`re.search(pattern, string, flags=0)`

Scan through `string` looking for the first location where the regular expression `pattern` produces a match, and return a corresponding match object. Return None if no position in the string matches the pattern; note that this is different from finding a zero-length match at some point in the string.

`re.match(pattern, string, flags=0)`

If zero or more characters at the beginning of `string` match the regular expression `pattern`, return a corresponding match object. Return None if the string does not match the pattern; note that this is different from a zero-length match.

Note that even in MULTILINE mode, `re.match()` will only match at the beginning of the string and not at the beginning of each line.

If you want to locate a match anywhere in `string`, use `search()` instead (see also `search()` vs. `match()`).

`re.fullmatch(pattern, string, flags=0)`

If the whole `string` matches the regular expression `pattern`, return a corresponding match object. Return None if the string does not match the pattern; note that this is different from a zero-length match.
New in version 3.4.

\texttt{re.split(pattern, string, maxsplit=0, flags=0)}

Split \textit{string} by the occurrences of \textit{pattern}. If capturing parentheses are used in \textit{pattern}, then the text of all groups in the pattern are also returned as part of the resulting list. If \textit{maxsplit} is nonzero, at most \textit{maxsplit} splits occur, and the remainder of the string is returned as the final element of the list.

\begin{verbatim}
>>> re.split('\\W+', 'Words, words, words. ')
['Words', 'words', 'words', '']
>>> re.split('(\\W+)', 'Words, words, words. ')
['Words', '', '', 'words', '', '', 'words', '.','.','']
>>> re.split('\\W+', 'Words, words, words.', 1)
['Words', 'words, words. ']
>>> re.split('[a-f]+', '0a3B9', flags=re.IGNORECASE)
['0', '3', '9']
\end{verbatim}

If there are capturing groups in the separator and it matches at the start of the string, the result will start with an empty string. The same holds for the end of the string:

\begin{verbatim}
>>> re.split('(\\W+)', '...words, words...')
['', '...', 'words', '', '', 'words', '...', ',']
\end{verbatim}

That way, separator components are always found at the same relative indices within the result list.

\textbf{Note:} \texttt{split()} doesn’t currently split a string on an empty pattern match. For example:

\begin{verbatim}
>>> re.split('x*', 'axbc')
['a', 'bc']
\end{verbatim}
Even though 'x*' also matches 0 'x' before 'a', between 'b' and 'c', and after 'c', currently these matches are ignored. The correct behavior (i.e. splitting on empty matches too and returning ['' , 'a', 'b', 'c', '']) will be implemented in future versions of Python, but since this is a backward incompatible change, a FutureWarning will be raised in the meanwhile.

Patterns that can only match empty strings currently never split the string. Since this doesn’t match the expected behavior, a ValueError will be raised starting from Python 3.5:

```python
>>> re.split("^$", "foo\n\nbar\n")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
...
ValueError: split() requires a non-empty pattern
```

Changed in version 3.1: Added the optional flags argument.

Changed in version 3.5: Splitting on a pattern that could match an empty string now raises a warning. Patterns that can only match empty strings are now rejected.

```
re.findall(pattern, string, flags=0)
```

Return all non-overlapping matches of pattern in string, as a list of strings. The string is scanned left-to-right, and matches are returned in the order found. If one or more groups are present in the pattern, return a list of groups; this will be a list of tuples if the pattern has more than one group. Empty matches are included in the result unless they touch the beginning of another match.

```
re.finditer(pattern, string, flags=0)
```

Return an iterator yielding match objects over all non-overlapping
matches for the RE pattern in string. The string is scanned left-to-right, and matches are returned in the order found. Empty matches are included in the result unless they touch the beginning of another match.

re.sub(pattern, repl, string, count=0, flags=0)
Return the string obtained by replacing the leftmost non-overlapping occurrences of pattern in string by the replacement repl. If the pattern isn't found, string is returned unchanged. repl can be a string or a function; if it is a string, any backslash escapes in it are processed. That is, \n is converted to a single newline character, \r is converted to a carriage return, and so forth. Unknown escapes such as \\& are left alone. Backreferences, such as \6, are replaced with the substring matched by group 6 in the pattern. For example:

```
>>> re.sub(r'def\s+([a-zA-Z_][a-zA-Z_0-9]*)\s*\(\s*\):
...     r'static PyObject*\npy_\1(void)\n{',
...     'def myfunc():
     static PyObject*\npy_myfunc(void)\n{

>>> def dashrepl(matchobj):
...     if matchobj.group(0) == '-': return '
...     else: return '-'
>>> re.sub(r'-{1,2}', dashrepl, 'pro----gram-files'
        'pro--gram files'
>>> re.sub(r'\sAND\s', ' & ', 'Baked Beans And Sp
        Baked Beans & Spam'
```

If repl is a function, it is called for every non-overlapping occurrence of pattern. The function takes a single match object argument, and returns the replacement string. For example:
The pattern may be a string or an RE object.

The optional argument `count` is the maximum number of pattern occurrences to be replaced; `count` must be a non-negative integer. If omitted or zero, all occurrences will be replaced. Empty matches for the pattern are replaced only when not adjacent to a previous match, so `sub('x*', ' - ', 'abc')` returns '-a-b-c-'.

In string-type `repl` arguments, in addition to the character escapes and backreferences described above, \g<name> will use the substring matched by the group named name, as defined by the (? P<name>...) syntax. \g<number> uses the corresponding group number; \g<2> is therefore equivalent to \2, but isn’t ambiguous in a replacement such as \g<2>0. \20 would be interpreted as a reference to group 20, not a reference to group 2 followed by the literal character '0'. The backreference \g<0> substitutes in the entire substring matched by the RE.

*Changed in version 3.1:* Added the optional flags argument.

*Changed in version 3.5:* Unmatched groups are replaced with an empty string.

*Deprecated since version 3.5, will be removed in version 3.6:* Unknown escapes consist of '\' and ASCII letter now raise a deprecation warning and will be forbidden in Python 3.6.

```python
re.subn(pattern, repl, string, count=0, flags=0)
```

Perform the same operation as `sub()`, but return a tuple `(new_string, number_of_subs_made)`.

*Changed in version 3.1:* Added the optional flags argument.
*Changed in version 3.5:* Unmatched groups are replaced with an empty string.

`re.escape(string)`

Escape all the characters in pattern except ASCII letters, numbers and `'_'`. This is useful if you want to match an arbitrary literal string that may have regular expression metacharacters in it.

*Changed in version 3.3:* The `'_'` character is no longer escaped.

`re.purge()`

Clear the regular expression cache.

**exception** `re.error(msg, pattern=None, pos=None)`

Exception raised when a string passed to one of the functions here is not a valid regular expression (for example, it might contain unmatched parentheses) or when some other error occurs during compilation or matching. It is never an error if a string contains no match for a pattern. The error instance has the following additional attributes:

- **msg**
  - The unformatted error message.

- **pattern**
  - The regular expression pattern.

- **pos**
  - The index of *pattern* where compilation failed.

- **lineno**
  - The line corresponding to *pos*. 
colno

The column corresponding to pos.

*Changed in version 3.5:* Added additional attributes.
6.2.3. Regular Expression Objects

Compiled regular expression objects support the following methods and attributes:

\[
\text{regex}. \text{search}(\text{string}[, \text{pos}[, \text{endpos}]])
\]

Scan through \textit{string} looking for a location where this regular expression produces a match, and return a corresponding \textit{match object}. Return None if no position in the string matches the pattern; note that this is different from finding a zero-length match at some point in the string.

The optional second parameter \textit{pos} gives an index in the string where the search is to start; it defaults to 0. This is not completely equivalent to slicing the string; the '\^' pattern character matches at the real beginning of the string and at positions just after a newline, but not necessarily at the index where the search is to start.

The optional parameter \textit{endpos} limits how far the string will be searched; it will be as if the string is \textit{endpos} characters long, so only the characters from \textit{pos} to \textit{endpos} - 1 will be searched for a match. If \textit{endpos} is less than \textit{pos}, no match will be found; otherwise, if \textit{rx} is a compiled regular expression object, \textit{rx.search(string, 0, 50)} is equivalent to \textit{rx.search(string[0:50], 0)}.

```python
>>> pattern = re.compile("d")
>>> pattern.search("dog")  # Match at index 0
<_sre.SRE_Match object; span=(0, 1), match='d'>
>>> pattern.search("dog", 1)  # No match; search
```
regex.\texttt{match}(\texttt{string[, pos[, endpos]]})

If zero or more characters at the \textit{beginning} of \texttt{string} match this regular expression, return a corresponding \texttt{match} \texttt{object}. Return None if the string does not match the pattern; note that this is different from a zero-length match.

The optional \texttt{pos} and \texttt{endpos} parameters have the same meaning as for the \texttt{search()} method.

\begin{verbatim}
>>> pattern = re.compile("o")
>>> pattern.match("dog")      # No match as "o" is not at the start of "dog".
>>> pattern.match("dog", 1)  # Match as "o" is the 2nd character of "dog".
<_sre.SRE_Match object; span=(1, 2), match='o'>
\end{verbatim}

If you want to locate a match anywhere in \texttt{string}, use \texttt{search()} instead (see also \texttt{search()} vs. \texttt{match()}).

regex.\texttt{fullmatch}(\texttt{string[, pos[, endpos]]})

If the whole \texttt{string} matches this regular expression, return a corresponding \texttt{match} \texttt{object}. Return None if the string does not match the pattern; note that this is different from a zero-length match.

The optional \texttt{pos} and \texttt{endpos} parameters have the same meaning as for the \texttt{search()} method.

\begin{verbatim}
>>> pattern = re.compile("o[gh]")
>>> pattern.fullmatch("dog")       # No match as "o" is not at the start of "dog".
>>> pattern.fullmatch("ogre")     # No match as not the full string matches.
>>> pattern.fullmatch("doggie", 1, 3)  # Matches within given limits.
<_sre.SRE_Match object; span=(1, 3), match='og'>
\end{verbatim}
New in version 3.4.

\texttt{regex.split(string, maxsplit=0)}

Identical to the \texttt{split()} function, using the compiled pattern.

\texttt{regex.findall(string[, pos[, endpos]])}

Similar to the \texttt{findall()} function, using the compiled pattern, but also accepts optional \texttt{pos} and \texttt{endpos} parameters that limit the search region like for \texttt{match()}.

\texttt{regex.finditer(string[, pos[, endpos]])}

Similar to the \texttt{finditer()} function, using the compiled pattern, but also accepts optional \texttt{pos} and \texttt{endpos} parameters that limit the search region like for \texttt{match()}.

\texttt{regex.sub(repl, string, count=0)}

Identical to the \texttt{sub()} function, using the compiled pattern.

\texttt{regex.subn(repl, string, count=0)}

Identical to the \texttt{subn()} function, using the compiled pattern.

\texttt{regex.flags}

The regex matching flags. This is a combination of the flags given to \texttt{compile()}, any (?...) inline flags in the pattern, and implicit flags such as UNICODE if the pattern is a Unicode string.

\texttt{regex.groups}

The number of capturing groups in the pattern.

\texttt{regex.groupindex}

A dictionary mapping any symbolic group names defined by (? P<id>) to group numbers. The dictionary is empty if no symbolic
groups were used in the pattern.

regex.pattern

The pattern string from which the RE object was compiled.
6.2.4. Match Objects

Match objects always have a boolean value of True. Since match() and search() return None when there is no match, you can test whether there was a match with a simple if statement:

```python
match = re.search(pattern, string)
if match:
    process(match)
```

Match objects support the following methods and attributes:

**match.expand(template)**

Return the string obtained by doing backslash substitution on the template string `template`, as done by the `sub()` method. Escapes such as \n are converted to the appropriate characters, and numeric backreferences (\1, \2) and named backreferences (\g<1>, \g<name>) are replaced by the contents of the corresponding group.

*Changed in version 3.5:* Unmatched groups are replaced with an empty string.

**match.group([group1,...])**

Returns one or more subgroups of the match. If there is a single argument, the result is a single string; if there are multiple arguments, the result is a tuple with one item per argument. Without arguments, `group1` defaults to zero (the whole match is returned). If a `groupN` argument is zero, the corresponding return value is the entire matching string; if it is in the inclusive range [1..99], it is the string matching the corresponding parenthesized
group. If a group number is negative or larger than the number of groups defined in the pattern, an `IndexError` exception is raised. If a group is contained in a part of the pattern that did not match, the corresponding result is None. If a group is contained in a part of the pattern that matched multiple times, the last match is returned.

```python
>>> m = re.match(r"(^\w+) (\w+)", "Isaac Newton, physicist")
>>> m.group(0)  # The entire match
'Isaac Newton'
>>> m.group(1)  # The first parenthesized subgroup.
'Isaac'
>>> m.group(2)  # The second parenthesized subgroup.
'Newton'
>>> m.group(1, 2)  # Multiple arguments give us a tuple.
('Isaac', 'Newton')
```

If the regular expression uses the `(?!P<name>...)` syntax, the `groupN` arguments may also be strings identifying groups by their group name. If a string argument is not used as a group name in the pattern, an `IndexError` exception is raised.

A moderately complicated example:

```python
>>> m = re.match(r"(?P<first_name>\w+) (?P<last_name>\w+)", "Malcolm Reynolds")
>>> m.group('first_name')
'Malcolm'
>>> m.group('last_name')
'Reynolds'
```

Named groups can also be referred to by their index:

```python
>>> m.group(1)
'Malcolm'
```
If a group matches multiple times, only the last match is accessible:

```
>>> m = re.match(r"(.)+", "a1b2c3")  # Matches 3 times.
>>> m.group(1)
'c3'
```

`match.groups(default=None)`

Return a tuple containing all the subgroups of the match, from 1 up to however many groups are in the pattern. The `default` argument is used for groups that did not participate in the match; it defaults to None.

For example:

```
>>> m = re.match(r"(\d+)\.(\d+)", "24.1632")
>>> m.groups()
('24', '1632')
```

If we make the decimal place and everything after it optional, not all groups might participate in the match. These groups will default to None unless the `default` argument is given:

```
>>> m = re.match(r"(\d+)\.?\.(\d+)?", "24")
>>> m.groups()  # Second group defaults to None.
('24', None)
>>> m.groups('0')  # Now, the second group defaults to '0'.
('24', '0')
```

`match.groupdict(default=None)`

Return a dictionary containing all the named subgroups of the
match, keyed by the subgroup name. The default argument is used for groups that did not participate in the match; it defaults to None. For example:

```python
>>> m = re.match(r"(?P<first_name>\w+) (?P<last_name>\w+)
>>> m.groupdict()
{'first_name': 'Malcolm', 'last_name': 'Reynolds'}
```

```
match.start([group])
m.match.end([group])
```

Return the indices of the start and end of the substring matched by group; group defaults to zero (meaning the whole matched substring). Return -1 if group exists but did not contribute to the match. For a match object m, and a group g that did contribute to the match, the substring matched by group g (equivalent to m.group(g)) is

```
m.string[m.start(g):m.end(g)]
```

Note that m.start(group) will equal m.end(group) if group matched a null string. For example, after m = re.search('b(c?)', 'cba'), m.start(0) is 1, m.end(0) is 2, m.start(1) and m.end(1) are both 2, and m.start(2) raises an IndexError exception.

An example that will remove remove_this from email addresses:

```python
>>> email = "tony@tiremove_thisger.net"
>>> m = re.search("remove_this", email)
>>> email[:m.start()] + email[m.end():]
'tony@tiger.net'
```
match.span([\textit{group}])

For a match $m$, return the 2-tuple ($m$.start(group), $m$.end(group)). Note that if \textit{group} did not contribute to the match, this is (-1, -1). \textit{group} defaults to zero, the entire match.

match.pos

The value of \textit{pos} which was passed to the \textit{search()} or \textit{match()} method of a \texttt{regex object}. This is the index into the string at which the RE engine started looking for a match.

match.endpos

The value of \textit{endpos} which was passed to the \textit{search()} or \textit{match()} method of a \texttt{regex object}. This is the index into the string beyond which the RE engine will not go.

match.lastindex

The integer index of the last matched capturing group, or None if no group was matched at all. For example, the expressions (a)b, ((a)(b)), and ((ab)) will have \textit{lastindex} == 1 if applied to the string 'ab', while the expression (a)(b) will have \textit{lastindex} == 2, if applied to the same string.

match.lastgroup

The name of the last matched capturing group, or None if the group didn't have a name, or if no group was matched at all.

match.re

The regular expression object whose \textit{match()} or \textit{search()} method produced this match instance.

match.string

The string passed to \textit{match()} or \textit{search()}. 
6.2.5. Regular Expression Examples

6.2.5.1. Checking for a Pair

In this example, we'll use the following helper function to display match objects a little more gracefully:

```python
def displaymatch(match):
    if match is None:
        return None
    return '<Match: %r, groups=%r>' % (match.group(),)
```

Suppose you are writing a poker program where a player's hand is represented as a 5-character string with each character representing a card, “a” for ace, “k” for king, “q” for queen, “j” for jack, “t” for 10, and “2” through “9” representing the card with that value.

To see if a given string is a valid hand, one could do the following:

```python
>>> valid = re.compile(r'^[a2-9tjqk]{5}$')
>>> displaymatch(valid.match('akt5q'))  # Valid.
'<Match: 'akt5q', groups=()>'
>>> displaymatch(valid.match('akt5e'))  # Invalid.
>>> displaymatch(valid.match('akt'))  # Invalid.
>>> displaymatch(valid.match('727ak'))  # Valid.
'<Match: '727ak', groups=()>'
```

That last hand, "727ak", contained a pair, or two of the same valued cards. To match this with a regular expression, one could use backreferences as such:

```python
>>> pair = re.compile(r'.*(.).*\1')
>>> displaymatch(pair.match('717ak'))  # Pair of
```
To find out what card the pair consists of, one could use the `group()` method of the match object in the following manner:

```python
>>> pair.match("717ak").group(1)
'7'
```

# Error because `re.match()` returns None, which doesn't have a `group()` method:

```python
>>> pair.match("718ak").group(1)
Traceback (most recent call last):
  File "<pyshell#23>", line 1, in <module>
    re.match(r".*(.).*\1", "718ak").group(1)
AttributeError: 'NoneType' object has no attribute 'group'
```
To extract the filename and numbers from a string like

```
/usr/sbin/sendmail - 0 errors, 4 warnings
```

you would use a `scanf()` format like

```
%s - %d errors, %d warnings
```

The equivalent regular expression would be

```
(\S+) - (\d+) errors, (\d+) warnings
```

### 6.2.5.3. search() vs. match()

Python offers two different primitive operations based on regular expressions: `re.match()` checks for a match only at the beginning of the string, while `re.search()` checks for a match anywhere in the string (this is what Perl does by default).

For example:
Regular expressions beginning with '^' can be used with `search()` to restrict the match at the beginning of the string:

```python
>>> re.match("c", "abcdef")  # No match
>>> re.search("^c", "abcdef")  # Match
<_sre.SRE_Match object; span=(2, 3), match='c'>
```

Note however that in `MULTILINE` mode `match()` only matches at the beginning of the string, whereas using `search()` with a regular expression beginning with '^' will match at the beginning of each line.

```python
>>> re.match("c", "abcdef")  # No match
>>> re.search("^c", "abcdef")  # No match
>>> re.search("^a", "abcdef")  # Match
<_sre.SRE_Match object; span=(0, 1), match='a'>
```

6.2.5.4. Making a Phonebook

`split()` splits a string into a list delimited by the passed pattern. The method is invaluable for converting textual data into data structures that can be easily read and modified by Python as demonstrated in the following example that creates a phonebook.

First, here is the input. Normally it may come from a file, here we are using triple-quoted string syntax:

```python
>>> text = """Ross McFluff: 834.345.1254 155 Elm Street
... Ronald Heathmore: 892.345.3428 436 Finley Avenue"
```
The entries are separated by one or more newlines. Now we convert the string into a list with each nonempty line having its own entry:

```python
>>>
entries = re.split("\n+", text)
```

```python
['Ross McFluff: 834.345.1254 155 Elm Street', 'Ronald Heathmore: 892.345.3428 436 Finley Avenue', 'Frank Burger: 925.541.7625 662 South Dogwood Way', 'Heather Albrecht: 548.326.4584 919 Park Place']
```

Finally, split each entry into a list with first name, last name, telephone number, and address. We use the maxsplit parameter of `split()` because the address has spaces, our splitting pattern, in it:

```python
>>>
[re.split(":?\s", entry, 3) for entry in entries]
```

```python
[['Ross', 'McFluff', '834.345.1254', '155 Elm Street', '155', 'Elm Street'], ['Ronald', 'Heathmore', '892.345.3428', '436 Finley Avenue', '436', 'Finley Avenue'], ['Frank', 'Burger', '925.541.7625', '662 South Dogwood Way', '662', 'South Dogwood Way'], ['Heather', 'Albrecht', '548.326.4584', '919 Park Place', '919', 'Park Place']]
```

The :? pattern matches the colon after the last name, so that it does not occur in the result list. With a maxsplit of 4, we could separate the house number from the street name:

```python
>>>
[re.split(":?:\s", entry, 4) for entry in entries]
```

```python
[['Ross', 'McFluff', '834.345.1254', '155', 'Elm Street', '155', 'Elm Street'], ['Ronald', 'Heathmore', '892.345.3428', '436', 'Finley Avenue', '436', 'Finley Avenue'], ['Frank', 'Burger', '925.541.7625', '662', 'South Dogwood Way', '662', 'South Dogwood Way'], ['Heather', 'Albrecht', '548.326.4584', '919', 'Park Place', '919', 'Park Place']]
```
6.2.5.5. Text Munging

sub() replaces every occurrence of a pattern with a string or the result of a function. This example demonstrates using sub() with a function to “munge” text, or randomize the order of all the characters in each word of a sentence except for the first and last characters:

```python
>>> def repl(m):
...     inner_word = list(m.group(2))
...     random.shuffle(inner_word)
...     return m.group(1) + ''.join(inner_word) + m.group(3)

>>> text = "Professor Abdolmalek, please report your absences promptly."
>>> re.sub(r"(\w)(\w+)(\w)", repl, text)
'Poefsrosr Aealmlobdk, pslaee reorpt your abnseces p

>>> re.sub(r"(\w)(\w+)(\w)", repl, text)
'Pofsroser Aodlambelk, plasee reoprt yuor asnebces p
```

6.2.5.6. Finding all Adverbs

findall() matches all occurrences of a pattern, not just the first one as search() does. For example, if one was a writer and wanted to find all of the adverbs in some text, he or she might use findall() in the following manner:

```python
>>> text = "He was carefully disguised but captured quickly by police."
>>> re.findall(r"\w+ly", text)
['carefully', 'quickly']
```

6.2.5.7. Finding all Adverbs and their Positions
If one wants more information about all matches of a pattern than the matched text, \texttt{finditer()} is useful as it provides match objects instead of strings. Continuing with the previous example, if one was a writer who wanted to find all of the adverbs \textit{and their positions} in some text, he or she would use \texttt{finditer()} in the following manner:

```python
>>> text = "He was carefully disguised but captured quickly by police."
>>> for m in re.finditer(r"\w+ly", text):
...     print('%02d-%02d: %s' % (m.start(), m.end(),
07-16: carefully
40-47: quickly
```
6.2.5.9. Writing a Tokenizer

A **tokenizer or scanner** analyzes a string to categorize groups of characters. This is a useful first step in writing a compiler or interpreter.

The text categories are specified with regular expressions. The technique is to combine those into a single master regular expression and to loop over successive matches:

```python
import collections
import re

Token = collections.namedtuple('Token', ['typ', 'value'])

def tokenize(code):
    keywords = {'IF', 'THEN', 'ENDIF', 'FOR', 'NEXT'}
    token_specification = [
        ('NUMBER', r'\d+(\.\d*)?'),  # Integer or decimal number
        ('ASSIGN', r':='),            # Assignment operator
        ('END', r';'),               # Statement terminator
        ('ID', r'[A-Za-z]+'),        # Identifiers
        ('OP', r'[\+\-*/)'),         # Arithmetic operators
        ('NEWLINE', r'\n'),          # Line endings
        ('SKIP', r'[\t ]+'),         # Skip over spaces and tabs
        ('MISMATCH', r'.'),          # Any other character
    ]
    tok_regex = '|'.join('(?P<%s>%s)' % pair for pair in token_specification)

    line_num = 1
    line_start = 0
    for mo in re.finditer(tok_regex, code):
        kind = mo.lastgroup
        value = mo.group(kind)
        if kind == 'NEWLINE'
```
line_start = mo.end()
line_num += 1
elif kind == 'SKIP':
    pass
elif kind == 'MISMATCH':
    raise RuntimeError('%r unexpected on line %d')
else:
    if kind == 'ID' and value in keywords:
        kind = value
    column = mo.start() - line_start
    yield Token(kind, value, line_num, column)

statements = '''
    IF quantity THEN
        total := total + price * quantity;
        tax := price * 0.05;
    ENDIF;
    ...
'''

for token in tokenize(statements):
    print(token)

The tokenizer produces the following output:

Token(typ='IF', value='IF', line=2, column=4)
Token(typ='ID', value='quantity', line=2, column=7)
Token(typ='THEN', value='THEN', line=2, column=16)
Token(typ='ID', value='total', line=3, column=8)
Token(typ='ASSIGN', value=':=', line=3, column=14)
Token(typ='ID', value='total', line=3, column=17)
Token(typ='OP', value='+', line=3, column=23)
Token(typ='ID', value='price', line=3, column=25)
Token(typ='OP', value='*', line=3, column=31)
Token(typ='ID', value='quantity', line=3, column=33)
Token(typ='END', value=';', line=3, column=41)
Token(typ='ID', value='tax', line=4, column=8)
Token(typed='ASSIGN', value=':='), line=4, column=12)
Token(typed='ID', value='price'), line=4, column=15)
Token(typed='OP', value='*', line=4, column=21)
Token(typed='NUMBER', value='0.05'), line=4, column=23)
Token(typed='END', value=';', line=4, column=27)
Token(typed='ENDIF', value='ENDIF'), line=5, column=4)
Token(typed='END', value=';', line=5, column=9)
6.3. **difflib** — Helpers for computing deltas

**Source code:** Lib/difflib.py

This module provides classes and functions for comparing sequences. It can be used for example, for comparing files, and can produce difference information in various formats, including HTML and context and unified diffs. For comparing directories and files, see also, the **filecmp** module.

```python
class difflib.SequenceMatcher
```

This is a flexible class for comparing pairs of sequences of any type, so long as the sequence elements are hashable. The basic algorithm predates, and is a little fancier than, an algorithm published in the late 1980's by Ratcliff and Obershlep under the hyperbolic name “gestalt pattern matching.” The idea is to find the longest contiguous matching subsequence that contains no “junk” elements; these “junk” elements are ones that are uninteresting in some sense, such as blank lines or whitespace. (Handling junk is an extension to the Ratcliff and Obershlep algorithm.) The same idea is then applied recursively to the pieces of the sequences to the left and to the right of the matching subsequence. This does not yield minimal edit sequences, but does tend to yield matches that “look right” to people.

**Timing:** The basic Ratcliff-Obershlep algorithm is cubic time in the worst case and quadratic time in the expected case. **SequenceMatcher** is quadratic time for the worst case and has expected-case behavior dependent in a complicated way on how
many elements the sequences have in common; best case time is linear.

**Automatic junk heuristic:** `SequenceMatcher` supports a heuristic that automatically treats certain sequence items as junk. The heuristic counts how many times each individual item appears in the sequence. If an item’s duplicates (after the first one) account for more than 1% of the sequence and the sequence is at least 200 items long, this item is marked as “popular” and is treated as junk for the purpose of sequence matching. This heuristic can be turned off by setting the `autojunk` argument to `False` when creating the `SequenceMatcher`.

*New in version 3.2:* The `autojunk` parameter.

```python
class difflib.Differ
```

This is a class for comparing sequences of lines of text, and producing human-readable differences or deltas. Differ uses `SequenceMatcher` both to compare sequences of lines, and to compare sequences of characters within similar (near-matching) lines.

Each line of a `Differ` delta begins with a two-letter code:

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'-'</td>
<td>line unique to sequence 1</td>
</tr>
<tr>
<td>'+'</td>
<td>line unique to sequence 2</td>
</tr>
<tr>
<td>'='</td>
<td>line common to both sequences</td>
</tr>
<tr>
<td>'?'</td>
<td>line not present in either input sequence</td>
</tr>
</tbody>
</table>

Lines beginning with '?' attempt to guide the eye to intraline
differences, and were not present in either input sequence. These lines can be confusing if the sequences contain tab characters.

**class difflib.HtmlDiff**

This class can be used to create an HTML table (or a complete HTML file containing the table) showing a side by side, line by line comparison of text with inter-line and intra-line change highlights. The table can be generated in either full or contextual difference mode.

The constructor for this class is:

```python
__init__(tabsize=8, wrapcolumn=None, linejunk=None, charjunk=IS_CHARACTER_JUNK)
```

Initializes instance of `HtmlDiff`.

- `tabsize` is an optional keyword argument to specify tab stop spacing and defaults to 8.

- `wrapcolumn` is an optional keyword to specify column number where lines are broken and wrapped, defaults to None where lines are not wrapped.

- `linejunk` and `charjunk` are optional keyword arguments passed into `ndiff()` (used by `HtmlDiff` to generate the side by side HTML differences). See `ndiff()` documentation for argument default values and descriptions.

The following methods are public:

```python
make_file(fromlines, tolines, fromdesc='', todesc='', context=False, numlines=5, *, charset='utf-8')
```

Compared `fromlines` and `tolines` (lists of strings) and returns a
string which is a complete HTML file containing a table showing line by line differences with inter-line and intra-line changes highlighted.

`fromdesc` and `todesc` are optional keyword arguments to specify from/to file column header string (both default to an empty string).

`context` and `numlines` are both optional keyword arguments. Set `context` to True when contextual differences are to be shown, else the default is False to show the full files. `numlines` defaults to 5. When `context` is True `numlines` controls the number of context lines which surround the difference highlights. When `context` is False `numlines` controls the number of lines which are shown before a difference highlight when using the “next” hyperlinks (setting to zero would cause the “next” hyperlinks to place the next difference highlight at the top of the browser without any leading context).

*Changed in version 3.5:* charset keyword-only argument was added. The default charset of HTML document changed from 'ISO-8859-1' to 'utf-8'.

**make_table**(`fromlines`, `tolines`, `fromdesc=",  todesc="`, `context=False`, `numlines=5`)

Compared `fromlines` and `tolines` (lists of strings) and returns a string which is a complete HTML table showing line by line differences with inter-line and intra-line changes highlighted.

The arguments for this method are the same as those for the **make_file()** method.

**Tools/scripts/diff.py** is a command-line front-end to this
class and contains a good example of its use.

difflib.context_diff(a, b, fromfile='', tofile='', fromfiledate='', tofiledate='', n=3, lineterm='\n')

Compare a and b (lists of strings); return a delta (a generator generating the delta lines) in context diff format.

Context diffs are a compact way of showing just the lines that have changed plus a few lines of context. The changes are shown in a before/after style. The number of context lines is set by n which defaults to three.

By default, the diff control lines (those with *** or ---) are created with a trailing newline. This is helpful so that inputs created from io.IOBase.readlines() result in diffs that are suitable for use with io.IOBase.writelines() since both the inputs and outputs have trailing newlines.

For inputs that do not have trailing newlines, set the lineterm argument to "" so that the output will be uniformly newline free.

The context diff format normally has a header for filenames and modification times. Any or all of these may be specified using strings for fromfile, tofile, fromfiledate, and tofiledate. The modification times are normally expressed in the ISO 8601 format. If not specified, the strings default to blanks.

```python
>>> s1 = ['bacon\n', 'eggs\n', 'ham\n', 'guido\n'
>>> s2 = ['python\n', 'eggy\n', 'hamster\n', 'guido

```
See A command-line interface to difflib for a more detailed example.

difflib.get_close_matches(word, possibilities, n=3, cutoff=0.6)

Return a list of the best “good enough” matches. word is a sequence for which close matches are desired (typically a string), and possibilities is a list of sequences against which to match word (typically a list of strings).

Optional argument n (default 3) is the maximum number of close matches to return; n must be greater than 0.

Optional argument cutoff (default 0.6) is a float in the range [0, 1]. Possibilities that don’t score at least that similar to word are ignored.

The best (no more than n) matches among the possibilities are returned in a list, sorted by similarity score, most similar first.

>>> get_close_matches('appel', ['ape', 'apple', ' [ 'apple', 'ape']
>>> import keyword
>>> get_close_matches('wheel', keyword.kwlist)
['while']
>>> get_close_matches('apple', keyword.kwlist)
[]
>>> get_close_matches('accept', keyword.kwlist)
['except']

difflib.ndiff(a, b, linejunk=None, charjunk=IS_CHARACTER_JUNK)

Compare a and b (lists of strings); return a Differ-style delta (a generator generating the delta lines).

Optional keyword parameters linejunk and charjunk are filtering functions (or None):

linejunk: A function that accepts a single string argument, and returns true if the string is junk, or false if not. The default is None. There is also a module-level function IS_LINE_JUNK(), which filters out lines without visible characters, except for at most one pound character ('#') – however the underlying SequenceMatcher class does a dynamic analysis of which lines are so frequent as to constitute noise, and this usually works better than using this function.

charjunk: A function that accepts a character (a string of length 1), and returns if the character is junk, or false if not. The default is module-level function IS_CHARACTER_JUNK(), which filters out whitespace characters (a blank or tab; it's a bad idea to include newline in this!).

Tools/scripts/ndiff.py is a command-line front-end to this function.
difflib.\texttt{restore}(sequence, which)

Return one of the two sequences that generated a delta.

Given a sequence produced by \texttt{Differ.compare()} or \texttt{ndiff()}, extract lines originating from file 1 or 2 (parameter \texttt{which}), stripping off line prefixes.

Example:

```python
>>> diff = ndiff('one\ntwo\nthree\n'.splitlines(keepends=True) +
                'ore\ntree\nemu\n'.splitlines(keepends=True))
>>> print(''.join(diff), end='''
- one
  + ore
- two
- three
+ tree
+ emu
```

```python
>>> print(''.join(restore(diff, 1)), end='''
one
two
three
```
difflib.unified_diff(a, b, fromfile='', tofile='', fromfiledate='', tofiledate='', n=3, lineterm='\n')

Compare a and b (lists of strings); return a delta (a generator generating the delta lines) in unified diff format.

Unified diffs are a compact way of showing just the lines that have changed plus a few lines of context. The changes are shown in an inline style (instead of separate before/after blocks). The number of context lines is set by n which defaults to three.

By default, the diff control lines (those with ---, +++, or @@) are created with a trailing newline. This is helpful so that inputs created from io.IOBase.readlines() result in diffs that are suitable for use with io.IOBase.writelines() since both the inputs and outputs have trailing newlines.

For inputs that do not have trailing newlines, set the lineterm argument to '' so that the output will be uniformly newline free.

The context diff format normally has a header for filenames and modification times. Any or all of these may be specified using strings for fromfile, tofile, fromfiledate, and tofiledate. The modification times are normally expressed in the ISO 8601 format. If not specified, the strings default to blanks.

```python
>>> s1 = ['bacon\n', 'eggs\n', 'ham\n', 'guido\n'
>>> s2 = ['python\n', 'eggy\n', 'hamster\n', 'gui
>>> for line in unified_diff(s1, s2, fromfile='be...
... sys.stdout.write(line)
--- before.py
+++ after.py
@@ -1,4 +1,4 @@
-bacon
-eggs
```
See A command-line interface to difflib for a more detailed example.

difflib.diff_bytes(dfunc, a, b, fromfile=b'', tofile=b'', fromfiledate=b'', tofiledate=b'', n=3, lineterm=b'\n')

Compare a and b (lists of bytes objects) using dfunc; yield a sequence of delta lines (also bytes) in the format returned by dfunc. dfunc must be a callable, typically either unified_diff() or context_diff().

Allows you to compare data with unknown or inconsistent encoding. All inputs except n must be bytes objects, not str. Works by losslessly converting all inputs (except n) to str, and calling dfunc(a, b, fromfile, tofile, fromfiledate, tofiledate, n, lineterm). The output of dfunc is then converted back to bytes, so the delta lines that you receive have the same unknown/inconsistent encodings as a and b.

New in version 3.5.

difflib.IS_LINE_JUNK(line)

Return true for ignorable lines. The line line is ignorable if line is blank or contains a single '#', otherwise it is not ignorable. Used as a default for parameter linejunk in ndiff() in older versions.

difflib.IS_CHARACTER_JUNK(ch)

Return true for ignorable characters. The character ch is ignorable
if \( ch \) is a space or tab, otherwise it is not ignorable. Used as a default for parameter \textit{charjunk} in \texttt{ndiff()}.

See also:

**Pattern Matching: The Gestalt Approach**
Discussion of a similar algorithm by John W. Ratcliff and D. E. Metzener. This was published in \textit{Dr. Dobb's Journal} in July, 1988.
6.3.1. SequenceMatcher Objects

The `SequenceMatcher` class has this constructor:

```python
class difflib.SequenceMatcher(isjunk=None, a='', b='', autojunk=True)
```

Optional argument `isjunk` must be `None` (the default) or a one-argument function that takes a sequence element and returns true if and only if the element is “junk” and should be ignored. Passing `None` for `isjunk` is equivalent to passing `lambda x: 0`; in other words, no elements are ignored. For example, pass:

```python
lambda x: x in " \t"
```

if you’re comparing lines as sequences of characters, and don’t want to synch up on blanks or hard tabs.

The optional arguments `a` and `b` are sequences to be compared; both default to empty strings. The elements of both sequences must be `hashable`.

The optional argument `autojunk` can be used to disable the automatic junk heuristic.

*New in version 3.2*: The `autojunk` parameter.

SequenceMatcher objects get three data attributes: `bjunk` is the set of elements of `b` for which `isjunk` is `True`; `bpopular` is the set of non-junk elements considered popular by the heuristic (if it is not disabled); `b2j` is a dict mapping the remaining elements of `b` to a list of positions where they occur. All three are reset whenever `b` is reset with `set_seqs()` or `set_seq2()`.
New in version 3.2: The *bjunk* and *bpopular* attributes.

**SequenceMatcher** objects have the following methods:

**set_seqs**(*a*, *b*)

Set the two sequences to be compared.

**SequenceMatcher** computes and caches detailed information about the second sequence, so if you want to compare one sequence against many sequences, use **set_seq2()** to set the commonly used sequence once and call **set_seq1()** repeatedly, once for each of the other sequences.

**set_seq1**(*a*)

Set the first sequence to be compared. The second sequence to be compared is not changed.

**set_seq2**(*b*)

Set the second sequence to be compared. The first sequence to be compared is not changed.

**find_longest_match**(*alo*, *ahi*, *blo*, *bhi*)

Find longest matching block in *a*[alo:ahi] and *b*[blo:bhi].

If *isjunk* was omitted or None, **find_longest_match()** returns (*i*, *j*, *k*) such that *a*[i:i+k] is equal to *b*[j:j+k], where alo <= i <= i+k <= ahi and blo <= j <= j+k <= bhi. For all (*i′*, *j′*, *k′*) meeting those conditions, the additional conditions k >= k′, i <= i′, and if i == i′, j <= j′ are also met. In other words, of all maximal matching blocks, return one that starts earliest in *a*, and of all those maximal matching blocks that start earliest in *a*, return the
one that starts earliest in $b$.

```python
>>> s = SequenceMatcher(None, "abcd", "abcd at
```

```python
>>> s.find_longest_match(0, 5, 0, 9)
Match(a=0, b=4, size=5)
```

If $isjunk$ was provided, first the longest matching block is determined as above, but with the additional restriction that no junk element appears in the block. Then that block is extended as far as possible by matching (only) junk elements on both sides. So the resulting block never matches on junk except as identical junk happens to be adjacent to an interesting match.

Here's the same example as before, but considering blanks to be junk. That prevents 'abcd' from matching the 'abcd' at the tail end of the second sequence directly. Instead only the 'abcd' can match, and matches the leftmost 'abcd' in the second sequence:

```python
>>> s = SequenceMatcher(lambda x: x==" ", "abcd
```

```python
>>> s.find_longest_match(0, 5, 0, 9)
Match(a=1, b=0, size=4)
```

If no blocks match, this returns (alo, blo, 0).

This method returns a named tuple `Match(a, b, size)`.

**get_matching_blocks()**

Return list of triples describing matching subsequences. Each triple is of the form $(i, j, n)$, and means that $a[i:i+n] == b[j:j+n]$. The triples are monotonically increasing in $i$ and $j$. 
The last triple is a dummy, and has the value (len(a), len(b), 0). It is the only triple with n == 0. If (i, j, n) and (i', j', n') are adjacent triples in the list, and the second is not the last triple in the list, then i+n != i' or j+n != j'; in other words, adjacent triples always describe non-adjacent equal blocks.

```python
>>> s = SequenceMatcher(None, "abxcd", "abcd")
```

```python
>>> s.get_matching_blocks()
[Match(a=0, b=0, size=2), Match(a=3, b=2, size=2), Match(a=5, b=4, size=0)]
```

**get_opcodes()**

Return list of 5-tuples describing how to turn a into b. Each tuple is of the form (tag, i1, i2, j1, j2). The first tuple has i1 == j1 == 0, and remaining tuples have i1 equal to the i2 from the preceding tuple, and, likewise, j1 equal to the previous j2.

The *tag* values are strings, with these meanings:

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'replace'</td>
<td>a[i1:i2] should be replaced by b[j1:j2].</td>
</tr>
<tr>
<td>'delete'</td>
<td>a[i1:i2] should be deleted. Note that j1 == j2 in this case.</td>
</tr>
<tr>
<td>'insert'</td>
<td>b[j1:j2] should be inserted at a[i1:i1]. Note that i1 == i2 in this case.</td>
</tr>
<tr>
<td>'equal'</td>
<td>a[i1:i2] == b[j1:j2] (the subsequences are equal).</td>
</tr>
</tbody>
</table>
```python
>>> a = "qabxcd"
>>> b = "abycdf"

>>> s = SequenceMatcher(None, a, b)

```n```
```python
>>> for tag, i1, i2, j1, j2 in s.get_opcodes:
    print('{:7}			a[{}:{}]	-->	b[{}:{}]	{!r:>8}	-->	{!r}'.format(tag, i1, i2, j1, j2, a[i1:i2], b[j1:j2]))
```

**get_grouped_opcodes** *(n=3)*

Return a generator of groups with up to n lines of context.

Starting with the groups returned by **get_opcodes()**, this method splits out smaller change clusters and eliminates intervening ranges which have no changes.

The groups are returned in the same format as **get_opcodes()**.

**ratio()**

Return a measure of the sequences' similarity as a float in the range [0, 1].

Where T is the total number of elements in both sequences, and M is the number of matches, this is 2.0*M / T. Note that this is 1.0 if the sequences are identical, and 0.0 if they have nothing in common.

This is expensive to compute if **get_matching_blocks()** or **get_opcodes()** hasn't already been called, in which case you may want to try **quick_ratio()** or **real_quick_ratio()**
first to get an upper bound.

**quick_ratio()**

Return an upper bound on `ratio()` relatively quickly.

**real_quick_ratio()**

Return an upper bound on `ratio()` very quickly.

The three methods that return the ratio of matching to total characters can give different results due to differing levels of approximation, although `quick_ratio()` and `real_quick_ratio()` are always at least as large as `ratio()`:

```python
>>> s = SequenceMatcher(None, "abcd", "bcde")
>>> s.ratio()
0.75
>>> s.quick_ratio()
0.75
>>> s.real_quick_ratio()
1.0
```
6.3.2. SequenceMatcher Examples

This example compares two strings, considering blanks to be “junk”:

```python
>>> s = SequenceMatcher(lambda x: x == " ",
                      ...
                      "private Thread currentThread;
                      "private volatile Thread current;
```

`ratio()` returns a float in $[0, 1]$, measuring the similarity of the sequences. As a rule of thumb, a `ratio()` value over 0.6 means the sequences are close matches:

```python
>>> print(round(s.ratio(), 3))
0.866
```

If you're only interested in where the sequences match, `get_matching_blocks()` is handy:

```python
>>> for block in s.get_matching_blocks():
...     print("a[{}]	and	b[{}]	match for {} elements".
...            a[0] and b[0] match for 8 elements
...            a[8] and b[17] match for 21 elements
...            a[29] and b[38] match for 0 elements
```

Note that the last tuple returned by `get_matching_blocks()` is always a dummy, `(len(a), len(b), 0)`, and this is the only case in which the last tuple element (number of elements matched) is 0.

If you want to know how to change the first sequence into the second, use `get_opcodes()`:

```python
>>> for opcode in s.get_opcodes():
```
...    print("%6s a[%d:%d] b[%d:%d]\n" % opcode)
    equal a[0:8]  b[0:8]
    insert a[8:8]  b[8:17]
    equal a[8:29]  b[17:38]

See also:

- The `get_close_matches()` function in this module which shows how simple code building on `SequenceMatcher` can be used to do useful work.
- Simple version control recipe for a small application built with `SequenceMatcher`. 
6.3.3. Differ Objects

Note that Differ-generated deltas make no claim to be minimal diffs. To the contrary, minimal diffs are often counter-intuitive, because they synch up anywhere possible, sometimes accidental matches 100 pages apart. Restricting synch points to contiguous matches preserves some notion of locality, at the occasional cost of producing a longer diff.

The Differ class has this constructor:

class difflib.Differ(linejunk=None, charjunk=None)

Optional keyword parameters linejunk and charjunk are for filter functions (or None):

linejunk: A function that accepts a single string argument, and returns true if the string is junk. The default is None, meaning that no line is considered junk.

charjunk: A function that accepts a single character argument (a string of length 1), and returns true if the character is junk. The default is None, meaning that no character is considered junk.

These junk-filtering functions speed up matching to find differences and do not cause any differing lines or characters to be ignored. Read the description of the find_longest_match() method's isjunk parameter for an explanation.

Differ objects are used (deltas generated) via a single method:

compare(a, b)

Compare two sequences of lines, and generate the delta (a
sequence of lines).

Each sequence must contain individual single-line strings ending with newlines. Such sequences can be obtained from the `readlines()` method of file-like objects. The delta generated also consists of newline-terminated strings, ready to be printed as-is via the `writelines()` method of a file-like object.
6.3.4. Differ Example

This example compares two texts. First we set up the texts, sequences of individual single-line strings ending with newlines (such sequences can also be obtained from the `readlines()` method of file-like objects):

```python
>>> text1 = ''' 1. Beautiful is better than ugly.
... 2. Explicit is better than implicit.
... 3. Simple is better than complex.
... 4. Complex is better than complicated.
... '''.splitlines(keepends=True)
>>> len(text1)
4
>>> text1[0][-1]
'\n'
```

```python
>>> text2 = ''' 1. Beautiful is better than ugly.
... 3. Simple is better than complex.
... 4. Complicated is better than complex.
... 5. Flat is better than nested.
... '''.splitlines(keepends=True)
```

Next we instantiate a Differ object:

```python
>>> d = Differ()
```

Note that when instantiating a `Differ` object we may pass functions to filter out line and character “junk.” See the `Differ()` constructor for details.

Finally, we compare the two:

```python
>>> result = list(d.compare(text1, text2))
```
result is a list of strings, so let's pretty-print it:

```python
>>> from pprint import pprint
>>> pprint(result)
['  1. Beautiful is better than ugly.
 ', ' 2. Explicit is better than implicit.
 ', ' 3. Simple is better than complex.
 ', '+ 3. Simple is better than complex.
 ', '?   ++\n ', '- 4. Complex is better than complicated.
 ', '?   ^   ---- ^\n ', '+ 4. Complicated is better than complex.
 ', '?   ++++ ^   ^\n ', '+ 5. Flat is better than nested.
 ']
```

As a single multi-line string it looks like this:

```python
>>> import sys
>>> sys.stdout.writelines(result)
  1. Beautiful is better than ugly.
 - 2. Explicit is better than implicit.
 - 3. Simple is better than complex.
 + 3. Simple is better than complex.
 ?   ++
 - 4. Complex is better than complicated.
 ?   ^   ---- ^
 + 4. Complicated is better than complex.
 ?   ++++ ^   ^
 + 5. Flat is better than nested.
```
6.3.5. A command-line interface to difflib
This example shows how to use difflib to create a diff-like utility. It is
also
contained
in
the
Python
source
distribution,
as
Tools/scripts/diff.py.
#!/usr/bin/env python3
""" Command line interface to difflib.py providing diffs in
*
*
*
*

ndiff:
context:
unified:
html:

lists every line and highlights interline change
highlights clusters of changes in a before/after
highlights clusters of changes in an inline form
generates side by side comparison with change hi

"""
import sys, os, time, difflib, argparse
from datetime import datetime, timezone
def file_mtime(path):
t = datetime.fromtimestamp(os.stat(path).st_mtime
timezone.utc)
return t.astimezone().isoformat()
def main():
parser = argparse.ArgumentParser()
parser.add_argument('-c', action='store_true', default
help='Produce a context format diff
parser.add_argument('-u', action='store_true', default
help='Produce a unified format diff'
parser.add_argument('-m', action='store_true', default
help='Produce HTML side by side diff
'(can use -c and -l in conjunct
parser.add_argument('-n', action='store_true', default


help='Produce a ndiff format
parser.add_argument('-l', '--lines', type=int, default=3, help='Set number of context lines (default 3)
parser.add_argument('fromfile')
parser.add_argument('tofile')
options = parser.parse_args()

n = options.lines
fromfile = options.fromfile
tofile = options.tofile

fromdate = file_mtime(fromfile)
todate = file_mtime(tofile)
with open(fromfile) as ff:
    fromlines = ff.readlines()
with open(tofile) as tf:
    tolines = tf.readlines()

if options.u:
    diff = difflib.unified_diff(fromlines, tolines)
elif options.n:
    diff = difflib.ndiff(fromlines, tolines)
elif options.m:
    diff = difflib.HtmlDiff().make_file(fromlines, tolines)
else:
    diff = difflib.context_diff(fromlines, tolines)
sys.stdout.writelines(diff)

if __name__ == '__main__':
    main()
6.4. `textwrap` — Text wrapping and filling

Source code: Lib/textwrap.py

The `textwrap` module provides some convenience functions, as well as `TextWrapper`, the class that does all the work. If you’re just wrapping or filling one or two text strings, the convenience functions should be good enough; otherwise, you should use an instance of `TextWrapper` for efficiency.

`textwrap.wrap(text, width=70, **kwargs)`

Wraps the single paragraph in `text` (a string) so every line is at most `width` characters long. Returns a list of output lines, without final newlines.

Optional keyword arguments correspond to the instance attributes of `TextWrapper`, documented below. `width` defaults to 70.

See the `TextWrapper.wrap()` method for additional details on how `wrap()` behaves.

`textwrap.fill(text, width=70, **kwargs)`

Wraps the single paragraph in `text`, and returns a single string containing the wrapped paragraph. `fill()` is shorthand for

```
"\n".join(wrap(text, ...))
```

In particular, `fill()` accepts exactly the same keyword arguments as `wrap()`.
textwrap.shorten(text, width, **kwargs)

Collapse and truncate the given text to fit in the given width.

First the whitespace in text is collapsed (all whitespace is replaced by single spaces). If the result fits in the width, it is returned. Otherwise, enough words are dropped from the end so that the remaining words plus the placeholder fit within width:

```python
>>> textwrap.shorten("Hello world!", width=12)
'Hello world!'
>>> textwrap.shorten("Hello world!", width=11)
'Hello [...]
>>> textwrap.shorten("Hello world", width=10, placeholder='Hello...'
```

Optional keyword arguments correspond to the instance attributes of TextWrapper, documented below. Note that the whitespace is collapsed before the text is passed to the TextWrapper fill() function, so changing the value of tabsize, expand_tabs, drop_whitespace, and replace_whitespace will have no effect.

*New in version 3.4.*

textwrap.dedent(text)

Remove any common leading whitespace from every line in text.

This can be used to make triple-quoted strings line up with the left edge of the display, while still presenting them in the source code in indented form.

Note that tabs and spaces are both treated as whitespace, but they are not equal: the lines " hello" and "\thello" are
considered to have no common leading whitespace.

For example:

```python
def test():
    # end first line with \ to avoid the empty line!
    s = '''
    hello
    world
    '''
    print(repr(s))  # prints '    hello
    print(repr(dedent(s)))  # prints 'hello

    textwrap.indent(text, prefix, predicate=None)
    Add prefix to the beginning of selected lines in text.
    Lines are separated by calling text.splitlines(True).
    By default, prefix is added to all lines that do not consist solely of whitespace (including any line endings).
    For example:

>>> s = 'hello

    world'
>>> indent(s, '  ')  
'  hello

    world'

    The optional predicate argument can be used to control which lines are indented. For example, it is easy to add prefix to even empty and whitespace-only lines:

>>> print(indent(s, '+ ', lambda line: True))
+ hello
+ +
```
+ world

*New in version 3.3.*

`wrap()`, `fill()` and `shorten()` work by creating a `TextWrapper` instance and calling a single method on it. That instance is not reused, so for applications that process many text strings using `wrap()` and/or `fill()`, it may be more efficient to create your own `TextWrapper` object.

Text is preferably wrapped on whitespaces and right after the hyphens in hyphenated words; only then will long words be broken if necessary, unless `TextWrapper.break_long_words` is set to false.

```python
class textwrap.TextWrapper(**kwargs)

    The TextWrapper constructor accepts a number of optional keyword arguments. Each keyword argument corresponds to an instance attribute, so for example

    wrapper = TextWrapper(initial_indent="* ")

    is the same as

    wrapper = TextWrapper()
    wrapper.initial_indent = "* "
```

You can re-use the same `TextWrapper` object many times, and you can change any of its options through direct assignment to instance attributes between uses.

The `TextWrapper` instance attributes (and keyword arguments to the constructor) are as follows:
**width**

(default: 70) The maximum length of wrapped lines. As long as there are no individual words in the input text longer than `width`, TextWrapper guarantees that no output line will be longer than `width` characters.

**expand_tabs**

(default: True) If true, then all tab characters in `text` will be expanded to spaces using the `expandtabs()` method of `text`.

**tabsize**

(default: 8) If `expand_tabs` is true, then all tab characters in `text` will be expanded to zero or more spaces, depending on the current column and the given tab size.

*New in version 3.3.*

**replace_whitespace**

(default: True) If true, after tab expansion but before wrapping, the `wrap()` method will replace each whitespace character with a single space. The whitespace characters replaced are as follows: tab, newline, vertical tab, formfeed, and carriage return (`'\t\n\v\f\r'`).

**Note:** If `expand_tabs` is false and `replace_whitespace` is true, each tab character will be replaced by a single space, which is not the same as tab expansion.

**Note:** If `replace_whitespace` is false, newlines may appear in the middle of a line and cause strange output. For this reason, text should be split into paragraphs (using `str.splitlines()` or similar) which are wrapped
**drop_whitespace**
(default: True) If true, whitespace at the beginning and ending of every line (after wrapping but before indenting) is dropped. Whitespace at the beginning of the paragraph, however, is not dropped if non-whitespace follows it. If whitespace being dropped takes up an entire line, the whole line is dropped.

**initial_indent**
(default: '') String that will be prepended to the first line of wrapped output. Counts towards the length of the first line. The empty string is not indented.

**subsequent_indent**
(default: '') String that will be prepended to all lines of wrapped output except the first. Counts towards the length of each line except the first.

**fix_sentence_endings**
(default: False) If true, TextWrapper attempts to detect sentence endings and ensure that sentences are always separated by exactly two spaces. This is generally desired for text in a monospaced font. However, the sentence detection algorithm is imperfect: it assumes that a sentence ending consists of a lowercase letter followed by one of '.', '!', or '?', possibly followed by one of ''' or """, followed by a space. One problem with this algorithm is that it is unable to detect the difference between “Dr.” in

```plaintext
[...] Dr. Frankenstein's monster [...] 
```
and “Spot.” in

[...]

Fix_sentence_endings is false by default.

Since the sentence detection algorithm relies on string.lowercase for the definition of “lowercase letter,” and a convention of using two spaces after a period to separate sentences on the same line, it is specific to English-language texts.

**break_long_words**

(default: True) If true, then words longer than width will be broken in order to ensure that no lines are longer than width. If it is false, long words will not be broken, and some lines may be longer than width. (Long words will be put on a line by themselves, in order to minimize the amount by which width is exceeded.)

**break_on_hyphens**

(default: True) If true, wrapping will occur preferably on whitespaces and right after hyphens in compound words, as it is customary in English. If false, only whitespaces will be considered as potentially good places for line breaks, but you need to set **break_long_words** to false if you want truly inseparable words. Default behaviour in previous versions was to always allow breaking hyphenated words.

**max_lines**

(default: None) If not None, then the output will contain at most max_lines lines, with placeholder appearing at the end of the
output.

*New in version 3.4.*

**placeholder**

(default: ' [...]' ) String that will appear at the end of the output text if it has been truncated.

*New in version 3.4.*

**TextWrapper** also provides some public methods, analogous to the module-level convenience functions:

**wrap**(text)

Wraps the single paragraph in text (a string) so every line is at most width characters long. All wrapping options are taken from instance attributes of the **TextWrapper** instance. Returns a list of output lines, without final newlines. If the wrapped output has no content, the returned list is empty.

**fill**(text)

Wraps the single paragraph in text, and returns a single string containing the wrapped paragraph.
6.5. `unicodedata` — Unicode Database

This module provides access to the Unicode Character Database (UCD) which defines character properties for all Unicode characters. The data contained in this database is compiled from the UCD version 8.0.0.

The module uses the same names and symbols as defined by Unicode Standard Annex #44, “Unicode Character Database”. It defines the following functions:

`unicodedata.lookup(name)`

Look up character by name. If a character with the given name is found, return the corresponding character. If not found, `KeyError` is raised.

*Changed in version 3.3:* Support for name aliases [1] and named sequences [2] has been added.

`unicodedata.name(chr[, default])`

Returns the name assigned to the character `chr` as a string. If no name is defined, `default` is returned, or, if not given, `ValueError` is raised.

`unicodedata.decimal(chr[, default])`

Returns the decimal value assigned to the character `chr` as integer. If no such value is defined, `default` is returned, or, if not given, `ValueError` is raised.
unicodedata.\texttt{digit}(\texttt{chr}[, \texttt{default}])

Returns the digit value assigned to the character \texttt{chr} as integer. If no such value is defined, \texttt{default} is returned, or, if not given, \texttt{ValueError} is raised.

unicodedata.\texttt{numeric}(\texttt{chr}[, \texttt{default}])

Returns the numeric value assigned to the character \texttt{chr} as float. If no such value is defined, \texttt{default} is returned, or, if not given, \texttt{ValueError} is raised.

unicodedata.\texttt{category}(\texttt{chr})

Returns the general category assigned to the character \texttt{chr} as string.

unicodedata.\texttt{bidirectional}(\texttt{chr})

Returns the bidirectional class assigned to the character \texttt{chr} as string. If no such value is defined, an empty string is returned.

unicodedata.\texttt{combining}(\texttt{chr})

Returns the canonical combining class assigned to the character \texttt{chr} as integer. Returns 0 if no combining class is defined.

unicodedata.\texttt{east\_asian\_width}(\texttt{chr})

Returns the east asian width assigned to the character \texttt{chr} as string.

unicodedata.\texttt{mirrored}(\texttt{chr})

Returns the mirrored property assigned to the character \texttt{chr} as integer. Returns 1 if the character has been identified as a “mirrored” character in bidirectional text, 0 otherwise.

unicodedata.\texttt{decomposition}(\texttt{chr})
Returns the character decomposition mapping assigned to the character \textit{chr} as string. An empty string is returned in case no such mapping is defined.

\texttt{unicodedata.normalise(form, unistr)}

Return the normal form \textit{form} for the Unicode string \textit{unistr}. Valid values for \textit{form} are ‘NFC’, ‘NFKC’, ‘NFD’, and ‘NFKD’.

The Unicode standard defines various normalization forms of a Unicode string, based on the definition of canonical equivalence and compatibility equivalence. In Unicode, several characters can be expressed in various ways. For example, the character \U+00C7 (LATIN CAPITAL LETTER C WITH CEDILLA) can also be expressed as the sequence \U+0043 (LATIN CAPITAL LETTER C) \U+0327 (COMBINING CEDILLA).

For each character, there are two normal forms: normal form C and normal form D. Normal form D (NFD) is also known as canonical decomposition, and translates each character into its decomposed form. Normal form C (NFC) first applies a canonical decomposition, then composes pre-combined characters again.

In addition to these two forms, there are two additional normal forms based on compatibility equivalence. In Unicode, certain characters are supported which normally would be unified with other characters. For example, \U+2160 (ROMAN NUMERAL ONE) is really the same thing as \U+0049 (LATIN CAPITAL LETTER I). However, it is supported in Unicode for compatibility with existing character sets (e.g. gb2312).

The normal form KD (NFKD) will apply the compatibility decomposition, i.e. replace all compatibility characters with their equivalents. The normal form KC (NFKC) first applies the
compatibility decomposition, followed by the canonical composition.

Even if two unicode strings are normalized and look the same to a human reader, if one has combining characters and the other doesn't, they may not compare equal.

In addition, the module exposes the following constant:

unicodedata.unidata_version

The version of the Unicode database used in this module.

unicodedata.ucd_3_2_0

This is an object that has the same methods as the entire module, but uses the Unicode database version 3.2 instead, for applications that require this specific version of the Unicode database (such as IDNA).

Examples:

```python
>>> import unicodedata
>>> unicodedata.lookup('LEFT CURLY BRACKET')
'{'
>>> unicodedata.name('/')
'SOLIDUS'
>>> unicodedata.decimal('9')
9
>>> unicodedata.decimal('a')
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: not a decimal
>>> unicodedata.category('A')  # 'L'etter, 'u'ppercase
'Lu'
>>> unicodedata.bidirectional(('٠')  # 'A'rabic, 'AN'
```
Footnotes

[1] http://www.unicode.org/Public/8.0.0/ucd/NameAliases.txt

6.6. **stringprep** — Internet String Preparation

When identifying things (such as host names) in the internet, it is often necessary to compare such identifications for “equality”. Exactly how this comparison is executed may depend on the application domain, e.g. whether it should be case-insensitive or not. It may be also necessary to restrict the possible identifications, to allow only identifications consisting of “printable” characters.

**RFC 3454** defines a procedure for “preparing” Unicode strings in internet protocols. Before passing strings onto the wire, they are processed with the preparation procedure, after which they have a certain normalized form. The RFC defines a set of tables, which can be combined into profiles. Each profile must define which tables it uses, and what other optional parts of the stringprep procedure are part of the profile. One example of a stringprep profile is nameprep, which is used for internationalized domain names.

The module **stringprep** only exposes the tables from RFC 3454. As these tables would be very large to represent them as dictionaries or lists, the module uses the Unicode character database internally. The module source code itself was generated using the `mkstringprep.py` utility.

As a result, these tables are exposed as functions, not as data structures. There are two kinds of tables in the RFC: sets and mappings. For a set, **stringprep** provides the “characteristic function”, i.e. a function that returns true if the parameter is part of the set. For mappings, it provides the mapping function: given the key, it
returns the associated value. Below is a list of all functions available in the module.

**stringprep.in_table_a1(code)**

Determine whether `code` is in tableA.1 (Unassigned code points in Unicode 3.2).

**stringprep.in_table_b1(code)**

Determine whether `code` is in tableB.1 (Commonly mapped to nothing).

**stringprep.map_table_b2(code)**

Return the mapped value for `code` according to tableB.2 (Mapping for case-folding used with NFKC).

**stringprep.map_table_b3(code)**

Return the mapped value for `code` according to tableB.3 (Mapping for case-folding used with no normalization).

**stringprep.in_table_c11(code)**

Determine whether `code` is in tableC.1.1 (ASCII space characters).

**stringprep.in_table_c12(code)**

Determine whether `code` is in tableC.1.2 (Non-ASCII space characters).

**stringprep.in_table_c11_c12(code)**

Determine whether `code` is in tableC.1 (Space characters, union of C.1.1 and C.1.2).

**stringprep.in_table_c21(code)**

Determine whether `code` is in tableC.2.1 (ASCII control characters).
stringprep.in_table_c22(code)
  Determine whether code is in tableC.2.2 (Non-ASCII control characters).

stringprep.in_table_c21_c22(code)
  Determine whether code is in tableC.2 (Control characters, union of C.2.1 and C.2.2).

stringprep.in_table_c3(code)
  Determine whether code is in tableC.3 (Private use).

stringprep.in_table_c4(code)
  Determine whether code is in tableC.4 (Non-character code points).

stringprep.in_table_c5(code)
  Determine whether code is in tableC.5 (Surrogate codes).

stringprep.in_table_c6(code)
  Determine whether code is in tableC.6 (Inappropriate for plain text).

stringprep.in_table_c7(code)
  Determine whether code is in tableC.7 (Inappropriate for canonical representation).

stringprep.in_table_c8(code)
  Determine whether code is in tableC.8 (Change display properties or are deprecated).

stringprep.in_table_c9(code)
  Determine whether code is in tableC.9 (Tagging characters).

stringprep.in_table_d1(code)
Determine whether `code` is in tableD.1 (Characters with bidirectional property “R” or “AL”).

`stringprep.in_table_d2(code)`

Determine whether `code` is in tableD.2 (Characters with bidirectional property “L”).
6.7. `readline` — GNU readline interface

The `readline` module defines a number of functions to facilitate completion and reading/writing of history files from the Python interpreter. This module can be used directly or via the `rlcompleter` module. Settings made using this module affect the behaviour of both the interpreter’s interactive prompt and the prompts offered by the built-in `input()` function.

**Note:** On MacOS X the `readline` module can be implemented using the `libedit` library instead of GNU readline.

The configuration file for `libedit` is different from that of GNU readline. If you programmatically load configuration strings you can check for the text “libedit” in `readline.__doc__` to differentiate between GNU readline and libedit.

The `readline` module defines the following functions:

- `readline.parse_and_bind(string)`
  - Parse and execute single line of a readline init file.

- `readline.get_line_buffer()`
  - Return the current contents of the line buffer.

- `readline.insert_text(string)`
  - Insert text into the command line.

- `readline.read_init_file([filename])`
Parse a readline initialization file. The default filename is the last filename used.

```python
readline.read_history_file([filename])
Load a readline history file. The default filename is ~/.history.
```

```python
readline.write_history_file([filename])
Save a readline history file. The default filename is ~/.history.
```

```python
readline.append_history_file(nelements[, filename])
Append the last nelements of history to a file. The default filename is ~/.history. The file must already exist.

*New in version 3.5.*
```

```python
readline.clear_history()
Clear the current history. (Note: this function is not available if the installed version of GNU readline doesn't support it.)
```

```python
readline.get_history_length()
Return the desired length of the history file. Negative values imply unlimited history file size.
```

```python
readline.set_history_length(length)
Set the number of lines to save in the history file. write_history_file() uses this value to truncate the history file when saving. Negative values imply unlimited history file size.
```

```python
readline.get_current_history_length()
Return the number of lines currently in the history. (This is different from get_history_length(), which returns the maximum number of lines that will be written to a history file.)
```
readline.get_history_item(index)
    Return the current contents of history item at index.

readline.remove_history_item(pos)
    Remove history item specified by its position from the history.

readline.replace_history_item(pos, line)
    Replace history item specified by its position with the given line.

readline.redisplay()
    Change what’s displayed on the screen to reflect the current contents of the line buffer.

readline.set_startup_hook([function])
    Set or remove the startup_hook function. If function is specified, it will be used as the new startup_hook function; if omitted or None, any hook function already installed is removed. The startup_hook function is called with no arguments just before readline prints the first prompt.

readline.set_pre_input_hook([function])
    Set or remove the pre_input_hook function. If function is specified, it will be used as the new pre_input_hook function; if omitted or None, any hook function already installed is removed. The pre_input_hook function is called with no arguments after the first prompt has been printed and just before readline starts reading input characters.

readline.set_completer([function])
    Set or remove the completer function. If function is specified, it will be used as the new completer function; if omitted or None, any completer function already installed is removed. The completer
function is called as `function(text, state)`, for `state` in 0, 1, 2, ..., until it returns a non-string value. It should return the next possible completion starting with `text`.

```
readline.get_completer()
    Get the completer function, or None if no completer function has been set.

readline.get_completion_type()
    Get the type of completion being attempted.

readline.get_begidx()
    Get the beginning index of the readline tab-completion scope.

readline.get_endidx()
    Get the ending index of the readline tab-completion scope.

readline.set_completer_delims(string)
    Set the readline word delimiters for tab-completion.

readline.get_completer_delims()
    Get the readline word delimiters for tab-completion.

readline.set_completion_display_matches_hook([full]
    Set or remove the completion display function. If `function` is specified, it will be used as the new completion display function; if omitted or None, any completion display function already installed is removed. The completion display function is called as `function(substitution, [matches], longest_match_length)` once each time matches need to be displayed.
```
readline.add_history(line)

Append a line to the history buffer, as if it was the last line typed.

See also:

Module rlcompleter

Completion of Python identifiers at the interactive prompt.
6.7.1. Example

The following example demonstrates how to use the `readline` module's history reading and writing functions to automatically load and save a history file named `.python_history` from the user's home directory. The code below would normally be executed automatically during interactive sessions from the user's `PYTHONSTARTUP` file.

```python
import atexit
import os
import readline

histfile = os.path.join(os.path.expanduser("~"), ".python_history")

try:
    readline.read_history_file(histfile)
except FileNotFoundError:
    pass

atexit.register(readline.write_history_file, histfile)
```

This code is actually automatically run when Python is run in interactive mode (see Readline configuration).

The following example achieves the same goal but supports concurrent interactive sessions, by only appending the new history.

```python
import atexit
import os
import readline

histfile = os.path.join(os.path.expanduser("~"), ".python_history")

try:
```
The following example extends the `code.InteractiveConsole` class to support history save/restore.

```python
import atexit
import code
import os
import readline

class HistoryConsole(code.InteractiveConsole):
    def __init__(self, locals=None, filename="<console>",
                 histfile=os.path.expanduser("~/.console-history"),
                 **kwargs):
        code.InteractiveConsole.__init__(self, locals, filename=filename,
                                          **kwargs)
        self.init_history(histfile)

    def init_history(self, histfile):
        readline.parse_and_bind("tab: complete")
        if hasattr(readline, "read_history_file"):
            try:
                readline.read_history_file(histfile)
            except FileNotFoundError:
                pass
        atexit.register(self.save_history, histfile)

    def save_history(self, histfile):
        readline.write_history_file(histfile)
```
6.8. **rlcompleter** — Completion function for GNU readline

**Source code:** [Lib/rlcompleter.py](#)

The `rlcompleter` module defines a completion function suitable for the `readline` module by completing valid Python identifiers and keywords.

When this module is imported on a Unix platform with the `readline` module available, an instance of the Completer class is automatically created and its `complete()` method is set as the `readline` completer.

Example:

```python
>>> import rlcompleter
>>> import readline

>>> readline.parse_and_bind("tab: complete")
>>> readline.<TAB PRESSED>

readline.__doc__  readline.get_line_buffer(
readline.__file__  readline.insert_text(
readline.__name__  readline.parse_and_bind(
>>> readline.
```

The `rlcompleter` module is designed for use with Python's **interactive mode**. Unless Python is run with the `-S` option, the module is automatically imported and configured (see Readline configuration).

On platforms without `readline`, the Completer class defined by this
module can still be used for custom purposes.
6.8.1. Completer Objects

Completer objects have the following method:

Completer.complete(text, state)

Return the stateful completion for text.

If called for text that doesn't include a period character ('. '), it will complete from names currently defined in __main__, builtins and keywords (as defined by the keyword module).

If called for a dotted name, it will try to evaluate anything without obvious side-effects (functions will not be evaluated, but it can generate calls to __getattr__() up to the last part, and find matches for the rest via the dir() function. Any exception raised during the evaluation of the expression is caught, silenced and None is returned.
7. Binary Data Services

The modules described in this chapter provide some basic services operations for manipulation of binary data. Other operations on binary data, specifically in relation to file formats and network protocols, are described in the relevant sections.

Some libraries described under Text Processing Services also work with either ASCII-compatible binary formats (for example, re) or all binary data (for example, difflib).

In addition, see the documentation for Python’s built-in binary data types in Binary Sequence Types — bytes, bytearray, memoryview.

- 7.1. struct — Interpret bytes as packed binary data
  - 7.1.1. Functions and Exceptions
  - 7.1.2. Format Strings
    - 7.1.2.1. Byte Order, Size, and Alignment
    - 7.1.2.2. Format Characters
    - 7.1.2.3. Examples
  - 7.1.3. Classes
- 7.2. codecs — Codec registry and base classes
  - 7.2.1. Codec Base Classes
    - 7.2.1.1. Error Handlers
    - 7.2.1.2. Stateless Encoding and Decoding
    - 7.2.1.3. Incremental Encoding and Decoding
      - 7.2.1.3.1. IncrementalEncoder Objects
      - 7.2.1.3.2. IncrementalDecoder Objects
    - 7.2.1.4. Stream Encoding and Decoding
      - 7.2.1.4.1. StreamWriter Objects
      - 7.2.1.4.2. StreamReader Objects
      - 7.2.1.4.3. StreamReaderWriter Objects
7.2.1.4.4. StreamRecoder Objects
7.2.2. Encodings and Unicode
7.2.3. Standard Encodings
7.2.4. Python Specific Encodings
  7.2.4.1. Text Encodings
  7.2.4.2. Binary Transforms
  7.2.4.3. Text Transforms
7.2.5. encodings.idna — Internationalized Domain Names in Applications
7.2.6. encodings.mbc5s — Windows ANSI codepage
7.2.7. encodings.utf_8_sig — UTF-8 codec with BOM signature
7.1. **struct** — Interpret bytes as packed binary data

This module performs conversions between Python values and C structs represented as Python `bytes` objects. This can be used in handling binary data stored in files or from network connections, among other sources. It uses Format Strings as compact descriptions of the layout of the C structs and the intended conversion to/from Python values.

**Note:** By default, the result of packing a given C struct includes pad bytes in order to maintain proper alignment for the C types involved; similarly, alignment is taken into account when unpacking. This behavior is chosen so that the bytes of a packed struct correspond exactly to the layout in memory of the corresponding C struct. To handle platform-independent data formats or omit implicit pad bytes, use standard size and alignment instead of native size and alignment: see Byte Order, Size, and Alignment for details.

Several `struct` functions (and methods of `Struct`) take a `buffer` argument. This refers to objects that implement the Buffer Protocol and provide either a readable or read-writable buffer. The most common types used for that purpose are `bytes` and `bytearray`, but many other types that can be viewed as an array of bytes implement the buffer protocol, so that they can be read/filled without additional copying from a `bytes` object.
7.1.1. Functions and Exceptions

The module defines the following exception and functions:

**exception struct.error**

Exception raised on various occasions; argument is a string describing what is wrong.

**struct.pack(fmt, v1, v2, ...)**

Return a bytes object containing the values $v1$, $v2$, ... packed according to the format string $fmt$. The arguments must match the values required by the format exactly.

**struct.pack_into(fmt, buffer, offset, v1, v2, ...)**

Pack the values $v1$, $v2$, ... according to the format string $fmt$ and write the packed bytes into the writable buffer $buffer$ starting at position $offset$. Note that $offset$ is a required argument.

**struct.unpack(fmt, buffer)**

Unpack from the buffer $buffer$ (presumably packed by pack($fmt$, ...) according to the format string $fmt$. The result is a tuple even if it contains exactly one item. The buffer must contain exactly the amount of data required by the format (len(bytes) must equal calcsize(fmt)).

**struct.unpack_from(fmt, buffer, offset=0)**

Unpack from $buffer$ starting at position $offset$, according to the format string $fmt$. The result is a tuple even if it contains exactly one item. $buffer$ must contain at least the amount of data required by the format (len(buffer[offset:]) must be at least calcsize(fmt)).
struct.iter_unpack(fmt, buffer)

Iteratively unpack from the buffer buffer according to the format string fmt. This function returns an iterator which will read equally-sized chunks from the buffer until all its contents have been consumed. The buffer’s size in bytes must be a multiple of the amount of data required by the format, as reflected by calcsize().

Each iteration yields a tuple as specified by the format string.

New in version 3.4.

struct.calcsize(fmt)

Return the size of the struct (and hence of the bytes object produced by pack(fmt, ...)) corresponding to the format string fmt.
7.1.2. Format Strings

Format strings are the mechanism used to specify the expected layout when packing and unpacking data. They are built up from Format Characters, which specify the type of data being packed/unpacked. In addition, there are special characters for controlling the Byte Order, Size, and Alignment.

7.1.2.1. Byte Order, Size, and Alignment

By default, C types are represented in the machine's native format and byte order, and properly aligned by skipping pad bytes if necessary (according to the rules used by the C compiler).

Alternatively, the first character of the format string can be used to indicate the byte order, size and alignment of the packed data, according to the following table:

<table>
<thead>
<tr>
<th>Character</th>
<th>Byte order</th>
<th>Size</th>
<th>Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>@</td>
<td>native</td>
<td>native</td>
<td>native</td>
</tr>
<tr>
<td>=</td>
<td>native</td>
<td>standard</td>
<td>none</td>
</tr>
<tr>
<td>&lt;</td>
<td>little-endian</td>
<td>standard</td>
<td>none</td>
</tr>
<tr>
<td>&gt;</td>
<td>big-endian</td>
<td>standard</td>
<td>none</td>
</tr>
<tr>
<td>!</td>
<td>network (= big-endian)</td>
<td>standard</td>
<td>none</td>
</tr>
</tbody>
</table>

If the first character is not one of these, '@' is assumed.

Native byte order is big-endian or little-endian, depending on the host system. For example, Intel x86 and AMD64 (x86-64) are little-endian; Motorola 68000 and PowerPC G5 are big-endian; ARM and Intel
Itanium feature switchable endianness (bi-endian). Use sys.byteorder to check the endianness of your system.

Native size and alignment are determined using the C compiler’s sizeof expression. This is always combined with native byte order.

Standard size depends only on the format character; see the table in the Format Characters section.

Note the difference between '@' and '=': both use native byte order, but the size and alignment of the latter is standardized.

The form '! ' is available for those poor souls who claim they can't remember whether network byte order is big-endian or little-endian.

There is no way to indicate non-native byte order (force byte-swapping); use the appropriate choice of '<' or '>'.

Notes:

1. Padding is only automatically added between successive structure members. No padding is added at the beginning or the end of the encoded struct.
2. No padding is added when using non-native size and alignment, e.g. with '<', '>', '=', and '!'.
3. To align the end of a structure to the alignment requirement of a particular type, end the format with the code for that type with a repeat count of zero. See Examples.

7.1.2.2. Format Characters

Format characters have the following meaning; the conversion between C and Python values should be obvious given their types. The ‘Standard size’ column refers to the size of the packed value in
bytes when using standard size; that is, when the format string starts with one of '<', '>', '!' or '='. When using native size, the size of the packed value is platform-dependent.

<table>
<thead>
<tr>
<th>Format</th>
<th>C Type</th>
<th>Python type</th>
<th>Standard size</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>pad byte</td>
<td>no value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>char</td>
<td>bytes of length 1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>signed char</td>
<td>integer</td>
<td>1</td>
<td>(1),(3)</td>
</tr>
<tr>
<td>B</td>
<td>unsigned char</td>
<td>integer</td>
<td>1</td>
<td>(3)</td>
</tr>
<tr>
<td>?</td>
<td>_Bool</td>
<td>bool</td>
<td>1</td>
<td>(1)</td>
</tr>
<tr>
<td>h</td>
<td>short</td>
<td>integer</td>
<td>2</td>
<td>(3)</td>
</tr>
<tr>
<td>H</td>
<td>unsigned short</td>
<td>integer</td>
<td>2</td>
<td>(3)</td>
</tr>
<tr>
<td>i</td>
<td>int</td>
<td>integer</td>
<td>4</td>
<td>(3)</td>
</tr>
<tr>
<td>I</td>
<td>unsigned int</td>
<td>integer</td>
<td>4</td>
<td>(3)</td>
</tr>
<tr>
<td>l</td>
<td>long</td>
<td>integer</td>
<td>4</td>
<td>(3)</td>
</tr>
<tr>
<td>L</td>
<td>unsigned long</td>
<td>integer</td>
<td>4</td>
<td>(3)</td>
</tr>
<tr>
<td>q</td>
<td>long long</td>
<td>integer</td>
<td>8</td>
<td>(2), (3)</td>
</tr>
<tr>
<td>Q</td>
<td>unsigned long long</td>
<td>integer</td>
<td>8</td>
<td>(2), (3)</td>
</tr>
<tr>
<td>n</td>
<td>ssize_t</td>
<td>integer</td>
<td></td>
<td>(4)</td>
</tr>
<tr>
<td>N</td>
<td>size_t</td>
<td>integer</td>
<td></td>
<td>(4)</td>
</tr>
<tr>
<td>f</td>
<td>float</td>
<td>float</td>
<td>4</td>
<td>(5)</td>
</tr>
<tr>
<td>d</td>
<td>double</td>
<td>float</td>
<td>8</td>
<td>(5)</td>
</tr>
<tr>
<td>s</td>
<td>char[]</td>
<td>bytes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>void *</td>
<td>integer</td>
<td>(6)</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
</tbody>
</table>

*Changed in version 3.3:* Added support for the 'n' and 'N' formats.

**Notes:**

1. The '?' conversion code corresponds to the _Bool type defined by C99. If this type is not available, it is simulated using a char. In standard mode, it is always represented by one byte.

2. The 'q' and 'Q' conversion codes are available in native mode only if the platform C compiler supports C long long, or, on Windows, __int64. They are always available in standard modes.

3. When attempting to pack a non-integer using any of the integer conversion codes, if the non-integer has a __index__() method then that method is called to convert the argument to an integer before packing.

   *Changed in version 3.2:* Use of the __index__() method for non-integers is new in 3.2.

4. The 'n' and 'N' conversion codes are only available for the native size (selected as the default or with the '@' byte order character). For the standard size, you can use whichever of the other integer formats fits your application.

5. For the 'f' and 'd' conversion codes, the packed representation uses the IEEE 754 binary32 (for 'f') or binary64 (for 'd') format, regardless of the floating-point format used by the platform.
6. The 'P' format character is only available for the native byte ordering (selected as the default or with the '@' byte order character). The byte order character '=' chooses to use little- or big-endian ordering based on the host system. The struct module does not interpret this as native ordering, so the 'P' format is not available.

A format character may be preceded by an integral repeat count. For example, the format string '4h' means exactly the same as 'hhhh'.

Whitespace characters between formats are ignored; a count and its format must not contain whitespace though.

For the 's' format character, the count is interpreted as the length of the bytes, not a repeat count like for the other format characters; for example, '10s' means a single 10-byte string, while '10c' means 10 characters. If a count is not given, it defaults to 1. For packing, the string is truncated or padded with null bytes as appropriate to make it fit. For unpacking, the resulting bytes object always has exactly the specified number of bytes. As a special case, '0s' means a single, empty string (while '0c' means 0 characters).

When packing a value x using one of the integer formats ('b', 'B', 'h', 'H', 'i', 'I', 'l', 'L', 'q', 'Q'), if x is outside the valid range for that format then struct.error is raised.

*Changed in version 3.1:* In 3.0, some of the integer formats wrapped out-of-range values and raised DeprecationWarning instead of struct.error.

The 'p' format character encodes a “Pascal string”, meaning a short variable-length string stored in a fixed number of bytes, given by the
count. The first byte stored is the length of the string, or 255, whichever is smaller. The bytes of the string follow. If the string passed in to `pack()` is too long (longer than the count minus 1), only the leading count - 1 bytes of the string are stored. If the string is shorter than count - 1, it is padded with null bytes so that exactly count bytes in all are used. Note that for `unpack()`, the 'p' format character consumes count bytes, but that the string returned can never contain more than 255 bytes.

For the '?' format character, the return value is either `True` or `False`. When packing, the truth value of the argument object is used. Either 0 or 1 in the native or standard bool representation will be packed, and any non-zero value will be `True` when unpacking.

### 7.1.2.3. Examples

**Note:** All examples assume a native byte order, size, and alignment with a big-endian machine.

A basic example of packing/unpacking three integers:

```python
>>> from struct import *
>>> pack('hhhl', 1, 2, 3)
b'\x00\x01\x00\x02\x00\x00\x00\x03'
>>> unpack('hhhl', b'\x00\x01\x00\x02\x00\x00\x00\x03')
(1, 2, 3)
>>> calcsize('hhhl')
8
```

Unpacked fields can be named by assigning them to variables or by wrapping the result in a named tuple:
The ordering of format characters may have an impact on size since the padding needed to satisfy alignment requirements is different:

```
>>> pack('ci', b'*', 0x12131415)
'b'*\x00\x00\x00\x12\x13\x14\x15'
>>> pack('ic', 0x12131415, b'*')
b'\x12\x13\x14\x15*'n
>>> calcsize('ci')
8
>>> calcsize('ic')
5
```

The following format 'llh0l' specifies two pad bytes at the end, assuming longs are aligned on 4-byte boundaries:

```
>>> pack('llh0l', 1, 2, 3)
b'\x00\x00\x00\x01\x00\x00\x00\x02\x00\x03\x00\x00'n
```

This only works when native size and alignment are in effect; standard size and alignment does not enforce any alignment.

See also:

Module array
   Packed binary storage of homogeneous data.
Module xdrlib
Packing and unpacking of XDR data.
7.1.3. Classes

The `struct` module also defines the following type:

```python
class struct.Struct(format)
```

Return a new Struct object which writes and reads binary data according to the format string `format`. Creating a Struct object once and calling its methods is more efficient than calling the `struct` functions with the same format since the format string only needs to be compiled once.

Compiled Struct objects support the following methods and attributes:

- **pack**\((v1, v2, ...))**
  Identical to the `pack()` function, using the compiled format. (\(\text{len(result)}\) will equal `self.size`).

- **pack_into**\((buffer, offset, v1, v2, ...))**
  Identical to the `pack_into()` function, using the compiled format.

- **unpack**\((buffer)\)**
  Identical to the `unpack()` function, using the compiled format. (\(\text{len(buffer)}\) must equal `self.size`).

- **unpack_from**\((buffer, offset=0)\)**
  Identical to the `unpack_from()` function, using the compiled format. (\(\text{len(buffer[offset:])}\) must be at least `self.size`).
iter_unpack(buffer)

Identical to the iter_unpack() function, using the compiled format. (len(buffer) must be a multiple of self.size).

New in version 3.4.

format

The format string used to construct this Struct object.

size

The calculated size of the struct (and hence of the bytes object produced by the pack() method) corresponding to format.
7.2. **codecs** — Codec registry and base classes

**Source code:** Lib/codecs.py

This module defines base classes for standard Python codecs (encoders and decoders) and provides access to the internal Python codec registry, which manages the codec and error handling lookup process. Most standard codecs are text encodings, which encode text to bytes, but there are also codecs provided that encode text to text, and bytes to bytes. Custom codecs may encode and decode between arbitrary types, but some module features are restricted to use specifically with text encodings, or with codecs that encode to bytes.

The module defines the following functions for encoding and decoding with any codec:

```python
codecs.encode(obj, encoding='utf-8', errors='strict')
```
Encodes `obj` using the codec registered for `encoding`.

*Errors* may be given to set the desired error handling scheme. The default error handler is 'strict' meaning that encoding errors raise `ValueError` (or a more codec specific subclass, such as `UnicodeEncodeError`). Refer to **Codec Base Classes** for more information on codec error handling.

```python
codecs.decode(obj, encoding='utf-8', errors='strict')
```
Decodes `obj` using the codec registered for `encoding`.

*Errors* may be given to set the desired error handling scheme. The default error handler is 'strict' meaning that decoding errors
raise `ValueError` (or a more codec specific subclass, such as `UnicodeDecodeError`). Refer to Codec Base Classes for more information on codec error handling.

The full details for each codec can also be looked up directly:

```python
codecs.lookup(encoding)
```

Looks up the codec info in the Python codec registry and returns a `CodecInfo` object as defined below.

Encodings are first looked up in the registry's cache. If not found, the list of registered search functions is scanned. If no `CodecInfo` object is found, a `LookupError` is raised. Otherwise, the `CodecInfo` object is stored in the cache and returned to the caller.

class codecs.CodecInfo(encode, decode, streamreader=None, streamwriter=None, incrementalencoder=None, incrementaldecoder=None, name=None)

Codec details when looking up the codec registry. The constructor arguments are stored in attributes of the same name:

- **name**
  The name of the encoding.

- **encode**
  The stateless encoding and decoding functions. These must be functions or methods which have the same interface as the `encode()` and `decode()` methods of Codec instances (see Codec Interface). The functions or methods are expected to work in a stateless mode.

- **incrementalencoder**
**incrementaldecoder**

Incremental encoder and decoder classes or factory functions. These have to provide the interface defined by the base classes **IncrementalEncoder** and **IncrementalDecoder**, respectively. Incremental codecs can maintain state.

**streamwriter**

**streamreader**

Stream writer and reader classes or factory functions. These have to provide the interface defined by the base classes **StreamWriter** and **StreamReader**, respectively. Stream codecs can maintain state.

To simplify access to the various codec components, the module provides these additional functions which use `lookup()` for the codec lookup:

**codecs.getencoder(encoding)**

Look up the codec for the given encoding and return its encoder function.

Raises a **LookupError** in case the encoding cannot be found.

**codecs.getdecoder(encoding)**

Look up the codec for the given encoding and return its decoder function.

Raises a **LookupError** in case the encoding cannot be found.

**codecs.getincrementalencoder(encoding)**

Look up the codec for the given encoding and return its incremental encoder class or factory function.
Raises a LookupError in case the encoding cannot be found or the codec doesn’t support an incremental encoder.

`codecs.getincrementaldecoder(encoding)`
Look up the codec for the given encoding and return its incremental decoder class or factory function.

Raises a LookupError in case the encoding cannot be found or the codec doesn’t support an incremental decoder.

`codecs.getreader(encoding)`
Look up the codec for the given encoding and return its StreamReader class or factory function.

Raises a LookupError in case the encoding cannot be found.

`codecs.getwriter(encoding)`
Look up the codec for the given encoding and return its StreamWriter class or factory function.

Raises a LookupError in case the encoding cannot be found.

Custom codecs are made available by registering a suitable codec search function:

`codecs.register(search_function)`
Register a codec search function. Search functions are expected to take one argument, being the encoding name in all lower case letters, and return a CodecInfo object. In case a search function cannot find a given encoding, it should return None.

**Note:** Search function registration is not currently reversible, which may cause problems in some cases, such as unit testing or
While the built-in `open()` and the associated `io` module are the recommended approach for working with encoded text files, this module provides additional utility functions and classes that allow the use of a wider range of codecs when working with binary files:

```python
import codecs

codecs.open(filename, mode='r', encoding=None, errors='strict', buffering=1)
```

Open an encoded file using the given `mode` and return an instance of `StreamReaderWriter`, providing transparent encoding/decoding. The default file mode is `'r'`, meaning to open the file in read mode.

**Note:** Underlying encoded files are always opened in binary mode. No automatic conversion of `'\n'` is done on reading and writing. The `mode` argument may be any binary mode acceptable to the built-in `open()` function; the `'b'` is automatically added.

`encoding` specifies the encoding which is to be used for the file. Any encoding that encodes to and decodes from bytes is allowed, and the data types supported by the file methods depend on the codec used.

`errors` may be given to define the error handling. It defaults to `'strict'` which causes a `ValueError` to be raised in case an encoding error occurs.

`buffering` has the same meaning as for the built-in `open()` function. It defaults to line buffered.

```python
import codecs

codecs.EncodedFile(file, data_encoding, file_encoding=None, errors='strict')
```
Return a `StreamRecoder` instance, a wrapped version of `file` which provides transparent transcoding. The original file is closed when the wrapped version is closed.

Data written to the wrapped file is decoded according to the given `data_encoding` and then written to the original file as bytes using `file_encoding`. Bytes read from the original file are decoded according to `file_encoding`, and the result is encoded using `data_encoding`.

If `file_encoding` is not given, it defaults to `data_encoding`.

`errors` may be given to define the error handling. It defaults to 'strict', which causes `ValueError` to be raised in case an encoding error occurs.

```
codecs.iterencode(iterator, encoding, errors='strict', **kwargs)
```

Uses an incremental encoder to iteratively encode the input provided by `iterator`. This function is a generator. The `errors` argument (as well as any other keyword argument) is passed through to the incremental encoder.

```
codecs.iterdecode(iterator, encoding, errors='strict', **kwargs)
```

Uses an incremental decoder to iteratively decode the input provided by `iterator`. This function is a generator. The `errors` argument (as well as any other keyword argument) is passed through to the incremental decoder.

The module also provides the following constants which are useful for reading and writing to platform dependent files:

```
codecs.BOM
codecs.BOM_BE
```
codecs.BOM_LE
codecs.BOM_UTF8
codecs.BOM_UTF16
codecs.BOM_UTF16_BE
codecs.BOM_UTF16_LE
codecs.BOM_UTF32
codecs.BOM_UTF32_BE
codecs.BOM_UTF32_LE

These constants define various byte sequences, being Unicode byte order marks (BOMs) for several encodings. They are used in UTF-16 and UTF-32 data streams to indicate the byte order used, and in UTF-8 as a Unicode signature. BOM_UTF16 is either BOM_UTF16_BE or BOM_UTF16_LE depending on the platform’s native byte order, BOM is an alias for BOM_UTF16, BOM_LE for BOM_UTF16_LE and BOM_BE for BOM_UTF16_BE. The others represent the BOM in UTF-8 and UTF-32 encodings.
7.2.1. Codec Base Classes

The codecs module defines a set of base classes which define the interfaces for working with codec objects, and can also be used as the basis for custom codec implementations.

Each codec has to define four interfaces to make it usable as codec in Python: stateless encoder, stateless decoder, stream reader and stream writer. The stream reader and writers typically reuse the stateless encoder/decoder to implement the file protocols. Codec authors also need to define how the codec will handle encoding and decoding errors.

7.2.1.1. Error Handlers

To simplify and standardize error handling, codecs may implement different error handling schemes by accepting the `errors` string argument. The following string values are defined and implemented by all standard Python codecs:

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
</table>
| 'strict'| Raise `UnicodeError` (or a subclass); this is the default. Implemented in `strict_errors()`.
| 'ignore'| Ignore the malformed data and continue without further notice. Implemented in `ignore_errors()`.

The following error handlers are only applicable to text encodings:

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
</table>
'replace'  Replace with a suitable replacement marker; Python will use the official U+FFFD REPLACEMENT CHARACTER for the built-in codecs on decoding, and ‘?’ on encoding. Implemented in `replace_errors()`.

'xmlcharrefreplace' Replace with the appropriate XML character reference (only for encoding). Implemented in `xmlcharrefreplace_errors()`.

'backslashreplace' Replace with backslashed escape sequences. Implemented in `backslashreplace_errors()`.

'namereplace' Replace with \N{...} escape sequences (only for encoding). Implemented in `namereplace_errors()`.

'surrogateescape' On decoding, replace byte with individual surrogate code ranging from U+DC80 to U+DCFF. This code will then be turned back into the same byte when the 'surrogateescape' error handler is used when encoding the data. (See PEP 383 for more.)

In addition, the following error handler is specific to the given codecs:

<table>
<thead>
<tr>
<th>Value</th>
<th>Codecs</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'surrogatepass'</td>
<td>utf-8, utf-16, utf-32, utf-16-be, utf-16-le, utf-32-be, utf-32-le</td>
<td>Allow encoding and decoding of surrogate codes. These codecs normally treat the presence of surrogates as an error.</td>
</tr>
</tbody>
</table>
New in version 3.1: The 'surrogateescape' and 'surrogatepass' error handlers.

Changed in version 3.4: The 'surrogatepass' error handlers now works with utf-16* and utf-32* codecs.

New in version 3.5: The 'namereplace' error handler.

Changed in version 3.5: The 'backslashreplace' error handlers now works with decoding and translating.

The set of allowed values can be extended by registering a new named error handler:

codecs.register_error(name, error_handler)

Register the error handling function error_handler under the name name. The error_handler argument will be called during encoding and decoding in case of an error, when name is specified as the errors parameter.

For encoding, error_handler will be called with a UnicodeEncodeError instance, which contains information about the location of the error. The error handler must either raise this or a different exception, or return a tuple with a replacement for the unencodable part of the input and a position where encoding should continue. The replacement may be either str or bytes. If the replacement is bytes, the encoder will simply copy them into the output buffer. If the replacement is a string, the encoder will encode the replacement. Encoding continues on original input at the specified position. Negative position values will be treated as being relative to the end of the input string. If the resulting position is out of bound an IndexError will be raised.
Decoding and translating works similarly, except `UnicodeDecodeError` or `UnicodeTranslateError` will be passed to the handler and that the replacement from the error handler will be put into the output directly.

Previously registered error handlers (including the standard error handlers) can be looked up by name:

```
codecs.lookup_error(name)
```

Return the error handler previously registered under the name `name`.

 Raises a `LookupError` in case the handler cannot be found.

The following standard error handlers are also made available as module level functions:

```
codecs.strict_errors(exception)
```

Implements the 'strict' error handling: each encoding or decoding error raises a `UnicodeError`.

```
codecs.replace_errors(exception)
```

Implements the 'replace' error handling (for text encodings only): substitutes '?' for encoding errors (to be encoded by the codec), and '\ufffd' (the Unicode replacement character) for decoding errors.

```
codecs.ignore_errors(exception)
```

Implements the 'ignore' error handling: malformed data is ignored and encoding or decoding is continued without further notice.

```
codecs.xmlcharrefreplace_errors(exception)
```
Implements the 'xmlcharrefreplace' error handling (for encoding with text encodings only): the unencodable character is replaced by an appropriate XML character reference.

codecs.\texttt{backslashreplace\_errors}(\texttt{exception})
Implements the 'backslashreplace' error handling (for text encodings only): malformed data is replaced by a backslashed escape sequence.

codecs.\texttt{namereplace\_errors}(\texttt{exception})
Implements the 'namereplace' error handling (for encoding with text encodings only): the unencodable character is replaced by a \texttt{\textbackslash N{...}} escape sequence.

\textit{New in version 3.5.}

7.2.1.2. Stateless Encoding and Decoding

The base Codec class defines these methods which also define the function interfaces of the stateless encoder and decoder:

Codec.\texttt{encode}(\texttt{input[, errors]})
Encodes the object \texttt{input} and returns a tuple (output object, length consumed). For instance, text encoding converts a string object to a bytes object using a particular character set encoding (e.g., cp1252 or iso-8859-1).

The \texttt{errors} argument defines the error handling to apply. It defaults to 'strict' handling.

The method may not store state in the Codec instance. Use \texttt{StreamWriter} for codecs which have to keep state in order to
make encoding efficient.

The encoder must be able to handle zero length input and return an empty object of the output object type in this situation.

Codec.decode(input[, errors])
Decodes the object input and returns a tuple (output object, length consumed). For instance, for a text encoding, decoding converts a bytes object encoded using a particular character set encoding to a string object.

For text encodings and bytes-to-bytes codecs, input must be a bytes object or one which provides the read-only buffer interface – for example, buffer objects and memory mapped files.

The errors argument defines the error handling to apply. It defaults to 'strict' handling.

The method may not store state in the Codec instance. Use StreamReader for codecs which have to keep state in order to make decoding efficient.

The decoder must be able to handle zero length input and return an empty object of the output object type in this situation.

7.2.1.3. Incremental Encoding and Decoding

The IncrementalEncoder and IncrementalDecoder classes provide the basic interface for incremental encoding and decoding. Encoding/decoding the input isn’t done with one call to the stateless encoder/decoder function, but with multiple calls to the encode() / decode() method of the incremental encoder/decoder.
The incremental encoder/decoder keeps track of the encoding/decoding process during method calls.

The joined output of calls to the `encode() / decode()` method is the same as if all the single inputs were joined into one, and this input was encoded/decoded with the stateless encoder/decoder.

### 7.2.1.3.1. IncrementalEncoder Objects

The `IncrementalEncoder` class is used for encoding an input in multiple steps. It defines the following methods which every incremental encoder must define in order to be compatible with the Python codec registry.

```python
class codecs.IncrementalEncoder(errors='strict')
    Constructor for an IncrementalEncoder instance.
```

All incremental encoders must provide this constructor interface. They are free to add additional keyword arguments, but only the ones defined here are used by the Python codec registry.

The `IncrementalEncoder` may implement different error handling schemes by providing the `errors` keyword argument. See Error Handlers for possible values.

The `errors` argument will be assigned to an attribute of the same name. Assigning to this attribute makes it possible to switch between different error handling strategies during the lifetime of the `IncrementalEncoder` object.

```python
encode(object[, final])
    Encodes object (taking the current state of the encoder into account) and returns the resulting encoded object. If this is the
last call to `encode()` final must be true (the default is false).

**reset()**
Reset the encoder to the initial state. The output is discarded: call `.encode(object, final=True)`, passing an empty byte or text string if necessary, to reset the encoder and to get the output.

**IncrementalEncoder.getstate()**
Return the current state of the encoder which must be an integer. The implementation should make sure that 0 is the most common state. (States that are more complicated than integers can be converted into an integer by marshaling/pickling the state and encoding the bytes of the resulting string into an integer).

**IncrementalEncoder.setstate(state)**
Set the state of the encoder to `state`. `state` must be an encoder state returned by `getstate()`.

### 7.2.1.3.2. IncrementalDecoder Objects

The `IncrementalDecoder` class is used for decoding an input in multiple steps. It defines the following methods which every incremental decoder must define in order to be compatible with the Python codec registry.

**class codecs.IncrementalDecoder(errors='strict')**
Constructor for an `IncrementalDecoder` instance.

All incremental decoders must provide this constructor interface. They are free to add additional keyword arguments, but only the ones defined here are used by the Python codec registry.
The IncrementalDecoder may implement different error handling schemes by providing the errors keyword argument. See Error Handlers for possible values.

The errors argument will be assigned to an attribute of the same name. Assigning to this attribute makes it possible to switch between different error handling strategies during the lifetime of the IncrementalDecoder object.

**decode**(object[, final])

Decodes object (taking the current state of the decoder into account) and returns the resulting decoded object. If this is the last call to decode() final must be true (the default is false). If final is true the decoder must decode the input completely and must flush all buffers. If this isn’t possible (e.g. because of incomplete byte sequences at the end of the input) it must initiate error handling just like in the stateless case (which might raise an exception).

**reset**( )

Reset the decoder to the initial state.

**getstate**( )

Return the current state of the decoder. This must be a tuple with two items, the first must be the buffer containing the still undecoded input. The second must be an integer and can be additional state info. (The implementation should make sure that 0 is the most common additional state info.) If this additional state info is 0 it must be possible to set the decoder to the state which has no input buffered and 0 as the additional state info, so that feeding the previously buffered input to the decoder returns it to the previous state without producing any
output. (Additional state info that is more complicated than integers can be converted into an integer by marshaling/pickling the info and encoding the bytes of the resulting string into an integer.)

**setstate(state)**

Set the state of the encoder to *state*. *state* must be a decoder state returned by `getstate()`.

### 7.2.1.4. Stream Encoding and Decoding

The `StreamWriter` and `StreamReader` classes provide generic working interfaces which can be used to implement new encoding submodules very easily. See `encodings.utf_8` for an example of how this is done.

#### 7.2.1.4.1. StreamWriter Objects

The `StreamWriter` class is a subclass of Codec and defines the following methods which every stream writer must define in order to be compatible with the Python codec registry.

```python
class codecs.StreamWriter(stream, errors='strict')
```

Constructor for a `StreamWriter` instance.

All stream writers must provide this constructor interface. They are free to add additional keyword arguments, but only the ones defined here are used by the Python codec registry.

The `stream` argument must be a file-like object open for writing text or binary data, as appropriate for the specific codec.
The **StreamWriter** may implement different error handling schemes by providing the `errors` keyword argument. See **Error Handlers** for the standard error handlers the underlying stream codec may support.

The `errors` argument will be assigned to an attribute of the same name. Assigning to this attribute makes it possible to switch between different error handling strategies during the lifetime of the **StreamWriter** object.

**write**(`object`)  
Writes the object's contents encoded to the stream.

**writelines**(`list`)  
Writes the concatenated list of strings to the stream (possibly by reusing the **write()** method). The standard bytes-to-bytes codecs do not support this method.

**reset()**  
Flushes and resets the codec buffers used for keeping state.

Calling this method should ensure that the data on the output is put into a clean state that allows appending of new fresh data without having to rescan the whole stream to recover state.

In addition to the above methods, the **StreamWriter** must also inherit all other methods and attributes from the underlying stream.

### 7.2.1.4.2. StreamReader Objects

The **StreamReader** class is a subclass of Codec and defines the following methods which every stream reader must define in order to be compatible with the Python codec registry.
class codecs.StreamReader(stream, errors='strict')

Constructor for a StreamReader instance.

All stream readers must provide this constructor interface. They are free to add additional keyword arguments, but only the ones defined here are used by the Python codec registry.

The stream argument must be a file-like object open for reading text or binary data, as appropriate for the specific codec.

The StreamReader may implement different error handling schemes by providing the errors keyword argument. See Error Handlers for the standard error handlers the underlying stream codec may support.

The errors argument will be assigned to an attribute of the same name. Assigning to this attribute makes it possible to switch between different error handling strategies during the lifetime of the StreamReader object.

The set of allowed values for the errors argument can be extended with register_error().

read([size[, chars[, firstline]]])

Decodes data from the stream and returns the resulting object.

The chars argument indicates the number of decoded code points or bytes to return. The read() method will never return more data than requested, but it might return less, if there is not enough available.

The size argument indicates the approximate maximum number of encoded bytes or code points to read for decoding. The
decoder can modify this setting as appropriate. The default value -1 indicates to read and decode as much as possible. This parameter is intended to prevent having to decode huge files in one step.

The *firstline* flag indicates that it would be sufficient to only return the first line, if there are decoding errors on later lines.

The method should use a greedy read strategy meaning that it should read as much data as is allowed within the definition of the encoding and the given size, e.g. if optional encoding endings or state markers are available on the stream, these should be read too.

**readline**([*size*, *keepends]*)

Read one line from the input stream and return the decoded data.

(size, if given, is passed as size argument to the stream's *read*() method.

If *keepends* is false line-endings will be stripped from the lines returned.

**readlines**([*sizehint*, *keepends]*)

Read all lines available on the input stream and return them as a list of lines.

Line-endings are implemented using the codec's decoder method and are included in the list entries if *keepends* is true.

(sizehint, if given, is passed as the *size* argument to the stream's *read*() method.)
**reset()**

Resets the codec buffers used for keeping state.

Note that no stream repositioning should take place. This method is primarily intended to be able to recover from decoding errors.

In addition to the above methods, the `StreamReader` must also inherit all other methods and attributes from the underlying stream.

### 7.2.1.4.3. StreamReaderWriter Objects

The `StreamReaderWriter` is a convenience class that allows wrapping streams which work in both read and write modes.

The design is such that one can use the factory functions returned by the `lookup()` function to construct the instance.

```python
class codecs.StreamReaderWriter(stream, Reader, Writer, errors)
```

Creates a `StreamReaderWriter` instance. `stream` must be a file-like object. `Reader` and `Writer` must be factory functions or classes providing the `StreamReader` and `StreamWriter` interface resp. Error handling is done in the same way as defined for the stream readers and writers.

`StreamReaderWriter` instances define the combined interfaces of `StreamReader` and `StreamWriter` classes. They inherit all other methods and attributes from the underlying stream.

### 7.2.1.4.4. StreamRecoder Objects

The `StreamRecoder` translates data from one encoding to another,
which is sometimes useful when dealing with different encoding environments.

The design is such that one can use the factory functions returned by the `lookup()` function to construct the instance.

```python
class codecs.StreamRecoder(stream, encode, decode, Reader, Writer, errors)
```

Creates a `StreamRecoder` instance which implements a two-way conversion: `encode` and `decode` work on the frontend — the data visible to code calling `read()` and `write()`, while `Reader` and `Writer` work on the backend — the data in `stream`.

You can use these objects to do transparent transcodings from e.g. Latin-1 to UTF-8 and back.

The `stream` argument must be a file-like object.

The `encode` and `decode` arguments must adhere to the Codec interface. `Reader` and `Writer` must be factory functions or classes providing objects of the `StreamReader` and `StreamWriter` interface respectively.

Error handling is done in the same way as defined for the stream readers and writers.

`StreamRecoder` instances define the combined interfaces of `StreamReader` and `StreamWriter` classes. They inherit all other methods and attributes from the underlying stream.
7.2.2. Encodings and Unicode

Strings are stored internally as sequences of code points in range 0x0-0x10FFFF. (See PEP 393 for more details about the implementation.) Once a string object is used outside of CPU and memory, endianness and how these arrays are stored as bytes become an issue. As with other codecs, serialising a string into a sequence of bytes is known as encoding, and recreating the string from the sequence of bytes is known as decoding. There are a variety of different text serialisation codecs, which are collectively referred to as text encodings.

The simplest text encoding (called 'latin-1' or 'iso-8859-1') maps the code points 0-255 to the bytes 0x0-0xff, which means that a string object that contains code points above U+00FF can't be encoded with this codec. Doing so will raise a UnicodeEncodeError that looks like the following (although the details of the error message may differ): UnicodeEncodeError: 'latin-1' codec can't encode character '\u1234' in position 3: ordinal not in range(256).

There's another group of encodings (the so called charmap encodings) that choose a different subset of all Unicode code points and how these code points are mapped to the bytes 0x0-0xff. To see how this is done simply open e.g. encodings/cp1252.py (which is an encoding that is used primarily on Windows). There's a string constant with 256 characters that shows you which character is mapped to which byte value.

All of these encodings can only encode 256 of the 1114112 code points defined in Unicode. A simple and straightforward way that can
store each Unicode code point, is to store each code point as four consecutive bytes. There are two possibilities: store the bytes in big endian or in little endian order. These two encodings are called UTF-32-BE and UTF-32-LE respectively. Their disadvantage is that if e.g. you use UTF-32-BE on a little endian machine you will always have to swap bytes on encoding and decoding. UTF-32 avoids this problem: bytes will always be in natural endianness. When these bytes are read by a CPU with a different endianness, then bytes have to be swapped though. To be able to detect the endianness of a UTF-16 or UTF-32 byte sequence, there’s the so called BOM (“Byte Order Mark”). This is the Unicode character U+FEFF. This character can be prepended to every UTF-16 or UTF-32 byte sequence. The byte swapped version of this character (0xFFFE) is an illegal character that may not appear in a Unicode text. So when the first character in an UTF-16 or UTF-32 byte sequence appears to be a U+FFE the bytes have to be swapped on decoding. Unfortunately the character U+FEFF had a second purpose as a ZERO WIDTH NO-BREAK SPACE: a character that has no width and doesn’t allow a word to be split. It can e.g. be used to give hints to a ligature algorithm. With Unicode 4.0 using U+FEFF as a ZERO WIDTH NO-BREAK SPACE has been deprecated (with U+2060 (WORD JOINER) assuming this role). Nevertheless Unicode software still must be able to handle U+FEFF in both roles: as a BOM it’s a device to determine the storage layout of the encoded bytes, and vanishes once the byte sequence has been decoded into a string; as a ZERO WIDTH NO-BREAK SPACE it’s a normal character that will be decoded like any other.

There’s another encoding that is able to encoding the full range of Unicode characters: UTF-8. UTF-8 is an 8-bit encoding, which means there are no issues with byte order in UTF-8. Each byte in a UTF-8 byte sequence consists of two parts: marker bits (the most significant
bits) and payload bits. The marker bits are a sequence of zero to four 1 bits followed by a 0 bit. Unicode characters are encoded like this (with x being payload bits, which when concatenated give the Unicode character):

<table>
<thead>
<tr>
<th>Range</th>
<th>Encoding</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-0000000000 ... U-00000007F</td>
<td>0xxxxxxx</td>
</tr>
<tr>
<td>U-0000000800 ... U-000007FF</td>
<td>110xxxxx 10xxxxxx</td>
</tr>
<tr>
<td>U-00000800 ... U-0000FFFF</td>
<td>1110xxxx 10xxxxxx 10xxxxxx</td>
</tr>
<tr>
<td>U-00010000 ... U-001FFFFF</td>
<td>11110xxx 10xxxxxx 10xxxxxx 10xxxxxx</td>
</tr>
</tbody>
</table>

The least significant bit of the Unicode character is the rightmost x bit.

As UTF-8 is an 8-bit encoding no BOM is required and any U+FEFF character in the decoded string (even if it’s the first character) is treated as a ZERO WIDTH NO-BREAK SPACE.

Without external information it’s impossible to reliably determine which encoding was used for encoding a string. Each charmap encoding can decode any random byte sequence. However that’s not possible with UTF-8, as UTF-8 byte sequences have a structure that doesn’t allow arbitrary byte sequences. To increase the reliability with which a UTF-8 encoding can be detected, Microsoft invented a variant of UTF-8 (that Python 2.5 calls "utf-8-sig") for its Notepad program: Before any of the Unicode characters is written to the file, a UTF-8 encoded BOM (which looks like this as a byte sequence: 0xef, 0xbb, 0xbf) is written. As it’s rather improbable that any charmap encoded file starts with these byte values (which would e.g. map to
in iso-8859-1), this increases the probability that a utf-8-sig encoding can be correctly guessed from the byte sequence. So here the BOM is not used to be able to determine the byte order used for generating the byte sequence, but as a signature that helps in guessing the encoding. On encoding the utf-8-sig codec will write 0xef, 0xbb, 0xbf as the first three bytes to the file. On decoding utf-8-sig will skip those three bytes if they appear as the first three bytes in the file. In UTF-8, the use of the BOM is discouraged and should generally be avoided.
7.2.3. Standard Encodings

Python comes with a number of codecs built-in, either implemented as C functions or with dictionaries as mapping tables. The following table lists the codecs by name, together with a few common aliases, and the languages for which the encoding is likely used. Neither the list of aliases nor the list of languages is meant to be exhaustive. Notice that spelling alternatives that only differ in case or use a hyphen instead of an underscore are also valid aliases; therefore, e.g. 'utf-8' is a valid alias for the 'utf_8' codec.

**CPython implementation detail:** Some common encodings can bypass the codecs lookup machinery to improve performance. These optimization opportunities are only recognized by CPython for a limited set of aliases: utf-8, utf8, latin-1, latin1, iso-8859-1, mbc (Windows only), ascii, utf-16, and utf-32. Using alternative spellings for these encodings may result in slower execution.

Many of the character sets support the same languages. They vary in individual characters (e.g. whether the EURO SIGN is supported or not), and in the assignment of characters to code positions. For the European languages in particular, the following variants typically exist:

- an ISO 8859 codeset
- a Microsoft Windows code page, which is typically derived from a 8859 codeset, but replaces control characters with additional graphic characters
- an IBM EBCDIC code page
- an IBM PC code page, which is ASCII compatible

<table>
<thead>
<tr>
<th>Codec</th>
<th>Aliases</th>
<th>Languages</th>
</tr>
</thead>
<tbody>
<tr>
<td>ascii</td>
<td>646, us-ascii</td>
<td>English</td>
</tr>
<tr>
<td>big5</td>
<td>big5-tw, csbig5</td>
<td>Traditional Chinese</td>
</tr>
<tr>
<td>-----------</td>
<td>------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>big5hkscs</td>
<td>big5-hkscs, hkscs</td>
<td>Traditional Chinese</td>
</tr>
<tr>
<td>cp037</td>
<td>IBM037, IBM039</td>
<td>English</td>
</tr>
<tr>
<td>cp273</td>
<td>273, IBM273, csIBM273</td>
<td>German</td>
</tr>
<tr>
<td>cp424</td>
<td>EBCDIC-CP-HE, IBM424</td>
<td>Hebrew</td>
</tr>
<tr>
<td>cp437</td>
<td>437, IBM437</td>
<td>English</td>
</tr>
<tr>
<td>cp500</td>
<td>EBCDIC-CP-BE, EBCDIC-CP-CH, IBM500</td>
<td>Western Europe</td>
</tr>
<tr>
<td>cp720</td>
<td></td>
<td>Arabic</td>
</tr>
<tr>
<td>cp737</td>
<td></td>
<td>Greek</td>
</tr>
<tr>
<td>cp775</td>
<td>IBM775</td>
<td>Baltic languages</td>
</tr>
<tr>
<td>cp850</td>
<td>850, IBM850</td>
<td>Western Europe</td>
</tr>
<tr>
<td>cp852</td>
<td>852, IBM852</td>
<td>Central and Eastern Europe</td>
</tr>
<tr>
<td>cp855</td>
<td>855, IBM855</td>
<td>Bulgarian, Byelorussian, Macedonian, Russian, Serbian</td>
</tr>
<tr>
<td>cp856</td>
<td></td>
<td>Hebrew</td>
</tr>
<tr>
<td>cp857</td>
<td>857, IBM857</td>
<td>Turkish</td>
</tr>
<tr>
<td>cp858</td>
<td>858, IBM858</td>
<td>Western Europe</td>
</tr>
<tr>
<td>cp860</td>
<td>860, IBM860</td>
<td>Portuguese</td>
</tr>
<tr>
<td>cp861</td>
<td>861, CP-IS, IBM861</td>
<td>Icelandic</td>
</tr>
<tr>
<td>Code</td>
<td>Name</td>
<td>Languages</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>cp862</td>
<td>862, IBM862</td>
<td>Hebrew</td>
</tr>
<tr>
<td>cp863</td>
<td>863, IBM863</td>
<td>Canadian</td>
</tr>
<tr>
<td>cp864</td>
<td>IBM864</td>
<td>Arabic</td>
</tr>
<tr>
<td>cp865</td>
<td>865, IBM865</td>
<td>Danish, Norwegian</td>
</tr>
<tr>
<td>cp866</td>
<td>866, IBM866</td>
<td>Russian</td>
</tr>
<tr>
<td>cp869</td>
<td>869, CP-GR, IBM869</td>
<td>Greek</td>
</tr>
<tr>
<td>cp874</td>
<td></td>
<td>Thai</td>
</tr>
<tr>
<td>cp875</td>
<td></td>
<td>Greek</td>
</tr>
<tr>
<td>cp932</td>
<td>932, ms932, mskanji,</td>
<td>Japanese</td>
</tr>
<tr>
<td></td>
<td>ms-kanji</td>
<td></td>
</tr>
<tr>
<td>cp949</td>
<td>949, ms949, uhc</td>
<td>Korean</td>
</tr>
<tr>
<td>cp950</td>
<td>950, ms950</td>
<td>Traditional Chinese</td>
</tr>
<tr>
<td>cp1006</td>
<td></td>
<td>Urdu</td>
</tr>
<tr>
<td>cp1026</td>
<td>ibm1026</td>
<td>Turkish</td>
</tr>
<tr>
<td>cp1125</td>
<td>1125, ibm1125, cp866u, ruscii</td>
<td>Ukrainian</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>New in version 3.4.</em></td>
</tr>
<tr>
<td>cp1140</td>
<td>ibm1140</td>
<td>Western Europe</td>
</tr>
<tr>
<td>cp1250</td>
<td>windows-1250</td>
<td>Central and Eastern Europe</td>
</tr>
<tr>
<td>cp1251</td>
<td>windows-1251</td>
<td>Bulgarian, Byelorussian, Macedonian, Russian, Serbian</td>
</tr>
<tr>
<td>cp1252</td>
<td>windows-1252</td>
<td>Western Europe</td>
</tr>
<tr>
<td>cp1253</td>
<td>windows-1253</td>
<td>Greek</td>
</tr>
<tr>
<td>cp1254</td>
<td>windows-1254</td>
<td>Turkish</td>
</tr>
<tr>
<td>Code</td>
<td>Windows Code</td>
<td>Language</td>
</tr>
<tr>
<td>---------</td>
<td>--------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>cp1255</td>
<td>windows-1255</td>
<td>Hebrew</td>
</tr>
<tr>
<td>cp1256</td>
<td>windows-1256</td>
<td>Arabic</td>
</tr>
<tr>
<td>cp1257</td>
<td>windows-1257</td>
<td>Baltic languages</td>
</tr>
<tr>
<td>cp1258</td>
<td>windows-1258</td>
<td>Vietnamese</td>
</tr>
<tr>
<td>cp65001</td>
<td></td>
<td>Windows only:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Windows UTF-8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(CP_UTF8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New in version 3.3.</td>
</tr>
<tr>
<td>euc_jp</td>
<td>eucjp, ujis, u-jis</td>
<td>Japanese</td>
</tr>
<tr>
<td>euc_jis_2004</td>
<td>jisx0213, eucjis2004</td>
<td>Japanese</td>
</tr>
<tr>
<td>euc_jisx0213</td>
<td>eucjisx0213</td>
<td>Japanese</td>
</tr>
<tr>
<td>euc_kr</td>
<td>euckr, korean, ksc5601, ks_c-5601, ks_c-5601-1987, ksx1001, ks_x-1001</td>
<td>Korean</td>
</tr>
<tr>
<td>gb2312</td>
<td>chinese, csiso58gb231280, euc-cn, eucn, eucgb2312-cn, gb2312-1980, gb2312-80, iso-ir-58</td>
<td>Simplified Chinese</td>
</tr>
<tr>
<td>gbk</td>
<td>936, cp936, ms936</td>
<td>Unified Chinese</td>
</tr>
<tr>
<td>gb18030</td>
<td>gb18030-2000</td>
<td>Unified Chinese</td>
</tr>
<tr>
<td>hz</td>
<td>hzgb, hz-gb, hz-gb-2312</td>
<td>Simplified Chinese</td>
</tr>
<tr>
<td>iso2022_jp</td>
<td>csiso2022jp, iso2022jp, iso-2022-jp</td>
<td>Japanese</td>
</tr>
<tr>
<td></td>
<td>iso2022jp-1, iso-2022-</td>
<td></td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
<td>Language</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>iso2022_jp_1</td>
<td>jp-1</td>
<td>Japanese</td>
</tr>
<tr>
<td>iso2022_jp_2</td>
<td>iso2022jp-2, iso-2022-jp-2</td>
<td>Japanese, Korean, Simplified Chinese, Western Europe, Greek</td>
</tr>
<tr>
<td>iso2022_jp_3</td>
<td>iso2022jp-3, iso-2022-jp-3</td>
<td>Japanese</td>
</tr>
<tr>
<td>iso2022_jp_ext</td>
<td>iso2022jp-ext, iso-2022-jp-ext</td>
<td>Japanese</td>
</tr>
<tr>
<td>latin_1</td>
<td>iso-8859-1, iso8859-1, 8859, cp819, latin, latin1, L1</td>
<td>West Europe</td>
</tr>
<tr>
<td>iso8859_2</td>
<td>iso-8859-2, latin2, L2</td>
<td>Central and Eastern Europe</td>
</tr>
<tr>
<td>iso8859_3</td>
<td>iso-8859-3, latin3, L3</td>
<td>Esperanto, Maltese</td>
</tr>
<tr>
<td>iso8859_4</td>
<td>iso-8859-4, latin4, L4</td>
<td>Baltic languages</td>
</tr>
<tr>
<td>iso8859_5</td>
<td>iso-8859-5, cyrillic</td>
<td>Bulgarian, Byelorussian, Macedonian, Russian, Serbian</td>
</tr>
<tr>
<td>iso8859_6</td>
<td>iso-8859-6, arabic</td>
<td>Arabic</td>
</tr>
<tr>
<td>iso8859_7</td>
<td>iso-8859-7, greek, greek8</td>
<td>Greek</td>
</tr>
<tr>
<td>iso8859_8</td>
<td>iso-8859-8, hebrew</td>
<td>Hebrew</td>
</tr>
<tr>
<td>iso8859_9</td>
<td>iso-8859-9, latin5, L5</td>
<td>Turkish</td>
</tr>
<tr>
<td>Code</td>
<td>Representation</td>
<td>Languages</td>
</tr>
<tr>
<td>----------</td>
<td>-------------------------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td>iso8859_10</td>
<td>iso-8859-10, latin6, L6</td>
<td>Nordic languages</td>
</tr>
<tr>
<td>iso8859_11</td>
<td>iso-8859-11, thai</td>
<td>Thai languages</td>
</tr>
<tr>
<td>iso8859_13</td>
<td>iso-8859-13, latin7, L7</td>
<td>Baltic languages</td>
</tr>
<tr>
<td>iso8859_14</td>
<td>iso-8859-14, latin8, L8</td>
<td>Celtic languages</td>
</tr>
<tr>
<td>iso8859_15</td>
<td>iso-8859-15, latin9, L9</td>
<td>Western Europe</td>
</tr>
<tr>
<td>iso8859_16</td>
<td>iso-8859-16, latin10, L10</td>
<td>South-Eastern Europe</td>
</tr>
<tr>
<td>johab</td>
<td>cp1361, ms1361</td>
<td>Korean</td>
</tr>
<tr>
<td>koi8_r</td>
<td></td>
<td>Russian</td>
</tr>
<tr>
<td>koi8_t</td>
<td></td>
<td>Tajik</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>New in version 3.5.</em></td>
</tr>
<tr>
<td>koi8_u</td>
<td></td>
<td>Ukrainian</td>
</tr>
<tr>
<td>kz1048</td>
<td>kz_1048, strk1048_2002, rk1048</td>
<td>Kazakh</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>New in version 3.5.</em></td>
</tr>
<tr>
<td>mac_cyrillic</td>
<td>maccyrillic</td>
<td>Bulgarian, Byelorussian, Macedonian, Russian, Serbian</td>
</tr>
<tr>
<td>mac_greek</td>
<td>macgreek</td>
<td>Greek</td>
</tr>
<tr>
<td>mac_iceland</td>
<td>maciceland</td>
<td>Icelandic</td>
</tr>
<tr>
<td>mac_latin2</td>
<td>maclatin2, maccentraleurope</td>
<td>Central and Eastern Europe</td>
</tr>
<tr>
<td>mac_roman</td>
<td>macroman, macintosh</td>
<td>Western Europe</td>
</tr>
<tr>
<td>mac_turkish</td>
<td>macturkish</td>
<td>Turkish</td>
</tr>
<tr>
<td>Encoding</td>
<td>Variants</td>
<td>Language</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>ptcp154</td>
<td>csptcp154, pt154, cp154, cyrillic-asian</td>
<td>Kazakh</td>
</tr>
<tr>
<td>shift_jis</td>
<td>csshiftjis, shiftjis, sjis, s_jis</td>
<td>Japanese</td>
</tr>
<tr>
<td>shift_jisx0213</td>
<td>shiftjisx0213, sjisx0213, s_jisx0213</td>
<td>Japanese</td>
</tr>
<tr>
<td>utf_32</td>
<td>U32, utf32</td>
<td>all languages</td>
</tr>
<tr>
<td>utf_32_be</td>
<td>UTF-32BE</td>
<td>all languages</td>
</tr>
<tr>
<td>utf_32_le</td>
<td>UTF-32LE</td>
<td>all languages</td>
</tr>
<tr>
<td>utf_16</td>
<td>U16, utf16</td>
<td>all languages</td>
</tr>
<tr>
<td>utf_16_be</td>
<td>UTF-16BE</td>
<td>all languages</td>
</tr>
<tr>
<td>utf_16_le</td>
<td>UTF-16LE</td>
<td>all languages</td>
</tr>
<tr>
<td>utf_7</td>
<td>U7, unicode-1-1-utf-7</td>
<td>all languages</td>
</tr>
<tr>
<td>utf_8</td>
<td>U8, UTF, utf8</td>
<td>all languages</td>
</tr>
<tr>
<td>utf_8_sig</td>
<td></td>
<td>all languages</td>
</tr>
</tbody>
</table>

*Changed in version 3.4:* The utf-16* and utf-32* encoders no longer allow surrogate code points (U+D800–U+DFFF) to be encoded. The utf-32* decoders no longer decode byte sequences that correspond to surrogate code points.
7.2.4. Python Specific Encodings

A number of predefined codecs are specific to Python, so their codec names have no meaning outside Python. These are listed in the tables below based on the expected input and output types (note that while text encodings are the most common use case for codecs, the underlying codec infrastructure supports arbitrary data transforms rather than just text encodings). For asymmetric codecs, the stated purpose describes the encoding direction.

7.2.4.1. Text Encodings

The following codecs provide str to bytes encoding and bytes-like object to str decoding, similar to the Unicode text encodings.

<table>
<thead>
<tr>
<th>Codec</th>
<th>Aliases</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>idna</td>
<td></td>
<td>Implements RFC 3490, see also encodings.idna. Only errors='strict' is supported.</td>
</tr>
<tr>
<td>mbcsc</td>
<td>dbcs</td>
<td>Windows only: Encode operand according to the ANSI codepage (CP_ACP)</td>
</tr>
<tr>
<td>palmos</td>
<td></td>
<td>Encoding of PalmOS 3.5</td>
</tr>
<tr>
<td>punycode</td>
<td></td>
<td>Implements RFC 3492. Stateful codecs are not supported.</td>
</tr>
<tr>
<td>raw_unicode_escape</td>
<td></td>
<td>Latin-1 encoding with \uXXXX and \UXXXXXXXXXX for other code points. Existing backslashes are not escaped in any way. It is used in the</td>
</tr>
<tr>
<td>undefined</td>
<td>Raise an exception for all conversions, even empty strings. The error handler is ignored.</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>unicode_escape</td>
<td>Encoding suitable as the contents of a Unicode literal in ASCII-encoded Python source code, except that quotes are not escaped. Decodes from Latin-1 source code. Beware that Python source code actually uses UTF-8 by default.</td>
<td></td>
</tr>
<tr>
<td>unicode_internal</td>
<td>Return the internal representation of the operand. Stateful codecs are not supported.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Deprecated since version 3.3:</em> This representation is obsoleted by <a href="https://www.python.org/dev/peps/pep-0393/">PEP 393</a>.</td>
<td></td>
</tr>
</tbody>
</table>

### 7.2.4.2. Binary Transforms

The following codecs provide binary transforms: bytes-like object to bytes mappings. They are not supported by `bytes.decode()` (which only produces `str` output).

<table>
<thead>
<tr>
<th>Codec</th>
<th>Aliases</th>
<th>Purpose</th>
<th>Encoder / decoder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Convert operand to multiline MIME</td>
<td></td>
</tr>
<tr>
<td>Codec</td>
<td>Format</td>
<td>Description</td>
<td>Methods</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>----------------------------------------</td>
</tr>
</tbody>
</table>
| base64_codec [1] | base64, base_64        | base64 (the result always includes a trailing `
`)                         | base64.encode / base64.decode          |
| bz2_codec  | bz2                    | Compress the operand using bz2                                             | bz2.compress / bz2.decompress          |
| hex_codec  | hex                    | Convert operand to hexadecimal representation, with two digits per byte    | binascii.b2a_hex / binascii.a2b        |
| quopri_codec | quopri, quotedprintable, quoted_printable | Convert operand to MIME quoted printable                                   | quopri.encode / quotetabs=True / quopri.decode |
| uu_codec   | uu                     | Convert the operand using uuencode                                         | uu.encode() / uu.decode()              |
| zlib_codec | zip, zlib              | Compress the operand using gzip                                            | zlib.compress / zlib.decompress        |

In addition to bytes-like objects, 'base64_codec' also
accepts ASCII-only instances of `str` for decoding

New in version 3.2: Restoration of the binary transforms.

Changed in version 3.4: Restoration of the aliases for the binary transforms.

### 7.2.4.3. Text Transforms

The following codec provides a text transform: a `str` to `str` mapping. It is not supported by `str.encode()` (which only produces `bytes` output).

<table>
<thead>
<tr>
<th>Codec</th>
<th>Aliases</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>rot_13</td>
<td>rot13</td>
<td>Returns the Caesar-cypher encryption of the operand</td>
</tr>
</tbody>
</table>

New in version 3.2: Restoration of the `rot_13` text transform.

Changed in version 3.4: Restoration of the `rot13` alias.
7.2.5. **encodings.idna** — Internationalized Domain Names in Applications

This module implements **RFC 3490** (Internationalized Domain Names in Applications) and **RFC 3492** (Nameprep: A Stringprep Profile for Internationalized Domain Names (IDN)). It builds upon the punycode encoding and **stringprep**.

These RFCs together define a protocol to support non-ASCII characters in domain names. A domain name containing non-ASCII characters (such as `www.Alliancefrançaise.nu`) is converted into an ASCII-compatible encoding (ACE, such as `www.xn--alliancefranaise-npb.nu`). The ACE form of the domain name is then used in all places where arbitrary characters are not allowed by the protocol, such as DNS queries, HTTP Host fields, and so on. This conversion is carried out in the application; if possible invisible to the user: The application should transparently convert Unicode domain labels to IDNA on the wire, and convert back ACE labels to Unicode before presenting them to the user.

Python supports this conversion in several ways: the `idna` codec performs conversion between Unicode and ACE, separating an input string into labels based on the separator characters defined in section 3.1 (1) of **RFC 3490** and converting each label to ACE as required, and conversely separating an input byte string into labels based on the . separator and converting any ACE labels found into unicode. Furthermore, the `socket` module transparently converts Unicode host names to ACE, so that applications need not be concerned about converting host names themselves when they pass them to the socket
module. On top of that, modules that have host names as function parameters, such as `http.client` and `ftplib`, accept Unicode host names (`http.client` then also transparently sends an IDNA hostname in the Host field if it sends that field at all).

When receiving host names from the wire (such as in reverse name lookup), no automatic conversion to Unicode is performed: Applications wishing to present such host names to the user should decode them to Unicode.

The module `encodings.idna` also implements the nameprep procedure, which performs certain normalizations on host names, to achieve case-insensitivity of international domain names, and to unify similar characters. The nameprep functions can be used directly if desired.

`encodings.idna.nameprep(label)`

Return the nameprepped version of `label`. The implementation currently assumes query strings, so `AllowUnassigned` is true.

`encodings.idna.ToASCII(label)`

Convert a label to ASCII, as specified in RFC 3490. `UseSTD3ASCIIIRules` is assumed to be false.

`encodings.idna.ToUnicode(label)`

Convert a label to Unicode, as specified in RFC 3490.
7.2.6. **encodings.mbc** Windows ANSI codepage

Encode operand according to the ANSI codepage (CP_ACP).

Availability: Windows only.

*Changed in version 3.3:* Support any error handler.

*Changed in version 3.2:* Before 3.2, the errors argument was ignored; 'replace' was always used to encode, and 'ignore' to decode.
7.2.7. **encodings.utf_8_sig** — UTF-8 codec with BOM signature

This module implements a variant of the UTF-8 codec: On encoding a UTF-8 encoded BOM will be prepended to the UTF-8 encoded bytes. For the stateful encoder this is only done once (on the first write to the byte stream). For decoding an optional UTF-8 encoded BOM at the start of the data will be skipped.
8. Data Types

The modules described in this chapter provide a variety of specialized data types such as dates and times, fixed-type arrays, heap queues, synchronized queues, and sets.

Python also provides some built-in data types, in particular, `dict`, `list`, `set` and `frozenset`, and `tuple`. The `str` class is used to hold Unicode strings, and the `bytes` class is used to hold binary data.

The following modules are documented in this chapter:

- **8.1. datetime — Basic date and time types**
  - 8.1.1. Available Types
  - 8.1.2. `timedelta` Objects
  - 8.1.3. `date` Objects
  - 8.1.4. `datetime` Objects
  - 8.1.5. `time` Objects
  - 8.1.6. `tzinfo` Objects
  - 8.1.7. `timezone` Objects
  - 8.1.8. `strftime()` and `strptime()` Behavior
- **8.2. calendar — General calendar-related functions**
- **8.3. collections — Container datatypes**
  - 8.3.1. `ChainMap` objects
    - 8.3.1.1. `ChainMap` Examples and Recipes
  - 8.3.2. `Counter` objects
  - 8.3.3. `deque` objects
    - 8.3.3.1. `deque` Recipes
  - 8.3.4. `defaultdict` objects
    - 8.3.4.1. `defaultdict` Examples
  - 8.3.5. `namedtuple()` Factory Function for Tuples with
Named Fields
- 8.3.6. OrderedDict objects
  - 8.3.6.1. OrderedDict Examples and Recipes
- 8.3.7. UserDict objects
- 8.3.8. UserList objects
- 8.3.9. UserString objects

- 8.4. collections.abc — Abstract Base Classes for Containers
  - 8.4.1. Collections Abstract Base Classes

- 8.5. heapq — Heap queue algorithm
  - 8.5.1. Basic Examples
  - 8.5.2. Priority Queue Implementation Notes
  - 8.5.3. Theory

- 8.6. bisect — Array bisection algorithm
  - 8.6.1. Searching Sorted Lists
  - 8.6.2. Other Examples

- 8.7. array — Efficient arrays of numeric values

- 8.8. weakref — Weak references
  - 8.8.1. Weak Reference Objects
  - 8.8.2. Example
  - 8.8.3. Finalizer Objects
  - 8.8.4. Comparing finalizers with __del__() methods

- 8.9. types — Dynamic type creation and names for built-in types
  - 8.9.1. Dynamic Type Creation
  - 8.9.2. Standard Interpreter Types
  - 8.9.3. Additional Utility Classes and Functions
  - 8.9.4. Coroutine Utility Functions

- 8.10. copy — Shallow and deep copy operations

- 8.11. pprint — Data pretty printer
  - 8.11.1. PrettyPrinter Objects
  - 8.11.2. Example

- 8.12. reprlib — Alternate repr() implementation
  - 8.12.1. Repr Objects
  - 8.12.2. Subclassing Repr Objects
8.13. enum — Support for enumerations

- 8.13.1. Module Contents
- 8.13.2. Creating an Enum
- 8.13.3. Programmatic access to enumeration members and their attributes
- 8.13.4. Duplicating enum members and values
- 8.13.5. Ensuring unique enumeration values
- 8.13.6. Iteration
- 8.13.7. Comparisons
- 8.13.8. Allowed members and attributes of enumerations
- 8.13.9. Restricted subclassing of enumerations
- 8.13.10. Pickling
- 8.13.11. Functional API
- 8.13.12. Derived Enumerations
  - 8.13.12.1. IntEnum
  - 8.13.12.2. Others
- 8.13.13. Interesting examples
  - 8.13.13.1. AutoNumber
  - 8.13.13.2. OrderedEnum
  - 8.13.13.3. DuplicateFreeEnum
  - 8.13.13.4. Planet
- 8.13.14. How are Enums different?
  - 8.13.14.2. Enum Members (aka instances)
  - 8.13.14.3. Finer Points
8.1. datetime — Basic date and time types

Source code: Lib/datetime.py

The datetime module supplies classes for manipulating dates and times in both simple and complex ways. While date and time arithmetic is supported, the focus of the implementation is on efficient attribute extraction for output formatting and manipulation. For related functionality, see also the time and calendar modules.

There are two kinds of date and time objects: “naive” and “aware”.

An aware object has sufficient knowledge of applicable algorithmic and political time adjustments, such as time zone and daylight saving time information, to locate itself relative to other aware objects. An aware object is used to represent a specific moment in time that is not open to interpretation [1].

A naive object does not contain enough information to unambiguously locate itself relative to other date/time objects. Whether a naive object represents Coordinated Universal Time (UTC), local time, or time in some other timezone is purely up to the program, just like it is up to the program whether a particular number represents metres, miles, or mass. Naive objects are easy to understand and to work with, at the cost of ignoring some aspects of reality.

For applications requiring aware objects, datetime and time objects have an optional time zone information attribute, tzinfo, that can be set to an instance of a subclass of the abstract tzinfo class. These tzinfo objects capture information about the offset from UTC time,
the time zone name, and whether Daylight Saving Time is in effect. Note that only one concrete tzinfo class, the timezone class, is supplied by the datetime module. The timezone class can represent simple timezones with fixed offset from UTC, such as UTC itself or North American EST and EDT timezones. Supporting timezones at deeper levels of detail is up to the application. The rules for time adjustment across the world are more political than rational, change frequently, and there is no standard suitable for every application aside from UTC.

The datetime module exports the following constants:

datetime.MINYEAR

The smallest year number allowed in a date or datetime object. MINYEAR is 1.

datetime.MAXYEAR

The largest year number allowed in a date or datetime object. MAXYEAR is 9999.

See also:

Module calendar
General calendar related functions.

Module time
Time access and conversions.
8.1.1. Available Types

```python
class datetime.date
    An idealized naive date, assuming the current Gregorian calendar always was, and always will be, in effect. Attributes: year, month, and day.

class datetime.time
    An idealized time, independent of any particular day, assuming that every day has exactly 24*60*60 seconds (there is no notion of “leap seconds” here). Attributes: hour, minute, second, microsecond, and tzinfo.

class datetime.datetime
    A combination of a date and a time. Attributes: year, month, day, hour, minute, second, microsecond, and tzinfo.

class datetime.timedelta
    A duration expressing the difference between two date, time, or datetime instances to microsecond resolution.

class datetime.tzinfo
    An abstract base class for time zone information objects. These are used by the datetime and time classes to provide a customizable notion of time adjustment (for example, to account for time zone and/or daylight saving time).

class datetime.timezone
    A class that implements the tzinfo abstract base class as a fixed offset from the UTC.
```
**New in version 3.2.**

Objects of these types are immutable.

Objects of the `date` type are always naive.

An object of type `time` or `datetime` may be naive or aware. A `datetime` object \( d \) is aware if \( d.tzinfo \) is not `None` and \( d.tzinfo.utcoffset(d) \) does not return `None`. If \( d.tzinfo \) is `None`, or if \( d.tzinfo \) is not `None` but \( d.tzinfo.utcoffset(d) \) returns `None`, \( d \) is naive. A `time` object \( t \) is aware if \( t.tzinfo \) is not `None` and \( t.tzinfo.utcoffset(\text{None}) \) does not return `None`. Otherwise, \( t \) is naive.

The distinction between naive and aware doesn't apply to `timedelta` objects.

Subclass relationships:

```
object
timedelta
tzinfo
timezone
time
date
datetime
```
8.1.2. `timedelta` Objects

A `timedelta` object represents a duration, the difference between two dates or times.

```python
class datetime.timedelta(days=0, seconds=0, microseconds=0, milliseconds=0, minutes=0, hours=0, weeks=0)
```

All arguments are optional and default to 0. Arguments may be integers or floats, and may be positive or negative.

Only `days`, `seconds` and `microseconds` are stored internally. Arguments are converted to those units:

- A millisecond is converted to 1000 microseconds.
- A minute is converted to 60 seconds.
- An hour is converted to 3600 seconds.
- A week is converted to 7 days.

and days, seconds and microseconds are then normalized so that the representation is unique, with

- $0 \leq \text{microseconds} < 1000000$
- $0 \leq \text{seconds} < 3600*24$ (the number of seconds in one day)
- $-999999999 \leq \text{days} \leq 999999999$

If any argument is a float and there are fractional microseconds, the fractional microseconds left over from all arguments are combined and their sum is rounded to the nearest microsecond using round-half-to-even tiebreaker. If no argument is a float, the conversion and normalization processes are exact (no information is lost).

If the normalized value of days lies outside the indicated range,
OverflowError is raised.

Note that normalization of negative values may be surprising at first. For example,

```python
>>> from datetime import timedelta
>>> d = timedelta(microseconds=-1)
>>> (d.days, d.seconds, d.microseconds)
(-1, 86399, 999999)
```

Class attributes are:

`timedelta.min`
The most negative `timedelta` object, `timedelta(-999999999)`.

`timedelta.max`
The most positive `timedelta` object, `timedelta(days=999999999, hours=23, minutes=59, seconds=59, microseconds=999999)`.

`timedelta.resolution`
The smallest possible difference between non-equal `timedelta` objects, `timedelta(microseconds=1)`.

Note that, because of normalization, `timedelta.max > -timedelta.min`. `-timedelta.max` is not representable as a `timedelta` object.

Instance attributes (read-only):

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Between -999999999 and 999999999</td>
</tr>
</tbody>
</table>
### Supported operations:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_1 = t_2 + t_3 )</td>
<td>Sum of ( t_2 ) and ( t_3 ). Afterwards ( t_1-t_2 == t_3 ) and ( t_1-t_3 == t_2 ) are true. (1)</td>
</tr>
<tr>
<td>( t_1 = t_2 - t_3 )</td>
<td>Difference of ( t_2 ) and ( t_3 ). Afterwards ( t_1 == t_2 - t_3 ) and ( t_2 == t_1 + t_3 ) are true. (1)</td>
</tr>
<tr>
<td>( t_1 = t_2 \times i ) or ( t_1 = i \times t_2 )</td>
<td>Delta multiplied by an integer. Afterwards ( t_1 % i == t_2 ) is true, provided ( i \neq 0 ).</td>
</tr>
<tr>
<td>( t_1 = t_2 \times f ) or ( t_1 = f \times t_2 )</td>
<td>Delta multiplied by a float. The result is rounded to the nearest multiple of ( \text{timedelta}.\text{resolution} ) using round-half-to-even.</td>
</tr>
<tr>
<td>( f = t_2 / t_3 )</td>
<td>Division (3) of ( t_2 ) by ( t_3 ). Returns a \text{float} object.</td>
</tr>
<tr>
<td>( t_1 = t_2 / f ) or ( t_1 = t_2 / i )</td>
<td>Delta divided by a float or an int. The result is rounded to the nearest multiple of ( \text{timedelta}.\text{resolution} ) using round-half-to-even.</td>
</tr>
<tr>
<td>( t_1 = t_2 % i ) or ( t_1 = t_2 % t_3 )</td>
<td>The floor is computed and the remainder (if any) is thrown away. In the second case, an integer is returned. (3)</td>
</tr>
<tr>
<td></td>
<td>The remainder is computed as a</td>
</tr>
<tr>
<td>Expression</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>( t1 = t2 % t3 )</td>
<td>\textit{timedelta} object. (3)</td>
</tr>
<tr>
<td>((q, r) = \text{divmod}(t1, t2))</td>
<td>Computes the quotient and the remainder: ( q = t1 \div t2 ) (3) and ( r = t1 \mod t2 ). ( q ) is an integer and ( r ) is a \textit{timedelta} object.</td>
</tr>
<tr>
<td>(+t1)</td>
<td>Returns a \textit{timedelta} object with the same value. (2)</td>
</tr>
<tr>
<td>(-t1)</td>
<td>Equivalent to \textit{timedelta}(-(t1).days, -(t1).seconds, -(t1).microseconds), and to (-t1* -1). (1)(4)</td>
</tr>
<tr>
<td>\text{abs}(t)</td>
<td>Equivalent to (+t) when (t).days (\geq 0), and to (-t) when (t).days (&lt; 0). (2)</td>
</tr>
<tr>
<td>\text{str}(t)</td>
<td>Returns a string in the form ([D\ day[s], ])[H]:MM:SS[.UUUUUU], where (D) is negative for negative (t). (5)</td>
</tr>
<tr>
<td>\text{repr}(t)</td>
<td>Returns a string in the form \texttt{datetime.timedelta(D[, S[, U]])}, where (D) is negative for negative (t). (5)</td>
</tr>
</tbody>
</table>

**Notes:**

1. This is exact, but may overflow.

2. This is exact, and cannot overflow.

3. Division by 0 raises \texttt{ZeroDivisionError}.

4. \texttt{-timedelta.max} is not representable as a \textit{timedelta} object.

5. String representations of \textit{timedelta} objects are normalized similarly to their internal representation. This leads to somewhat
unusual results for negative timedeltas. For example:

```python
>>> timedelta(hours=-5)
datetime.timedelta(-1, 68400)
>>> print(_)
-1 day, 19:00:00
```

In addition to the operations listed above, `timedelta` objects support certain additions and subtractions with `date` and `datetime` objects (see below).

*Changed in version 3.2:* Floor division and true division of a `timedelta` object by another `timedelta` object are now supported, as are remainder operations and the `divmod()` function. True division and multiplication of a `timedelta` object by a `float` object are now supported.

Comparisons of `timedelta` objects are supported with the `timedelta` object representing the smaller duration considered to be the smaller timedelta. In order to stop mixed-type comparisons from falling back to the default comparison by object address, when a `timedelta` object is compared to an object of a different type, `TypeError` is raised unless the comparison is `==` or `!=`. The latter cases return `False` or `True`, respectively.

`timedelta` objects are hashable (usable as dictionary keys), support efficient pickling, and in Boolean contexts, a `timedelta` object is considered to be true if and only if it isn't equal to `timedelta(0)`.

**Instance methods:**

`timedelta.total_seconds()`

Return the total number of seconds contained in the duration.
Equivalent to \( \text{td} / \text{timedelta(seconds=1)} \).

Note that for very large time intervals (greater than 270 years on most platforms) this method will lose microsecond accuracy.

*New in version 3.2.*

Example usage:

```python
>>> from datetime import timedelta
>>> year = timedelta(days=365)
>>> another_year = timedelta(weeks=40, days=84, hours=... , minutes=50, seconds=600)
>>> year.total_seconds()
31536000.0
>>> year == another_year
True
>>> ten_years = 10 * year
>>> ten_years, ten_years.days // 365
(datetime.timedelta(3650), 10)
>>> nine_years = ten_years - year
>>> nine_years, nine_years.days // 365
(datetime.timedelta(3285), 9)
>>> three_years = nine_years // 3;
>>> three_years, three_years.days // 365
(datetime.timedelta(1095), 3)
>>> abs(three_years - ten_years) == 2 * three_years
True
```
8.1.3. **date** Objects

A `date` object represents a date (year, month and day) in an idealized calendar, the current Gregorian calendar indefinitely extended in both directions. January 1 of year 1 is called day number 1, January 2 of year 1 is called day number 2, and so on. This matches the definition of the “proleptic Gregorian” calendar in Dershowitz and Reingold's book Calendrical Calculations, where it's the base calendar for all computations. See the book for algorithms for converting between proleptic Gregorian ordinals and many other calendar systems.

```python
class datetime.date(year, month, day)
```

All arguments are required. Arguments may be integers, in the following ranges:

- `MINYEAR <= year <= MAXYEAR`
- `1 <= month <= 12`
- `1 <= day <= number of days in the given month and year`

If an argument outside those ranges is given, `ValueError` is raised.

Other constructors, all class methods:

```python
classmethod date.today()
```

Return the current local date. This is equivalent to `date.fromtimestamp(time.time())`.

```python
classmethod date.fromtimestamp(timestamp)
```

Return the local date corresponding to the POSIX timestamp, such as is returned by `time.time()`. This may raise `OverflowError`,
if the timestamp is out of the range of values supported by the platform C `localtime()` function, and `OSError` on `localtime()` failure. It's common for this to be restricted to years from 1970 through 2038. Note that on non-POSIX systems that include leap seconds in their notion of a timestamp, leap seconds are ignored by `fromtimestamp()`.

*Changed in version 3.3:* Raise `OverflowError` instead of `ValueError` if the timestamp is out of the range of values supported by the platform C `localtime()` function. Raise `OSError` instead of `ValueError` on `localtime()` failure.

```python
classmethod date.fromordinal(ordinal)
    Return the date corresponding to the proleptic Gregorian ordinal, where January 1 of year 1 has ordinal 1. `ValueError` is raised unless 1 <= ordinal <= date.max.toordinal(). For any date d, date.fromordinal(d.toordinal()) == d.
```

Class attributes:

date.min

The earliest representable date, `date(MINYEAR, 1, 1)`.

date.max

The latest representable date, `date(MAXYEAR, 12, 31)`.

date.resolution

The smallest possible difference between non-equal date objects, `timedelta(days=1)`.

Instance attributes (read-only):

date.year
Between **MINYEAR** and **MAXYEAR** inclusive.

```python
date.month
```
Baye between 1 and 12 inclusive.

```python
date.day
```
Baye between 1 and the number of days in the given month of the given year.

Supported operations:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>date2 = date1 + timedelta</code></td>
<td><code>date2</code> is <code>timedelta.days</code> days removed from <code>date1</code>. (1)</td>
</tr>
<tr>
<td><code>date2 = date1 - timedelta</code></td>
<td>Computes <code>date2</code> such that <code>date2 + timedelta == date1</code>. (2)</td>
</tr>
<tr>
<td><code>timedelta = date1 - date2</code></td>
<td>(3)</td>
</tr>
<tr>
<td><code>date1 &lt; date2</code></td>
<td><code>date1</code> is considered less than <code>date2</code> when <code>date1</code> precedes <code>date2</code> in time. (4)</td>
</tr>
</tbody>
</table>

Notes:

1. `date2` is moved forward in time if `timedelta.days` > 0, or backward if `timedelta.days` < 0. Afterward `date2 - date1 == timedelta.days`. `timedelta.seconds` and `timedelta.microseconds` are ignored. `OverflowError` is raised if `date2.year` would be smaller than **MINYEAR** or larger than **MAXYEAR**.
2. This isn’t quite equivalent to `date1 + (-timedelta)`, because `-timedelta` in isolation can overflow in cases where `date1 - timedelta` does not. `timedelta.seconds` and
timedelta.microseconds are ignored.
3. This is exact, and cannot overflow. timedelta.seconds and timedelta.microseconds are 0, and date2 + timedelta == date1 after.
4. In other words, date1 < date2 if and only if date1.toordinal() < date2.toordinal(). In order to stop comparison from falling back to the default scheme of comparing object addresses, date comparison normally raises TypeError if the other comparand isn't also a date object. However, NotImplemented is returned instead if the other comparand has a timetuple() attribute. This hook gives other kinds of date objects a chance at implementing mixed-type comparison. If not, when a date object is compared to an object of a different type, TypeError is raised unless the comparison is == or !=. The latter cases return False or True, respectively.

Dates can be used as dictionary keys. In Boolean contexts, all date objects are considered to be true.

Instance methods:

date.replace(year, month, day)
    Return a date with the same value, except for those parameters given new values by whichever keyword arguments are specified. For example, if d == date(2002, 12, 31), then d.replace(day=26) == date(2002, 12, 26).

date.timetuple()
    Return a time.struct_time such as returned by time.localtime(). The hours, minutes and seconds are 0, and the DST flag is -1. d.timetuple() is equivalent to time.struct_time((d.year, d.month, d.day, 0, 0,
0, d.weekday(), yday, -1)), where yday = d.toordinal() - date(d.year, 1, 1).toordinal() + 1 is the day number within the current year starting with 1 for January 1st.

date.toordinal()
Return the proleptic Gregorian ordinal of the date, where January 1 of year 1 has ordinal 1. For any date object d, date.fromordinal(d.toordinal()) == d.

date.weekday()
Return the day of the week as an integer, where Monday is 0 and Sunday is 6. For example, date(2002, 12, 4).weekday() == 2, a Wednesday. See also isoweekday().

date.isoweekday()
Return the day of the week as an integer, where Monday is 1 and Sunday is 7. For example, date(2002, 12, 4).isoweekday() == 3, a Wednesday. See also weekday(), isocalendar().

date.isocalendar()
Return a 3-tuple, (ISO year, ISO week number, ISO weekday).

The ISO calendar is a widely used variant of the Gregorian calendar. See http://www.staff.science.uu.nl/~gent0113/calendar/isocalendar.htm for a good explanation.

The ISO year consists of 52 or 53 full weeks, and where a week starts on a Monday and ends on a Sunday. The first week of an ISO year is the first (Gregorian) calendar week of a year containing
a Thursday. This is called week number 1, and the ISO year of that Thursday is the same as its Gregorian year.

For example, 2004 begins on a Thursday, so the first week of ISO year 2004 begins on Monday, 29 Dec 2003 and ends on Sunday, 4 Jan 2004, so that `date(2003, 12, 29).isocalendar() == (2004, 1, 1)` and `date(2004, 1, 4).isocalendar() == (2004, 1, 7)`.

date.isoformat()

Return a string representing the date in ISO 8601 format, ‘YYYY-MM-DD’. For example, `date(2002, 12, 4).isoformat() == '2002-12-04'`.

date.__str__()

For a date `d`, `str(d)` is equivalent to `d.isofomrat()`.

date.ctime()

Return a string representing the date, for example `date(2002, 12, 4).ctime() == 'Wed Dec 4 00:00:00 2002'`. 
`d.ctime()` is equivalent to `time.ctime(time.mktime(d.timetuple()))` on platforms where the native C `ctime()` function (which `time.ctime()` invokes, but which `date.ctime()` does not invoke) conforms to the C standard.

date.strftime(format)

Return a string representing the date, controlled by an explicit format string. Format codes referring to hours, minutes or seconds will see 0 values. For a complete list of formatting directives, see `strftime()` and `strptime()` Behavior.
date.__format__(format)

Same as date.strftime(). This makes it possible to specify format string for a date object when using str.format(). For a complete list of formatting directives, see strftime() and strptime().

Example of counting days to an event:

```python
>>> import time
>>> from datetime import date
>>> today = date.today()
>>> today
datetime.date(2007, 12, 5)
>>> today == date.fromtimestamp(time.time())
True
>>> my_birthday = date(today.year, 6, 24)
>>> if my_birthday < today:
...    my_birthday = my_birthday.replace(year=today.year)
>>> my_birthday
datetime.date(2008, 6, 24)
>>> time_to_birthday = abs(my_birthday - today)
... time_to_birthday.days
202
```

Example of working with date:

```python
>>> from datetime import date
>>> d = date.fromordinal(730920)  # 730920th day after 1.1.0001
>>> d
datetime.date(2002, 3, 11)
>>> t = d.timetuple()
>>> for i in t:
...    print(i)
2002            # year
3               # month
```
11     # day
0
0
0
0
0     # weekday (0 = Monday)
70     # 70th day in the year
-1

>>> ic = d.isocalendar()
>>> for i in ic:
...   print(i)
2002    # ISO year
11      # ISO week number
1      # ISO day number (1 = Monday)

>>> d.isoformat()
'2002-03-11'
>>> d.strftime("%d/%m/%y")
'11/03/02'
>>> d.strftime("%A %d. %B %Y")
'Monday 11. March 2002'

>>> 'The {1} is {0:%d}, the {2} is {0:%B}'.format(d, 11, 'March')
'The day is 11, the month is March.'
8.1.4. **datetime** Objects

A **datetime** object is a single object containing all the information from a **date** object and a **time** object. Like a **date** object, **datetime** assumes the current Gregorian calendar extended in both directions; like a time object, **datetime** assumes there are exactly \(3600 \times 24\) seconds in every day.

**Constructor:**

```python
class datetime.datetime(year, month, day, hour=0, minute=0, second=0, microsecond=0, tzinfo=None)
```

The year, month and day arguments are required. `tzinfo` may be None, or an instance of a `tzinfo` subclass. The remaining arguments may be integers, in the following ranges:

- \(\text{MINYEAR} \leq \text{year} \leq \text{MAXYEAR}\)
- \(1 \leq \text{month} \leq 12\)
- \(1 \leq \text{day} \leq \text{number of days in the given month and year}\)
- \(0 \leq \text{hour} < 24\)
- \(0 \leq \text{minute} < 60\)
- \(0 \leq \text{second} < 60\)
- \(0 \leq \text{microsecond} < 1000000\)

If an argument outside those ranges is given, `ValueError` is raised.

**Other constructors, all class methods:**

```python
classmethod datetime.today()
```

Return the current local datetime, with `tzinfo` None. This is
equivalent to `datetime.fromtimestamp(time.time())`. See also `now()`, `fromtimestamp()`.

**classmethod** `datetime.now(tz=None)`

Return the current local date and time. If optional argument `tz` is None or not specified, this is like `today()`, but, if possible, supplies more precision than can be gotten from going through a `time.time()` timestamp (for example, this may be possible on platforms supplying the C `gettimeofday()` function).

Else `tz` must be an instance of a class `tzinfo` subclass, and the current date and time are converted to `tz`'s time zone. In this case the result is equivalent to `tz.fromutc(datetime.utcnow().replace(tzinfo=tz))`. See also `today()`, `utcnow()`.

**classmethod** `datetime.utcnow()`

Return the current UTC date and time, with `tzinfo` None. This is like `now()`, but returns the current UTC date and time, as a naive `datetime` object. An aware current UTC datetime can be obtained by calling `datetime.now(timezone.utc)`. See also `now()`.

**classmethod** `datetime.fromtimestamp(timestamp, tz=None)`

Return the local date and time corresponding to the POSIX timestamp, such as is returned by `time.time()`. If optional argument `tz` is None or not specified, the timestamp is converted to the platform's local date and time, and the returned `datetime` object is naive.

Else `tz` must be an instance of a class `tzinfo` subclass, and the timestamp is converted to `tz`'s time zone. In this case the result is equivalent to
tz.fromutc(datetime.utcfromtimestamp(timestamp).replace(tzinfo=tz))

`fromtimestamp()` may raise **OverflowError**, if the timestamp is out of the range of values supported by the platform C `localtime()` or `gmtime()` functions, and **OSError** on `localtime()` or `gmtime()` failure. It's common for this to be restricted to years in 1970 through 2038. Note that on non-POSIX systems that include leap seconds in their notion of a timestamp, leap seconds are ignored by `fromtimestamp()`, and then it's possible to have two timestamps differing by a second that yield identical `datetime` objects. See also `utcfromtimestamp()`.

*Changed in version 3.3:* Raise **OverflowError** instead of **ValueError** if the timestamp is out of the range of values supported by the platform C `localtime()` or `gmtime()` functions. Raise **OSError** instead of **ValueError** on `localtime()` or `gmtime()` failure.

**classmethod** `datetime.utcfromtimestamp(timestamp)`

Return the UTC `datetime` corresponding to the POSIX timestamp, with `tzinfo` None. This may raise **OverflowError**, if the timestamp is out of the range of values supported by the platform C `gmtime()` function, and **OSError** on `gmtime()` failure. It's common for this to be restricted to years in 1970 through 2038.

To get an aware `datetime` object, call `fromtimestamp()`:

```python
datetime.fromtimestamp(timestamp, timezone.utc)
```

On the POSIX compliant platforms, it is equivalent to the following expression:
except the latter formula always supports the full years range: between MINYEAR and MAXYEAR inclusive.

*Changed in version 3.3:* Raise `OverflowError` instead of `ValueError` if the timestamp is out of the range of values supported by the platform C `gmtime()` function. Raise `OSError` instead of `ValueError` on `gmtime()` failure.

**classmethod** `datetime.fromordinal(ordinal)`

Return the `datetime` corresponding to the proleptic Gregorian ordinal, where January 1 of year 1 has ordinal 1. `ValueError` is raised unless `1 <= ordinal <= datetime.max.toordinal()`. The hour, minute, second and microsecond of the result are all 0, and `tzinfo` is `None`.

**classmethod** `datetime.combine(date, time)`

Return a new `datetime` object whose date components are equal to the given `date` object's, and whose time components and `tzinfo` attributes are equal to the given `time` object's. For any `datetime` object `d`, `d == datetime.combine(d.date(), d.timetz())`. If `date` is a `datetime` object, its time components and `tzinfo` attributes are ignored.

**classmethod** `datetime.strptime(date_string, format)`

Return a `datetime` corresponding to `date_string`, parsed according to `format`. This is equivalent to `datetime(* (time.strptime(date_string, format)[0:6]))`. `ValueError` is raised if the `date_string` and `format` can't be
parsed by `time.strptime()` or if it returns a value which isn’t a time tuple. For a complete list of formatting directives, see `strftime()` and `strptime()` Behavior.

Class attributes:

`datetime.min`

The earliest representable `datetime`, `datetime(MINYEAR, 1, 1, tzinfo=None)`.

`datetime.max`

The latest representable `datetime`, `datetime(MAXYEAR, 12, 31, 23, 59, 59, 999999, tzinfo=None)`.

`datetime.resolution`

The smallest possible difference between non-equal `datetime` objects, `timedelta(microseconds=1)`.

Instance attributes (read-only):

`datetime.year`

Between `MINYEAR` and `MAXYEAR` inclusive.

`datetime.month`

Between 1 and 12 inclusive.

`datetime.day`

Between 1 and the number of days in the given month of the given year.

`datetime.hour`

In range(24).
datetime.min tensorflow
datetime.minute
    In range(60).

datetime.second
    In range(60).

datetime.microsecond
    In range(1000000).

datetime.tzinfo
    The object passed as the tzinfo argument to the datetime constructor, or None if none was passed.

Supported operations:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>datetime2 = datetime1 + timedelta</td>
<td>(1)</td>
</tr>
<tr>
<td>datetime2 = datetime1 - timedelta</td>
<td>(2)</td>
</tr>
<tr>
<td>timedelta = datetime1 - datetime2</td>
<td>(3)</td>
</tr>
<tr>
<td>datetime1 &lt; datetime2</td>
<td>Compares datetime to datetime. (4)</td>
</tr>
</tbody>
</table>

1. datetime2 is a duration of timedelta removed from datetime1, moving forward in time if timedelta.days > 0, or backward if timedelta.days < 0. The result has the same tzinfo attribute as the input datetime, and datetime2 - datetime1 == timedelta after. OverflowError is raised if datetime2.year would be smaller than MINYEAR or larger than MAXYEAR. Note that no time zone adjustments are done even if the input is an aware object.
2. Computes the datetime2 such that datetime2 + timedelta == datetime1. As for addition, the result has the same tzinfo attribute as the input datetime, and no time zone adjustments are done even if the input is aware. This isn’t quite equivalent to datetime1 + (-timedelta), because -timedelta in isolation can overflow in cases where datetime1 - timedelta does not.

3. Subtraction of a datetime from a datetime is defined only if both operands are naive, or if both are aware. If one is aware and the other is naive, TypeError is raised.

   If both are naive, or both are aware and have the same tzinfo attribute, the tzinfo attributes are ignored, and the result is a timedelta object t such that datetime2 + t == datetime1. No time zone adjustments are done in this case.

   If both are aware and have different tzinfo attributes, a-b acts as if a and b were first converted to naive UTC datetimes first. The result is (a.replace(tzinfo=None) - a.utcoffset()) - (b.replace(tzinfo=None) - b.utcoffset()) except that the implementation never overflows.

4. datetime1 is considered less than datetime2 when datetime1 precedes datetime2 in time.

   If one comparand is naive and the other is aware, TypeError is raised if an order comparison is attempted. For equality comparisons, naive instances are never equal to aware instances.

   If both comparands are aware, and have the same tzinfo attribute, the common tzinfo attribute is ignored and the base
datetimes are compared. If both comparands are aware and have different \texttt{tzinfo} attributes, the comparands are first adjusted by subtracting their UTC offsets (obtained from self.utcoffset()).

\textit{Changed in version 3.3:} Equality comparisons between naive and aware \texttt{datetime} instances don't raise \texttt{TypeError}.

\begin{quote}
\textbf{Note:} In order to stop comparison from falling back to the default scheme of comparing object addresses, \texttt{datetime} comparison normally raises \texttt{TypeError} if the other comparand isn't also a \texttt{datetime} object. However, \texttt{NotImplemented} is returned instead if the other comparand has a \texttt{timetuple()} attribute. This hook gives other kinds of date objects a chance at implementing mixed-type comparison. If not, when a \texttt{datetime} object is compared to an object of a different type, \texttt{TypeError} is raised unless the comparison is == or !=. The latter cases return \texttt{False} or \texttt{True}, respectively.
\end{quote}

datetime objects can be used as dictionary keys. In Boolean contexts, all datetime objects are considered to be true.

Instance methods:

datetime.\texttt{date()}

Return \texttt{date} object with same year, month and day.

datetime.\texttt{time()}

Return \texttt{time} object with same hour, minute, second and microsecond. \texttt{tzinfo} is None. See also method \texttt{timetz()}.

datetime.\texttt{timetz()}
Return `time` object with same hour, minute, second, microsecond, and tzinfo attributes. See also method `time()`.

```python
datetime.replace([year[, month[, day[, hour[, minute[, second[, microsecond[, tzinfo]]]]]]]])
```
Return a datetime with the same attributes, except for those attributes given new values by whichever keyword arguments are specified. Note that tzinfo=None can be specified to create a naive datetime from an aware datetime with no conversion of date and time data.

```python
datetime.astimezone(tz=None)
```
Return a `datetime` object with new `tzinfo` attribute `tz`, adjusting the date and time data so the result is the same UTC time as `self`, but in `tz`'s local time.

If provided, `tz` must be an instance of a `tzinfo` subclass, and its `utcoffset()` and `dst()` methods must not return None. `self` must be aware (`self.tzinfo` must not be None, and `self.utcoffset()` must not return None).

If called without arguments (or with `tz=None`) the system local timezone is assumed. The `tzinfo` attribute of the converted datetime instance will be set to an instance of `timezone` with the zone name and offset obtained from the OS.

If `self.tzinfo` is `tz`, `self.astimezone(tz)` is equal to `self`: no adjustment of date or time data is performed. Else the result is local time in time zone `tz`, representing the same UTC time as `self`: after `astz = dt.astimezone(tz)`, `astz - astz.utcoffset()` will usually have the same date and time
data as \( dt \) - \( dt.\text{utcoffset}() \). The discussion of class \( tzinfo \) explains the cases at Daylight Saving Time transition boundaries where this cannot be achieved (an issue only if \( tz \) models both standard and daylight time).

If you merely want to attach a time zone object \( tz \) to a datetime \( dt \) without adjustment of date and time data, use \( dt.\text{replace}(tzinfo= tz) \). If you merely want to remove the time zone object from an aware datetime \( dt \) without conversion of date and time data, use \( dt.\text{replace}(tzinfo=None) \).

Note that the default \( tzinfo.\text{fromutc}() \) method can be overridden in a \( tzinfo \) subclass to affect the result returned by \( \text{astimezone}() \). Ignoring error cases, \( \text{astimezone}() \) acts like:

```python
def \text{astimezone}(self, tz):
    if self.tzinfo is \_self:
        return self
    \# Convert self to UTC, and attach the new time
    utc = (self - self.\text{utcoffset}()).replace(tzinf
    \# Convert from UTC to tz's local time.
    return \text{tz.\text{fromutc}}(utc)
```

*Changed in version 3.3:* \( tz \) now can be omitted.

\text{datetime.\text{utcoffset}}()

If \( tzinfo \) is None, returns None, else returns \( self.tzinfo.\text{utcoffset}(self) \), and raises an exception if the latter doesn't return None, or a \( \text{timedelta} \) object representing a whole number of minutes with magnitude less than one day.

\text{datetime.\text{dst}}()
If `tzinfo` is `None`, returns `None`, else returns `self.tzinfo.dst(self)`, and raises an exception if the latter doesn't return `None`, or a `timedelta` object representing a whole number of minutes with magnitude less than one day.

```python
datetime.tzname()
```
If `tzinfo` is `None`, returns `None`, else returns `self.tzinfo.tzname(self)`, raises an exception if the latter doesn't return `None` or a string object,

```python
datetime.timetuple()
```
Return a `time.struct_time` such as returned by `time.localtime()`. `d.timetuple()` is equivalent to `time.struct_time((d.year, d.month, d.day, d.hour, d.minute, d.second, d.weekday(), yday, dst))`, where

\[ yday = d.toordinal() - \text{date(d.year, 1, 1).toordinal()} + 1 \]

is the day number within the current year starting with 1 for January 1st. The `tm_isdst` flag of the result is set according to the `dst()` method: `tzinfo` is `None` or `dst()` returns `None`, `tm_isdst` is set to `-1`; else if `dst()` returns a non-zero value, `tm_isdst` is set to `1`; else `tm_isdst` is set to `0`.

```python
datetime.utctimetuple()
```
If `datetime` instance `d` is naive, this is the same as `d.timetuple()` except that `tm_isdst` is forced to `0` regardless of what `d.dst()` returns. DST is never in effect for a UTC time.

If `d` is aware, `d` is normalized to UTC time, by subtracting `d.utcoffset()`, and a `time.struct_time` for the normalized time is returned. `tm_isdst` is forced to `0`. Note that an `OverflowError` may be raised if `d.year` was `MINYEAR` or
MAXYEAR and UTC adjustment spills over a year boundary.

datetime.toordinal()
Return the proleptic Gregorian ordinal of the date. The same as self.date().toordinal().

datetime.timestamp()
Return POSIX timestamp corresponding to the datetime instance. The return value is a float similar to that returned by time.time().

Naive datetime instances are assumed to represent local time and this method relies on the platform C mktime() function to perform the conversion. Since datetime supports wider range of values than mktime() on many platforms, this method may raise OverflowError for times far in the past or far in the future.

For aware datetime instances, the return value is computed as:

\[
(dt - \text{datetime}(1970, 1, 1, \text{tzinfo} = \text{timezone.utc})).\text{total_seconds}
\]

New in version 3.3.

Note: There is no method to obtain the POSIX timestamp directly from a naive datetime instance representing UTC time. If your application uses this convention and your system timezone is not set to UTC, you can obtain the POSIX timestamp by supplying tzinfo=timezone.utc:

\[
\text{timestamp} = dt.\text{replace}(\text{tzinfo} = \text{timezone.utc}).\text{timestamp}
\]
or by calculating the timestamp directly:
timestamp = (dt - datetime(1970, 1, 1)) / timedelta

datetime.

Return the day of the week as an integer, where Monday is 0 and Sunday is 6. The same as self.date().weekday(). See also isoweekday().

datetime.

Return the day of the week as an integer, where Monday is 1 and Sunday is 7. The same as self.date().isoweekday(). See also weekday(), isocalendar().

datetime.

Return a 3-tuple, (ISO year, ISO week number, ISO weekday). The same as self.date().isocalendar().

datetime.

Return a string representing the date and time in ISO 8601 format, YYYY-MM-DDTHH:MM:SS.mmmmmm or, if microsecond is 0, YYYY-MM-DDTHH:MM:SS

If utcoffset() does not return None, a 6-character string is appended, giving the UTC offset in (signed) hours and minutes: YYYY-MM-DDTHH:MM:SS.mmmmmm+HH:MM or, if microsecond is 0 YYYY-MM-DDTHH:MM:SS+HH:MM

The optional argument sep (default 'T') is a one-character separator, placed between the date and time portions of the result. For example,

```python
>>> from datetime import tzinfo, timedelta, datet```
>> class TZ(tzinfo):
    ...     def utcoffset(self, dt): return timedelta
    ...
>>> datetime(2002, 12, 25, tzinfo=TZ()).isoformat
'2002-12-25 00:00:00-06:39'

datetime.__str__()
For a `datetime` instance `d`, `str(d)` is equivalent to `d.isoformat(' ')`.

datetime.ctime()
Return a string representing the date and time, for example
d.ctime() is equivalent to
time.ctime(time.mktime(d.timetuple())) on platforms where
the native C `ctime()` function (which `time.ctime()` invokes,
but which `datetime.ctime()` does not invoke) conforms to the C standard.

datetime.strftime(format)
Return a string representing the date and time, controlled by an
explicit format string. For a complete list of formatting directives,
see `strftime()` and `strptime()` Behavior.

datetime.__format__(format)
Same as `datetime.strftime()`. This makes it possible to
specify format string for a `datetime` object when using
`str.format()`. For a complete list of formatting directives,
see `strftime()` and `strptime()` Behavior.

Examples of working with datetime objects:
```python
>>> from datetime import datetime, date, time
>>> # Using datetime.combine()
>>> d = date(2005, 7, 14)
>>> t = time(12, 30)
>>> datetime.combine(d, t)
datetime.datetime(2005, 7, 14, 12, 30)
>>> # Using datetime.now() or datetime.utcnow()
>>> datetime.now()
datetime.datetime(2007, 12, 6, 16, 29, 43, 79043)  # GMT +1
>>> datetime.utcnow()
datetime.datetime(2007, 12, 6, 15, 29, 43, 79060)
>>> # Using datetime.strptime()
>>> dt = datetime.strptime("21/11/06 16:30", "%d/%m/%y %H:%M")
>>> dt
datetime.datetime(2006, 11, 21, 16, 30)
>>> # Using datetime.timetuple() to get tuple of all attributes
>>> tt = dt.timetuple()
>>> for it in tt:
...   print(it)
...
2006  # year
11  # month
21  # day
16  # hour
30  # minute
0  # second
1  # weekday (0 = Monday)
325  # number of days since 1st January
-1  # dst - method tzinfo.dst() returned None
>>> # Date in ISO format
>>> ic = dt.isocalendar()
>>> for it in ic:
...   print(it)
...
2006  # ISO year
47  # ISO week
2  # ISO weekday
```
Using datetime with tzinfo:

```python
>>> from datetime import timedelta, datetime, tzinfo

>>> class GMT1(tzinfo):
...     def utcoffset(self, dt):
...         return timedelta(hours=1) + self.dst(dt)

>>> class GMT2(tzinfo):
...     def utcoffset(self, dt):
...         return timedelta(hours=2) + self.dst(dt)
```
```python
... return timedelta(0)
... def tzname(self, dt):
...     return "GMT +2"
...
>>> gmt1 = GMT1()
>>> # Daylight Saving Time
>>> dt1 = datetime(2006, 11, 21, 16, 30, tzinfo=gmt1)
>>> dt1.dst()
datetime.timedelta(0)
>>> dt1.utcoffset()
datetime.timedelta(0, 3600)
>>> dt2 = datetime(2006, 6, 14, 13, 0, tzinfo=gmt1)
>>> dt2.dst()
datetime.timedelta(0, 3600)
>>> dt2.utcoffset()
datetime.timedelta(0, 7200)
>>> # Convert datetime to another time zone
>>> dt3 = dt2.astimezone(GMT2())
>>> dt3
datetime.datetime(2006, 6, 14, 14, 0, tzinfo=<GMT2 object at 0x...>)
>>> dt2
datetime.datetime(2006, 6, 14, 13, 0, tzinfo=<GMT1 object at 0x...>)
>>> dt2.utctimetuple() == dt3.utctimetuple()
True
```
8.1.5. **time** Objects

A time object represents a (local) time of day, independent of any particular day, and subject to adjustment via a *tzinfo* object.

```python
class datetime.time(hour=0, minute=0, second=0, microsecond=0, tzinfo=None)
```

All arguments are optional. *tzinfo* may be None, or an instance of a *tzinfo* subclass. The remaining arguments may be integers, in the following ranges:

- 0 <= hour < 24
- 0 <= minute < 60
- 0 <= second < 60
- 0 <= microsecond < 1000000.

If an argument outside those ranges is given, `ValueError` is raised. All default to 0 except *tzinfo*, which defaults to `None`.

Class attributes:

- `time.min`
  The earliest representable *time*, `time(0, 0, 0, microsecond=0)`.

- `time.max`
  The latest representable *time*, `time(23, 59, 59, microsecond=999999)`.

- `time.resolution`
  The smallest possible difference between non-equal *time* objects, `timedelta(microseconds=1)`, although note that arithmetic on *time* objects is not supported.
Instance attributes (read-only):

`time.hour`
In range(24).

`time.minute`
In range(60).

`time.second`
In range(60).

`time.microsecond`
In range(1000000).

`time.tzinfo`
The object passed as the tzinfo argument to the `time` constructor, or None if none was passed.

Supported operations:

- comparison of `time` to `time`, where `a` is considered less than `b` when `a` precedes `b` in time. If one comparand is naive and the other is aware, `TypeError` is raised if an order comparison is attempted. For equality comparisons, naive instances are never equal to aware instances.

  If both comparands are aware, and have the same `tzinfo` attribute, the common `tzinfo` attribute is ignored and the base times are compared. If both comparands are aware and have different `tzinfo` attributes, the comparands are first adjusted by subtracting their UTC offsets (obtained from `self.utcoffset()`). In order to stop mixed-type comparisons from falling back to the default comparison by object address,
when a `time` object is compared to an object of a different type, `TypeError` is raised unless the comparison is `==` or `!=`. The latter cases return `False` or `True`, respectively.

*Changed in version 3.3:* Equality comparisons between naive and aware `time` instances don’t raise `TypeError`.

- hash, use as dict key
- efficient pickling

In boolean contexts, a `time` object is always considered to be true.

*Changed in version 3.5:* Before Python 3.5, a `time` object was considered to be false if it represented midnight in UTC. This behavior was considered obscure and error-prone and has been removed in Python 3.5. See issue 13936 for full details.

Instance methods:

- `time.replace([hour[, minute[, second[, microsecond[, tzinfo]]]])`  
  Return a `time` with the same value, except for those attributes given new values by whichever keyword arguments are specified. Note that `tzinfo=None` can be specified to create a naive `time` from an aware `time`, without conversion of the time data.

- `time.isoformat()`  
  Return a string representing the time in ISO 8601 format, HH:MM:SS.mmmmmm or, if `self.microsecond` is 0, HH:MM:SS. If `utcoffset()` does not return `None`, a 6-character string is appended, giving the UTC offset in (signed) hours and minutes: HH:MM:SS.mmmmmm+HH:MM or, if `self.microsecond` is 0, HH:MM:SS+HH:MM
For a time \( t \), \( \text{str}(t) \) is equivalent to \( t.\text{isoformat}() \).

**time.strptime(format)**

Return a string representing the time, controlled by an explicit format string. For a complete list of formatting directives, see \texttt{strptime()} and \texttt{strptime()} Behavior.

**time.__format__(format)**

Same as \texttt{time.strptime()}. This makes it possible to specify format string for a \texttt{time} object when using \texttt{str.format()}. For a complete list of formatting directives, see \texttt{strptime()} and \texttt{strptime()} Behavior.

**time.utcoffset()**

If \texttt{tzinfo} is \texttt{None}, returns \texttt{None}, else returns \texttt{self.tzinfo.utcoffset(None)}, and raises an exception if the latter doesn't return \texttt{None} or a \texttt{timedelta} object representing a whole number of minutes with magnitude less than one day.

**time.dst()**

If \texttt{tzinfo} is \texttt{None}, returns \texttt{None}, else returns \texttt{self.tzinfo.dst(None)}, and raises an exception if the latter doesn't return \texttt{None} or a \texttt{timedelta} object representing a whole number of minutes with magnitude less than one day.

**time.tzname()**

If \texttt{tzinfo} is \texttt{None}, returns \texttt{None}, else returns \texttt{self.tzinfo.tzname(None)}, or raises an exception if the latter doesn't return \texttt{None} or a string object.

Example:
```python
>>> from datetime import time, tzinfo
>>> class GMT1(tzinfo):
...     def utcoffset(self, dt):
...         return timedelta(hours=1)
...     def dst(self, dt):
...         return timedelta(0)
...     def tzname(self, dt):
...         return "Europe/Prague"
...
>>> t = time(12, 10, 30, tzinfo=GMT1())
>>> t
datetime.time(12, 10, 30, tzinfo=<GMT1 object at 0x...>)
>>> gmt = GMT1()
>>> t.isoformat()
'12:10:30+01:00'
>>> t.dst()
datetime.timedelta(0)
>>> t.tzname()
'Europe/Prague'
>>> t.strftime("%H:%M:%S %Z")
'12:10:30 Europe/Prague'
>>> 'The {} is {:%H:%M}.'.format("time", t)
'The time is 12:10.'
```
8.1.6. tzinfo Objects

tzinfo is an abstract base class, meaning that this class should not be instantiated directly. You need to derive a concrete subclass, and (at least) supply implementations of the standard tzinfo methods needed by the datetime methods you use. The datetime module supplies a simple concrete subclass of tzinfo timezone which can represent timezones with fixed offset from UTC such as UTC itself or North American EST and EDT.

An instance of (a concrete subclass of) tzinfo can be passed to the constructors for datetime and time objects. The latter objects view their attributes as being in local time, and the tzinfo object supports methods revealing offset of local time from UTC, the name of the time zone, and DST offset, all relative to a date or time object passed to them.

Special requirement for pickling: A tzinfo subclass must have an __init__() method that can be called with no arguments, else it can be pickled but possibly not unpickled again. This is a technical requirement that may be relaxed in the future.

A concrete subclass of tzinfo may need to implement the following methods. Exactly which methods are needed depends on the uses made of aware datetime objects. If in doubt, simply implement all of them.

tzinfo.utcoffset(dt)

Return offset of local time from UTC, in minutes east of UTC. If local time is west of UTC, this should be negative. Note that this is intended to be the total offset from UTC; for example, if a tzinfo
object represents both time zone and DST adjustments, utcoffset() should return their sum. If the UTC offset isn't known, return None. Else the value returned must be a timedelta object specifying a whole number of minutes in the range -1439 to 1439 inclusive (1440 = 24*60; the magnitude of the offset must be less than one day). Most implementations of utcoffset() will probably look like one of these two:

```python
return CONSTANT  # fixed-offset class
return CONSTANT + self.dst(dt)  # daylight-aware
```

If utcoffset() does not return None, dst() should not return None either.

The default implementation of utcoffset() raises NotImplementError.

tzinfo.dst(dt)

Return the daylight saving time (DST) adjustment, in minutes east of UTC, or None if DST information isn’t known. Return timedelta(0) if DST is not in effect. If DST is in effect, return the offset as a timedelta object (see utcoffset() for details). Note that DST offset, if applicable, has already been added to the UTC offset returned by utcoffset(), so there’s no need to consult dst() unless you’re interested in obtaining DST info separately. For example, datetime.timetuple() calls its tzinfo attribute’s dst() method to determine how the tm_isdst flag should be set, and tzinfo.fromutc() calls dst() to account for DST changes when crossing time zones.

An instance tz of a tzinfo subclass that models both standard
and daylight times must be consistent in this sense:

tz.utcoffset(dt) - tz.dst(dt)

must return the same result for every `datetime dt` with `dt.tzinfo == tz`. For sane `tzinfo` subclasses, this expression yields the time zone’s “standard offset”, which should not depend on the date or the time, but only on geographic location. The implementation of `datetime.astimezone()` relies on this, but cannot detect violations; it’s the programmer’s responsibility to ensure it. If a `tzinfo` subclass cannot guarantee this, it may be able to override the default implementation of `tzinfo.fromutc()` to work correctly with `astimezone()` regardless.

Most implementations of `dst()` will probably look like one of these two:

```python
def dst(self, dt):
    # a fixed-offset class: doesn't account for DST
    return timedelta(0)
```

or

```python
def dst(self, dt):
    # Code to set dston and dstoff to the time zone's transition times based on
    # the input dt.year in standard local time. Then
    #
    if dston <= dt.replace(tzinfo=None) < dstoff:
        return timedelta(hours=1)
    else:
        return timedelta(0)
```
The default implementation of `dst()` raises `NotImplementedError`.

**tzinfo.tzname(dt)**

Return the time zone name corresponding to the `datetime` object `dt`, as a string. Nothing about string names is defined by the `datetime` module, and there’s no requirement that it mean anything in particular. For example, “GMT”, “UTC”, “-500”, “-5:00”, “EDT”, “US/Eastern”, “America/New York” are all valid replies. Return None if a string name isn’t known. Note that this is a method rather than a fixed string primarily because some `tzinfo` subclasses will wish to return different names depending on the specific value of `dt` passed, especially if the `tzinfo` class is accounting for daylight time.

The default implementation of `tzname()` raises `NotImplementedError`.

These methods are called by a `datetime` or `time` object, in response to their methods of the same names. A `datetime` object passes itself as the argument, and a `time` object passes None as the argument. A `tzinfo` subclass's methods should therefore be prepared to accept a `dt` argument of None, or of class `datetime`.

When None is passed, it’s up to the class designer to decide the best response. For example, returning None is appropriate if the class wishes to say that time objects don’t participate in the `tzinfo` protocols. It may be more useful for `utcoffset(None)` to return the standard UTC offset, as there is no other convention for discovering the standard offset.

When a `datetime` object is passed in response to a `datetime`
method, `dt.tzinfo` is the same object as `self`. `tzinfo` methods can rely on this, unless user code calls `tzinfo` methods directly. The intent is that the `tzinfo` methods interpret `dt` as being in local time, and not need worry about objects in other timezones.

There is one more `tzinfo` method that a subclass may wish to override:

```
tzinfo.fromutc(dt)
```

This is called from the default `datetime.astimezone()` implementation. When called from that, `dt.tzinfo` is `self`, and `dt`'s date and time data are to be viewed as expressing a UTC time. The purpose of `fromutc()` is to adjust the date and time data, returning an equivalent datetime in `self`'s local time.

Most `tzinfo` subclasses should be able to inherit the default `fromutc()` implementation without problems. It's strong enough to handle fixed-offset time zones, and time zones accounting for both standard and daylight time, and the latter even if the DST transition times differ in different years. An example of a time zone the default `fromutc()` implementation may not handle correctly in all cases is one where the standard offset (from UTC) depends on the specific date and time passed, which can happen for political reasons. The default implementations of `astimezone()` and `fromutc()` may not produce the result you want if the result is one of the hours straddling the moment the standard offset changes.

Skipping code for error cases, the default `fromutc()` implementation acts like:

```python
def fromutc(self, dt):
```
# raise ValueError error if dt.tzinfo is not None
dtoff = dt.utcoffset()
dtdst = dt.dst()

# raise ValueError if dtoff is None or dtdst is None
delta = dtoff - dtdst  # this is self's standard offset
if delta:
    dt += delta  # convert to standard local time
    dtdst = dt.dst()
    # raise ValueError if dtdst is None
    if dtdst:
        return dt + dtdst
else:
    return dt

Example tzinfo classes:

```python
from datetime import tzinfo, timedelta, datetime

ZERO = timedelta(0)
HOUR = timedelta(hours=1)

# A UTC class.

class UTC(tzinfo):
    """UTC""

    def utcoffset(self, dt):
        return ZERO

    def tzname(self, dt):
        return "UTC"

    def dst(self, dt):
        return ZERO

utc = UTC()
```
# A class building tzinfo objects for fixed-offset time zones.
# Note that FixedOffset(0, "UTC") is a different way to build a UTC tzinfo object.

class FixedOffset(tzinfo):
    """Fixed offset in minutes east from UTC."""
    
    def __init__(self, offset, name):
        self.__offset = timedelta(minutes=offset)
        self.__name = name

    def utcoffset(self, dt):
        return self.__offset

    def tzname(self, dt):
        return self.__name

    def dst(self, dt):
        return ZERO

# A class capturing the platform's idea of local time.

import time as _time

STDOFFSET = timedelta(seconds = -_time.timezone)
if _time.daylight:
    DSTOFFSET = timedelta(seconds = -_time.altzone)
else:
    DSTOFFSET = STDOFFSET

DSTDIFF = DSTOFFSET - STDOFFSET

class LocalTimezone(tzinfo):

    def utcoffset(self, dt):
        if self._isdst(dt):
```python
    return DSTOFFSET
else:
    return STDOFFSET

def dst(self, dt):
    if self._isdst(dt):
        return DSTDIFF
    else:
        return ZERO

def tzname(self, dt):
    return _time.tzname[self._isdst(dt)]

def _isdst(self, dt):
    tt = (dt.year, dt.month, dt.day,
          dt.hour, dt.minute, dt.second,
          dt.weekday(), 0, 0)
    stamp = _time.mktime(tt)
    tt = _time.localtime(stamp)
    return tt.tm_isdst > 0

Local = LocalTimezone()

# A complete implementation of current DST rules for
# US DST Rules
# This is a simplified (i.e., wrong for a few cases)
# DST start and end times. For a complete and up-to-
```
# and timezone definitions, visit the Olson Database
# http://www.twinsun.com/tz/tz-link.htm
# http://sourceforge.net/projects/pytz/ (might not be up-to-date)

# In the US, since 2007, DST starts at 2am (standard time)
# Sunday in March, which is the first Sunday on or after Mar 8.
DSTSTART_2007 = datetime(1, 3, 8, 2)
# and ends at 2am (DST time; 1am standard time) on the
DSTEND_2007 = datetime(1, 11, 1, 1)

# From 1987 to 2006, DST used to start at 2am (standard time)
# Sunday in April and to end at 2am (DST time; 1am standard time) on the
# Sunday of October, which is the first Sunday on or after Oct 25.
DSTSTART_1987_2006 = datetime(1, 4, 1, 2)
DSTEND_1987_2006 = datetime(1, 10, 25, 1)

# From 1967 to 1986, DST used to start at 2am (standard time)
# Sunday in April (the one on or after April 24) and
# 1am standard time) on the last Sunday of October,
# on or after Oct 25.
DSTSTART_1967_1986 = datetime(1, 4, 24, 2)

class USTimeZone(tzinfo):
    def __init__(self, hours, reprname, stdname, dstname):
        self.stdoffset = timedelta(hours=hours)
        self.reprname = reprname
        self.stdname = stdname
        self.dstname = dstname

    def __repr__(self):
        return self.reprname

    def tzname(self, dt):
        if self.dst(dt):
            return self.dstname
        else:
            return self.stdname
def utcoffset(self, dt):
    return self.stdoffset + self.dst(dt)

def dst(self, dt):
    if dt is None or dt.tzinfo is None:
        # An exception may be sensible here, in
        # It depends on how you want to treat the
        # fromutc() implementation (called by the
        # implementation) passes a datetime with
        return ZERO
    assert dt.tzinfo is self

    # Find start and end times for US DST. For years
    # ZERO for no DST.
    if 2006 < dt.year:
        dststart, dstend = DSTSTART_2007, DSTEND_2007
    elif 1986 < dt.year < 2007:
    elif 1966 < dt.year < 1987:
    else:
        return ZERO

    start = first_sunday_on_or_after(dststart.replace(tzinfo=None))
    end = first_sunday_on_or_after(dstend.replace(tzinfo=None))

    # Can't compare naive to aware objects, so strip
    # dt first.
    if start <= dt.replace(tzinfo=None) < end:
        return HOUR
    else:
        return ZERO

Eastern = USTimeZone(-5, "Eastern", "EST", "EDT")
Central = USTimeZone(-6, "Central", "CST", "CDT")
Mountain = USTimeZone(-7, "Mountain", "MST", "MDT")
Pacific = USTimeZone(-8, "Pacific", "PST", "PDT")

Note that there are unavoidable subtleties twice per year in a tzinfo subclass accounting for both standard and daylight time, at the DST transition points. For concreteness, consider US Eastern (UTC -0500), where EDT begins the minute after 1:59 (EST) on the second Sunday in March, and ends the minute after 1:59 (EDT) on the first Sunday in November:

|------|------|------|------|------|------|------|

When DST starts (the “start” line), the local wall clock leaps from 1:59 to 3:00. A wall time of the form 2:MM doesn’t really make sense on that day, so astimezone(Eastern) won’t deliver a result with hour == 2 on the day DST begins. In order for astimezone() to make this guarantee, the tzinfo.dst() method must consider times in the “missing hour” (2:MM for Eastern) to be in daylight time.

When DST ends (the “end” line), there’s a potentially worse problem: there’s an hour that can’t be spelled unambiguously in local wall time: the last hour of daylight time. In Eastern, that’s times of the form 5:MM UTC on the day daylight time ends. The local wall clock leaps from 1:59 (daylight time) back to 1:00 (standard time) again. Local times of the form 1:MM are ambiguous. astimezone() mimics the local clock’s behavior by mapping two adjacent UTC hours into the same local hour then. In the Eastern example, UTC times of the form 5:MM
and 6:MM both map to 1:MM when converted to Eastern. In order for `astimezone()` to make this guarantee, the `tzinfo.dst()` method must consider times in the “repeated hour” to be in standard time. This is easily arranged, as in the example, by expressing DST switch times in the time zone’s standard local time.

Applications that can’t bear such ambiguities should avoid using hybrid `tzinfo` subclasses; there are no ambiguities when using `timezone`, or any other fixed-offset `tzinfo` subclass (such as a class representing only EST (fixed offset -5 hours), or only EDT (fixed offset -4 hours)).

**See also:**

**pytz**

The standard library has `timezone` class for handling arbitrary fixed offsets from UTC and `timezone.utc` as UTC timezone instance.

`pytz` library brings the IANA timezone database (also known as the Olson database) to Python and its usage is recommended.

**IANA timezone database**

The Time Zone Database (often called tz or zoneinfo) contains code and data that represent the history of local time for many representative locations around the globe. It is updated periodically to reflect changes made by political bodies to time zone boundaries, UTC offsets, and daylight-saving rules.
8.1.7. timezone Objects

The timezone class is a subclass of tzinfo, each instance of which represents a timezone defined by a fixed offset from UTC. Note that objects of this class cannot be used to represent timezone information in the locations where different offsets are used in different days of the year or where historical changes have been made to civil time.

class datetime.timezone(offset[, name])

The offset argument must be specified as a timedelta object representing the difference between the local time and UTC. It must be strictly between -timedelta(hours=24) and timedelta(hours=24) and represent a whole number of minutes, otherwise ValueError is raised.

The name argument is optional. If specified it must be a string that is used as the value returned by the tzname(dt) method. Otherwise, tzname(dt) returns a string ‘UTCsHH:MM’, where s is the sign of offset, HH and MM are two digits of offset.hours and offset.minutes respectively.

New in version 3.2.

timezone.utcoffset(dt)

Return the fixed value specified when the timezone instance is constructed. The dt argument is ignored. The return value is a timedelta instance equal to the difference between the local time and UTC.

timezone.tzname(dt)

Return the fixed value specified when the timezone instance is
constructed or a string ‘UTCsHH:MM’, where s is the sign of offset, HH and MM are two digits of offset.hours and offset.minutes respectively.

```
timezone.dst(dt)
    Always returns None.
```

```
timezone.fromutc(dt)
    Return dt + offset. The dt argument must be an aware datetime instance, with tzinfo set to self.
```

Class attributes:

```
timezone.utc
    The UTC timezone, timezone(timedelta(0)).
```
8.1.8. strftime() and strptime()

Behavior

date, datetime, and time objects all support a strftime(format) method, to create a string representing the time under the control of an explicit format string. Broadly speaking, d.strftime(fmt) acts like the time module's time.strftime(fmt, d.timetuple()) although not all objects support a timetuple() method.

Conversely, the datetime.strptime() class method creates a datetime object from a string representing a date and time and a corresponding format string. datetime.strptime(date_string, format) is equivalent to datetime(* (time.strptime(date_string, format)[0:6])).

For time objects, the format codes for year, month, and day should not be used, as time objects have no such values. If they're used anyway, 1900 is substituted for the year, and 1 for the month and day.

For date objects, the format codes for hours, minutes, seconds, and microseconds should not be used, as date objects have no such values. If they're used anyway, 0 is substituted for them.

The full set of format codes supported varies across platforms, because Python calls the platform C library's strftime() function, and platform variations are common. To see the full set of format codes supported on your platform, consult the strftime(3) documentation.

The following is a list of all the format codes that the C standard (1989
version) requires, and these work on all platforms with a standard C implementation. Note that the 1999 version of the C standard added additional format codes.

<table>
<thead>
<tr>
<th>Directive</th>
<th>Meaning</th>
<th>Example</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>%a</td>
<td>Weekday as locale's abbreviated name.</td>
<td>Sun, Mon, ..., Sat (en_US); So, Mo, ..., Sa (de_DE)</td>
<td>(1)</td>
</tr>
<tr>
<td>%A</td>
<td>Weekday as locale's full name.</td>
<td>Sunday, Monday, ..., Saturday (en_US); Sonntag, Montag, ..., Samstag (de_DE)</td>
<td>(1)</td>
</tr>
<tr>
<td>%w</td>
<td>Weekday as a decimal number, where 0 is Sunday and 6 is Saturday.</td>
<td>0, 1, ..., 6</td>
<td></td>
</tr>
<tr>
<td>%d</td>
<td>Day of the month as a zero-padded decimal number.</td>
<td>01, 02, ..., 31</td>
<td></td>
</tr>
<tr>
<td>%b</td>
<td>Month as locale's abbreviated name.</td>
<td>Jan, Feb, ..., Dec (en_US); Jan, Feb, ..., Dez (de_DE)</td>
<td>(1)</td>
</tr>
</tbody>
</table>

January, February, ..., December
<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>%B</td>
<td>Month as locale’s full name.</td>
<td>(en_US): Januar, Februar, ..., Dezember (de_DE)</td>
</tr>
<tr>
<td>%m</td>
<td>Month as a zero-padded decimal number.</td>
<td>01, 02, ..., 12</td>
</tr>
<tr>
<td>%y</td>
<td>Year without century as a zero-padded decimal number.</td>
<td>00, 01, ..., 99</td>
</tr>
<tr>
<td>%Y</td>
<td>Year with century as a decimal number.</td>
<td>0001, 0002, ..., 2013, 2014, ..., 9998, 9999</td>
</tr>
<tr>
<td>%H</td>
<td>Hour (24-hour clock) as a zero-padded decimal number.</td>
<td>00, 01, ..., 23</td>
</tr>
<tr>
<td>%I</td>
<td>Hour (12-hour clock) as a zero-padded decimal number.</td>
<td>01, 02, ..., 12</td>
</tr>
<tr>
<td>%p</td>
<td>Locale's equivalent of either AM or PM.</td>
<td>AM, PM (en_US); am, pm (de_DE)</td>
</tr>
<tr>
<td>%M</td>
<td>Minute as a zero-padded decimal number.</td>
<td>00, 01, ..., 59</td>
</tr>
<tr>
<td>%S</td>
<td>Second as a zero-padded decimal number.</td>
<td>00, 01, ..., 59</td>
</tr>
<tr>
<td>%f</td>
<td>Microsecond as a decimal number, zero-padded on the left.</td>
<td>000000, 000001, ..., 999999</td>
</tr>
<tr>
<td>%z</td>
<td>UTC offset in the form +HHMM or -HHMM (empty string if the the</td>
<td>(empty), +0000, -0400, +1030</td>
</tr>
<tr>
<td>Format</td>
<td>Description</td>
<td>Examples</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><code>%Z</code></td>
<td>Time zone name (empty string if the object is naive).</td>
<td>(empty), UTC, EST, CST</td>
</tr>
<tr>
<td><code>%j</code></td>
<td>Day of the year as a zero-padded decimal number.</td>
<td>001, 002, ..., 366</td>
</tr>
<tr>
<td><code>%U</code></td>
<td>Week number of the year (Sunday as the first day of the week) as a zero padded decimal number. All days in a new year preceding the first Sunday are considered to be in week 0.</td>
<td>00, 01, ..., 53</td>
</tr>
<tr>
<td><code>%W</code></td>
<td>Week number of the year (Monday as the first day of the week) as a decimal number. All days in a new year preceding the first Monday are considered to be in week 0.</td>
<td>00, 01, ..., 53</td>
</tr>
<tr>
<td><code>%c</code></td>
<td>Locale's appropriate date and time representation.</td>
<td>Tue Aug 16 21:30:00 1988 (en_US); Di 16 Aug 21:30:00 1988 (de_DE)</td>
</tr>
<tr>
<td><code>%x</code></td>
<td>Locale's appropriate date representation.</td>
<td>08/16/88 (None); 08/16/1988 (en_US); 16.08.1988 (de_DE)</td>
</tr>
<tr>
<td>%X</td>
<td>Locale’s appropriate time representation.</td>
<td>21:30:00 (en_US); 21:30:00 (de_DE)</td>
</tr>
<tr>
<td>----</td>
<td>----------------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>%%</td>
<td>A literal '%' character.</td>
<td>%</td>
</tr>
</tbody>
</table>

Notes:

1. Because the format depends on the current locale, care should be taken when making assumptions about the output value. Field orderings will vary (for example, “month/day/year” versus “day/month/year”), and the output may contain Unicode characters encoded using the locale’s default encoding (for example, if the current locale is ja_JP, the default encoding could be any one of eucJP, SJIS, or utf-8; use `locale.getlocale()` to determine the current locale’s encoding).

2. The `strptime()` method can parse years in the full [1, 9999] range, but years < 1000 must be zero-filled to 4-digit width.

   *Changed in version 3.2:* In previous versions, `strftime()` method was restricted to years >= 1900.

   *Changed in version 3.3:* In version 3.2, `strftime()` method was restricted to years >= 1000.

3. When used with the `strptime()` method, the `%p` directive only affects the output hour field if the `%I` directive is used to parse the hour.

4. Unlike the `time` module, the `datetime` module does not support
leap seconds.

5. When used with the `strptime()` method, the `%f` directive accepts from one to six digits and zero pads on the right. `%f` is an extension to the set of format characters in the C standard (but implemented separately in datetime objects, and therefore always available).

6. For a naive object, the `%z` and `%Z` format codes are replaced by empty strings.

   For an aware object:

   `%z`
   
   `utcoffset()` is transformed into a 5-character string of the form `+HHMM` or `-HHMM`, where `HH` is a 2-digit string giving the number of UTC offset hours, and `MM` is a 2-digit string giving the number of UTC offset minutes. For example, if `utcoffset()` returns `timedelta(hours=-3, minutes=-30)`, `%z` is replaced with the string `-0330`.

   `%Z`
   
   If `tzname()` returns `None`, `%Z` is replaced by an empty string. Otherwise `%Z` is replaced by the returned value, which must be a string.

   *Changed in version 3.2:* When the `%z` directive is provided to the `strptime()` method, an aware `datetime` object will be produced. The `tzinfo` of the result will be set to a `timezone` instance.

7. When used with the `strptime()` method, `%U` and `%W` are only used in calculations when the day of the week and the year are
specified.

Footnotes

[1] If, that is, we ignore the effects of Relativity
8.2. calendar — General calendar-related functions

Source code: Lib/calendar.py

This module allows you to output calendars like the Unix `cal` program, and provides additional useful functions related to the calendar. By default, these calendars have Monday as the first day of the week, and Sunday as the last (the European convention). Use `setfirstweekday()` to set the first day of the week to Sunday (6) or to any other weekday. Parameters that specify dates are given as integers. For related functionality, see also the `datetime` and `time` modules.

Most of these functions and classes rely on the `datetime` module which uses an idealized calendar, the current Gregorian calendar extended in both directions. This matches the definition of the “proleptic Gregorian” calendar in Dershowitz and Reingold’s book “Calendrical Calculations”, where it’s the base calendar for all computations.

```
class calendar.Calendar(firstweekday=0)

    Creates a Calendar object. firstweekday is an integer specifying
    the first day of the week. 0 is Monday (the default), 6 is Sunday.
```

A `Calendar` object provides several methods that can be used for preparing the calendar data for formatting. This class doesn’t do any formatting itself. This is the job of subclasses.

`Calendar` instances have the following methods:
iterweekdays()
Return an iterator for the week day numbers that will be used for one week. The first value from the iterator will be the same as the value of the firstweekday property.

itermonthdates(year, month)
Return an iterator for the month month (1-12) in the year year. This iterator will return all days (as datetime.date objects) for the month and all days before the start of the month or after the end of the month that are required to get a complete week.

itermonthdays2(year, month)
Return an iterator for the month month in the year year similar to itermonthdates(). Days returned will be tuples consisting of a day number and a week day number.

itermonthdays(year, month)
Return an iterator for the month month in the year year similar to itermonthdates(). Days returned will simply be day numbers.

monthdatescalendar(year, month)
Return a list of the weeks in the month month of the year as full weeks. Weeks are lists of seven datetime.date objects.

monthdays2calendar(year, month)
Return a list of the weeks in the month month of the year as full weeks. Weeks are lists of seven tuples of day numbers and weekday numbers.

monthdayscalendar(year, month)
Return a list of the weeks in the month month of the year as full
weeks. Weeks are lists of seven day numbers.

**yeardatescalendar**(year, width=3)

Return the data for the specified year ready for formatting. The return value is a list of month rows. Each month row contains up to `width` months (defaulting to 3). Each month contains between 4 and 6 weeks and each week contains 1–7 days. Days are `datetime.date` objects.

**yeardays2calendar**(year, width=3)

Return the data for the specified year ready for formatting (similar to `yeardatescalendar()`). Entries in the week lists are tuples of day numbers and weekday numbers. Day numbers outside this month are zero.

**yeardayscalendar**(year, width=3)

Return the data for the specified year ready for formatting (similar to `yeardatescalendar()`). Entries in the week lists are day numbers. Day numbers outside this month are zero.

**class** calendar.TextCalendar(firstweekday=0)

This class can be used to generate plain text calendars.

TextCalendar instances have the following methods:

**formatmonth**(theyear, themonth, w=0, l=0)

Return a month’s calendar in a multi-line string. If `w` is provided, it specifies the width of the date columns, which are centered. If `l` is given, it specifies the number of lines that each week will use. Depends on the first weekday as specified in the constructor or set by the `setfirstweekday()` method.

**prmonth**(theyear, themonth, w=0, l=0)
Print a month’s calendar as returned by `formatmonth()`.

`formatyear(theyear, w=2, l=1, c=6, m=3)`

Return a $m$-column calendar for an entire year as a multi-line string. Optional parameters $w$, $l$, and $c$ are for date column width, lines per week, and number of spaces between month columns, respectively. Depends on the first weekday as specified in the constructor or set by the `setfirstweekday()` method. The earliest year for which a calendar can be generated is platform-dependent.

`pryear(theyear, w=2, l=1, c=6, m=3)`

Print the calendar for an entire year as returned by `formatyear()`.

`class calendar.HTMLCalendar(firstweekday=0)`

This class can be used to generate HTML calendars.

`HTMLCalendar` instances have the following methods:

`formatmonth(theyear, themonth, withyear=True)`

Return a month’s calendar as an HTML table. If `withyear` is true the year will be included in the header, otherwise just the month name will be used.

`formatyear(theyear, width=3)`

Return a year’s calendar as an HTML table. `width` (defaulting to 3) specifies the number of months per row.

`formatyearpage(theyear, width=3, css='calendar.css', encoding=None)`

Return a year’s calendar as a complete HTML page. `width` (defaulting to 3) specifies the number of months per row. `css` is
the name for the cascading style sheet to be used. \texttt{None} can be passed if no style sheet should be used. \texttt{encoding} specifies the encoding to be used for the output (defaulting to the system default encoding).

\begin{verbatim}
class calendar.LocaleTextCalendar(firstweekday=0, locale=None)
    This subclass of \texttt{TextCalendar} can be passed a locale name in the constructor and will return month and weekday names in the specified locale. If this locale includes an encoding all strings containing month and weekday names will be returned as unicode.
\end{verbatim}

\begin{verbatim}
class calendar.LocaleHTMLCalendar(firstweekday=0, locale=None)
    This subclass of \texttt{HTMLCalendar} can be passed a locale name in the constructor and will return month and weekday names in the specified locale. If this locale includes an encoding all strings containing month and weekday names will be returned as unicode.
\end{verbatim}

\textbf{Note:} The \texttt{formatweekday()} and \texttt{formatmonthname()} methods of these two classes temporarily change the current locale to the given \texttt{locale}. Because the current locale is a process-wide setting, they are not thread-safe.

For simple text calendars this module provides the following functions.

\begin{verbatim}
calendar.setfirstweekday(weekday)
    Sets the weekday (0 is Monday, 6 is Sunday) to start each week. The values \texttt{MONDAY}, \texttt{TUESDAY}, \texttt{WEDNESDAY}, \texttt{THURSDAY}, \texttt{FRIDAY}, \texttt{SATURDAY}, and \texttt{SUNDAY} are provided for convenience. For example, to set the first weekday to Sunday:
\end{verbatim}
import calendar
calendar.setfirstweekday(calendar.SUNDAY)

calendar.firstweekday()
Returns the current setting for the weekday to start each week.

calendar.isleap(year)
Returns True if year is a leap year, otherwise False.

calendar.leapdays(y1, y2)
Returns the number of leap years in the range from y1 to y2 (exclusive), where y1 and y2 are years.
This function works for ranges spanning a century change.

calendar.weekday(year, month, day)
Returns the day of the week (0 is Monday) for year (1970—...), month (1–12), day (1–31).

calendar.weekheader(n)
Return a header containing abbreviated weekday names. n specifies the width in characters for one weekday.

calendar.monthrange(year, month)
Returns weekday of first day of the month and number of days in month, for the specified year and month.

calendar.monthcalendar(year, month)
Returns a matrix representing a month’s calendar. Each row represents a week; days outside of the month a represented by zeros. Each week begins with Monday unless set by setfirstweekday().
calendar `prmonth`(theyear, themonth, w=0, l=0)

Prints a month's calendar as returned by `month()`.

calendar `month`(theyear, themonth, w=0, l=0)

Returns a month's calendar in a multi-line string using the `formatmonth()` of the `TextCalendar` class.

calendar `prcal`(year, w=0, l=0, c=6, m=3)

Prints the calendar for an entire year as returned by `calendar()`.

calendar `calendar`(year, w=2, l=1, c=6, m=3)

Returns a 3-column calendar for an entire year as a multi-line string using the `formatyear()` of the `TextCalendar` class.

calendar `timegm`(tuple)

An unrelated but handy function that takes a time tuple such as returned by the `gmtime()` function in the `time` module, and returns the corresponding Unix timestamp value, assuming an epoch of 1970, and the POSIX encoding. In fact, `time.gmtime()` and `timegm()` are each others' inverse.

The calendar module exports the following data attributes:

calendar `day_name`

An array that represents the days of the week in the current locale.

calendar `day_abbr`

An array that represents the abbreviated days of the week in the current locale.

calendar `month_name`

An array that represents the months of the year in the current locale.
locale. This follows normal convention of January being month number 1, so it has a length of 13 and `month_name[0]` is the empty string.

`calendar.month_abbr`

An array that represents the abbreviated months of the year in the current locale. This follows normal convention of January being month number 1, so it has a length of 13 and `month_abbr[0]` is the empty string.

See also:

**Module datetime**

Object-oriented interface to dates and times with similar functionality to the `time` module.

**Module time**

Low-level time related functions.
8.3. collections — Container datatypes

Source code: Lib/collections/__init__.py

This module implements specialized container datatypes providing alternatives to Python's general purpose built-in containers, `dict`, `list`, `set`, and `tuple`.

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>namedtuple()</td>
<td>factory function for creating tuple subclasses with named fields</td>
</tr>
<tr>
<td>deque</td>
<td>list-like container with fast appends and pops on either end</td>
</tr>
<tr>
<td>ChainMap</td>
<td>dict-like class for creating a single view of multiple mappings</td>
</tr>
<tr>
<td>Counter</td>
<td>dict subclass for counting hashable objects</td>
</tr>
<tr>
<td>OrderedDict</td>
<td>dict subclass that remembers the order entries were added</td>
</tr>
<tr>
<td>defaultdict</td>
<td>dict subclass that calls a factory function to supply missing values</td>
</tr>
<tr>
<td>UserDict</td>
<td>wrapper around dictionary objects for easier dict subclassing</td>
</tr>
<tr>
<td>UserList</td>
<td>wrapper around list objects for easier list subclassing</td>
</tr>
<tr>
<td>UserString</td>
<td>wrapper around string objects for easier string subclassing</td>
</tr>
</tbody>
</table>

*Changed in version 3.3:* Moved Collections Abstract Base Classes to
the `collections.abc` module. For backwards compatibility, they continue to be visible in this module as well.
8.3.1. **ChainMap objects**

*New in version 3.3.*

A **ChainMap** class is provided for quickly linking a number of mappings so they can be treated as a single unit. It is often much faster than creating a new dictionary and running multiple `update()` calls.

The class can be used to simulate nested scopes and is useful in templating.

```python
class collections.ChainMap(*maps)
```

A **ChainMap** groups multiple dicts or other mappings together to create a single, updateable view. If no `maps` are specified, a single empty dictionary is provided so that a new chain always has at least one mapping.

The underlying mappings are stored in a list. That list is public and can accessed or updated using the `maps` attribute. There is no other state.

Lookups search the underlying mappings successively until a key is found. In contrast, writes, updates, and deletions only operate on the first mapping.

A **ChainMap** incorporates the underlying mappings by reference. So, if one of the underlying mappings gets updated, those changes will be reflected in **ChainMap**.

All of the usual dictionary methods are supported. In addition, there is a `maps` attribute, a method for creating new subcontexts, and a
property for accessing all but the first mapping:

maps

A user updateable list of mappings. The list is ordered from first-searched to last-searched. It is the only stored state and can be modified to change which mappings are searched. The list should always contain at least one mapping.

new_child(m=None)

Returns a new ChainMap containing a new map followed by all of the maps in the current instance. If m is specified, it becomes the new map at the front of the list of mappings; if not specified, an empty dict is used, so that a call to d.new_child() is equivalent to: ChainMap({}, *d.maps). This method is used for creating subcontexts that can be updated without altering values in any of the parent mappings.

Changed in version 3.4: The optional m parameter was added.

parents

Property returning a new ChainMap containing all of the maps in the current instance except the first one. This is useful for skipping the first map in the search. Use cases are similar to those for the nonlocal keyword used in nested scopes. The use cases also parallel those for the built-in super() function. A reference to d.parents is equivalent to: ChainMap(*d.maps[1:]).

See also:

- The MultiContext class in the Enthought CodeTools package has options to support writing to any mapping in the chain.
Django's **Context class** for templating is a read-only chain of mappings. It also features pushing and popping of contexts similar to the `new_child()` method and the `parents()` property.

The **Nested Contexts recipe** has options to control whether writes and other mutations apply only to the first mapping or to any mapping in the chain.

A **greatly simplified read-only version of Chainmap**.

### 8.3.1.1. **ChainMap** Examples and Recipes

This section shows various approaches to working with chained maps.

Example of simulating Python’s internal lookup chain:

```python
import builtins
pylookup = ChainMap(locals(), globals(), vars(builtins))
```

Example of letting user specified command-line arguments take precedence over environment variables which in turn take precedence over default values:

```python
import os, argparse

defaults = {'color': 'red', 'user': 'guest'}

parser = argparse.ArgumentParser()
parser.add_argument('-u', '--user')
parser.add_argument('-c', '--color')
namespace = parser.parse_args()
command_line_args = {k:v for k, v in vars(namespace)}
combined = ChainMap(command_line_args, os.environ, defaults)
print(combined['color'])
```
Example patterns for using the `ChainMap` class to simulate nested contexts:

c = ChainMap()  # Create root context
d = c.new_child()  # Create nested child context
e = c.new_child()  # Child of c, independent from
e.maps[0]  # Current context dictionary --
e.maps[-1]  # Root context -- like Python's
e.parents  # Enclosing context chain --

```
d['x']  # Get first key in the chain of
d['x'] = 1  # Set value in current context
del d['x']  # Delete from current context
list(d)  # All nested values
k in d  # Check all nested values
len(d)  # Number of nested values
d.items()  # All nested items
dict(d)  # Flatten into a regular dictionary
```

The `ChainMap` class only makes updates (writes and deletions) to the first mapping in the chain while lookups will search the full chain. However, if deep writes and deletions are desired, it is easy to make a subclass that updates keys found deeper in the chain:

```
class DeepChainMap(ChainMap):
    'Variant of ChainMap that allows direct updates

    def __setitem__(self, key, value):
        for mapping in self.maps:
            if key in mapping:
                mapping[key] = value
        return
```
def __delitem__(self, key):
    for mapping in self.maps:
        if key in mapping:
            del mapping[key]
    return
raise KeyError(key)

>>> d = DeepChainMap({'zebra': 'black'}, {'elephant': 'brown'})
>>> d['lion'] = 'orange'  # update an existing key
>>> d['snake'] = 'red'    # new keys get added to the topmost dict
>>> del d['elephant']    # remove an existing key
DeepChainMap({'zebra': 'black', 'snake': 'red'}, {}),
8.3.2. **Counter** objects

A counter tool is provided to support convenient and rapid tallies. For example:

```
>>> # Tally occurrences of words in a list
>>> cnt = Counter()
>>> for word in ['red', 'blue', 'red', 'green', 'blue', ...
...            cnt[word] += 1
>>> cnt
Counter({'blue': 3, 'red': 2, 'green': 1})
```

```
>>> # Find the ten most common words in Hamlet
>>> import re
>>> words = re.findall(r'\w+', open('hamlet.txt').read())
>>> Counter(words).most_common(10)
[('the', 1143), ('and', 966), ('to', 762), ('of', 668), ('you', 554), ('a', 546), ('my', 514), ('hamlet', 471)]
```

### class collections.Counter([iterable-or-mapping])

A `Counter` is a `dict` subclass for counting hashable objects. It is an unordered collection where elements are stored as dictionary keys and their counts are stored as dictionary values. Counts are allowed to be any integer value including zero or negative counts. The `Counter` class is similar to bags or multisets in other languages.

Elements are counted from an `iterable` or initialized from another `mapping` (or counter):

```
>>> c = Counter() # a new, empty counter
>>> c = Counter('gallahad') # a new counter from an iterable
```
Counter objects have a dictionary interface except that they return a zero count for missing items instead of raising a `KeyError`:

```
>>> c = Counter({'red': 4, 'blue': 2})  # a new counter from a mapping
>>> c = Counter(cats=4, dogs=8)          # a new counter from keyword args
```

Setting a count to zero does not remove an element from a counter. Use `del` to remove it entirely:

```
>>> c['sausage'] = 0                    # count of a missing element is zero
>>> del c['sausage']                    # del actually removes the entry
```

*New in version 3.1.*

Counter objects support three methods beyond those available for all dictionaries:

**elements()**

Return an iterator over elements repeating each as many times as its count. Elements are returned in arbitrary order. If an element’s count is less than one, `elements()` will ignore it.

```
>>> c = Counter(a=4, b=2, c=0, d=-2)
>>> list(c.elements())
['a', 'a', 'a', 'a', 'b', 'b']
```

**most_common([n])**

Return a list of the $n$ most common elements and their counts
from the most common to the least. If \( n \) is omitted or None, most_common() returns all elements in the counter. Elements with equal counts are ordered arbitrarily:

```python
>>> Counter('abracadabra').most_common(3)
[('a', 5), ('r', 2), ('b', 2)]
```

**subtract([iterable-or-mapping])**

Elements are subtracted from an *iterable* or from another *mapping* (or counter). Like dict.update() but subtracts counts instead of replacing them. Both inputs and outputs may be zero or negative.

```python
>>> c = Counter(a=4, b=2, c=0, d=-2)
>>> d = Counter(a=1, b=2, c=3, d=4)
>>> c.subtract(d)
>>> c
Counter({'a': 3, 'b': 0, 'c': -3, 'd': -6})
```

*New in version 3.2.*

The usual dictionary methods are available for Counter objects except for two which work differently for counters.

**fromkeys(iterable)**

This class method is not implemented for Counter objects.

**update([iterable-or-mapping])**

Elements are counted from an *iterable* or added-in from another *mapping* (or counter). Like dict.update() but adds counts instead of replacing them. Also, the *iterable* is expected to be a sequence of elements, not a sequence of (key, value) pairs.
Common patterns for working with `Counter` objects:

```python
sum(c.values())  # total of all counts
```

```python
c.clear()  # reset all counts
```

```python
list(c)  # list unique elements
```

```python
set(c)  # convert to a set
```

```python
dict(c)  # convert to a regular dictionary
```

```python
c.items()  # convert to a list of (elem, cnt) pairs
```

```python
Counter(dict(list_of_pairs))  # convert from a list of (elem, cnt) pairs
```

```python
c.most_common()[:-n-1:-1]  # n least common elements
```

```python
+c  # remove zero and negative counts
```

Several mathematical operations are provided for combining `Counter` objects to produce multisets (counters that have counts greater than zero). Addition and subtraction combine counters by adding or subtracting the counts of corresponding elements. Intersection and union return the minimum and maximum of corresponding counts. Each operation can accept inputs with signed counts, but the output will exclude results with counts of zero or less.

```python
>>> c = Counter(a=3, b=1)
>>> d = Counter(a=1, b=2)
>>> c + d  # add two counters together
Counter({'a': 4, 'b': 3})
```

```python
>>> c - d  # subtract (keeping only positive counts)
Counter({'a': 2})
```

```python
>>> c & d  # intersection: min
Counter({'a': 1, 'b': 1})
```

```python
>>> c | d  # union: max(c[x],
Counter({'a': 3, 'b': 2})
```

Unary addition and subtraction are shortcuts for adding an empty counter or subtracting from an empty counter.
New in version 3.3: Added support for unary plus, unary minus, and in-place multiset operations.

**Note:** Counters were primarily designed to work with positive integers to represent running counts; however, care was taken to not unnecessarily preclude use cases needing other types or negative values. To help with those use cases, this section documents the minimum range and type restrictions.

- The `Counter` class itself is a dictionary subclass with no restrictions on its keys and values. The values are intended to be numbers representing counts, but you *could* store anything in the value field.
- The `most_common()` method requires only that the values be orderable.
- For in-place operations such as `c[key] += 1`, the value type need only support addition and subtraction. So fractions, floats, and decimals would work and negative values are supported. The same is also true for `update()` and `subtract()` which allow negative and zero values for both inputs and outputs.
- The multiset methods are designed only for use cases with positive values. The inputs may be negative or zero, but only outputs with positive values are created. There are no type restrictions, but the value type needs to support addition, subtraction, and comparison.
- The `elements()` method requires integer counts. It ignores zero and negative counts.
See also:

- Bag class in Smalltalk.
- Wikipedia entry for Multisets.
- C++ multisets tutorial with examples.
- For mathematical operations on multisets and their use cases, see Knuth, Donald. The Art of Computer Programming Volume II, Section 4.6.3, Exercise 19.
- To enumerate all distinct multisets of a given size over a given set of elements, see itertools.combinations_with_replacement():

  ```python
  map(Counter, combinations_with_replacement('ABC', 2)) –
  > AA AB AC BB BC CC
  ```
8.3.3. deque objects

class collections.deque([iterable[, maxlen]])

Returns a new deque object initialized left-to-right (using append()) with data from iterable. If iterable is not specified, the new deque is empty.

Deques are a generalization of stacks and queues (the name is pronounced “deck” and is short for “double-ended queue”). Deques support thread-safe, memory efficient appends and pops from either side of the deque with approximately the same O(1) performance in either direction.

Though list objects support similar operations, they are optimized for fast fixed-length operations and incur O(n) memory movement costs for pop(0) and insert(0, v) operations which change both the size and position of the underlying data representation.

If maxlen is not specified or is None, deques may grow to an arbitrary length. Otherwise, the deque is bounded to the specified maximum length. Once a bounded length deque is full, when new items are added, a corresponding number of items are discarded from the opposite end. Bounded length deques provide functionality similar to the tail filter in Unix. They are also useful for tracking transactions and other pools of data where only the most recent activity is of interest.

Deque objects support the following methods:

append(x)
Add $x$ to the right side of the deque.

**appendleft**($x$)

Add $x$ to the left side of the deque.

**clear()**

Remove all elements from the deque leaving it with length 0.

**copy()**

Create a shallow copy of the deque.

*New in version 3.5.*

**count**($x$)

Count the number of deque elements equal to $x$.

*New in version 3.2.*

**extend**(iterable)

Extend the right side of the deque by appending elements from the iterable argument.

**extendleft**(iterable)

Extend the left side of the deque by appending elements from iterable. Note, the series of left appends results in reversing the order of elements in the iterable argument.

**index**(x[, start[, stop]])

Return the position of $x$ in the deque (at or after index start and before index stop). Returns the first match or raises **ValueError** if not found.

*New in version 3.5.*
**insert**(*i, x*)
Insert *x* into the deque at position *i*.

_New in version 3.5._

**pop()**
Remove and return an element from the right side of the deque. If no elements are present, raises an `IndexError`.

**popleft()**
Remove and return an element from the left side of the deque. If no elements are present, raises an `IndexError`.

**remove**(value)
Remove the first occurrence of *value*. If not found, raises a `ValueError`.

**reverse()**
Reverse the elements of the deque in-place and then return `None`.

_New in version 3.2._

**rotate**(n)
Rotate the deque *n* steps to the right. If *n* is negative, rotate to the left. Rotating one step to the right is equivalent to: `d.appendleft(d.pop())`.

Deque objects also provide one read-only attribute:

**maxlen**
Maximum size of a deque or `None` if unbounded.
New in version 3.1.

In addition to the above, deques support iteration, pickling, \texttt{len(d)}, \texttt{reversed(d)}, \texttt{copy.copy(d)}, \texttt{copy.deepcopy(d)}, membership testing with the \texttt{in} operator, and subscript references such as \texttt{d[-1]}. Indexed access is $O(1)$ at both ends but slows to $O(n)$ in the middle. For fast random access, use lists instead.

Starting in version 3.5, deques support \texttt{__add__()}, \texttt{__mul__()}, and \texttt{__imul__()}.

Example:

```python
>>> from collections import deque
>>> d = deque('ghi')                # make a new deque
>>> for elem in d:                  # iterate over
...     print(elem.upper())
G
H
I

>>> d.append('j')                  # add a new entry to the right side
>>> d.appendleft('f')              # add a new entry to the left side
>>> d                           # show the representation
deque(['f', 'g', 'h', 'i', 'j'])

>>> d.pop()                        # return and remove the rightmost item
'j'
>>> d.popleft()                    # return and remove the leftmost item
'f'
>>> list(d)                        # list the contents
['g', 'h', 'i']
>>> d[0]                           # peek at leftmost item
'g'
>>> d[-1]                          # peek at rightmost item
'i'
```
8.3.3.1. deque Recipes

This section shows various approaches to working with deques.

Bounded length deques provide functionality similar to the tail filter in Unix:
```python
def tail(filename, n=10):
    'Return the last n lines of a file'
    with open(filename) as f:
        return deque(f, n)

Another approach to using deques is to maintain a sequence of recently added elements by appending to the right and popping to the left:

```python
def moving_average(iterable, n=3):
    # moving_average([40, 30, 50, 46, 39, 44]) --> 4
    # http://en.wikipedia.org/wiki/Moving_average
    it = iter(iterable)
    d = deque(itertools.islice(it, n-1))
    d.appendleft(0)
    s = sum(d)
    for elem in it:
        s += elem - d.popleft()
        d.append(elem)
        yield s / n
```

The rotate() method provides a way to implement deque slicing and deletion. For example, a pure Python implementation of del d[n] relies on the rotate() method to position elements to be popped:

```python
def delete_nth(d, n):
    d.rotate(-n)
    d.popleft()
    d.rotate(n)
```

To implement deque slicing, use a similar approach applying rotate() to bring a target element to the left side of the deque. Remove old entries with popleft(), add new entries with
extend(), and then reverse the rotation. With minor variations on that approach, it is easy to implement Forth style stack manipulations such as dup, drop, swap, over, pick, rot, and roll.
8.3.4. **defaultdict** objects

```python
class collections.defaultdict([default_factory[, ...]])
```

Returns a new dictionary-like object. **defaultdict** is a subclass of the built-in **dict** class. It overrides one method and adds one writable instance variable. The remaining functionality is the same as for the **dict** class and is not documented here.

The first argument provides the initial value for the **default_factory** attribute; it defaults to None. All remaining arguments are treated the same as if they were passed to the **dict** constructor, including keyword arguments.

**defaultdict** objects support the following method in addition to the standard **dict** operations:

```python
__missing__(key)
```

If the **default_factory** attribute is None, this raises a **KeyError** exception with the key as argument.

If **default_factory** is not None, it is called without arguments to provide a default value for the given key, this value is inserted in the dictionary for the key, and returned.

If calling **default_factory** raises an exception this exception is propagated unchanged.

This method is called by the **__getitem__()** method of the **dict** class when the requested key is not found; whatever it returns or raises is then returned or raised by **__getitem__()**.
Note that __missing__() is not called for any operations besides __getitem__(). This means that get() will, like normal dictionaries, return None as a default rather than using default_factory.

defaultdict objects support the following instance variable:

**default_factory**

This attribute is used by the __missing__() method; it is initialized from the first argument to the constructor, if present, or to None, if absent.

### 8.3.4.1. defaultdict Examples

Using list as the default_factory, it is easy to group a sequence of key-value pairs into a dictionary of lists:

```python
>>> s = [('yellow', 1), ('blue', 2), ('yellow', 3),
>>> d = defaultdict(list)
>>> for k, v in s:
...     d[k].append(v)
...     ...
>>> list(d.items())
[('blue', [2, 4]), ('red', [1]), ('yellow', [1, 3])]
```

When each key is encountered for the first time, it is not already in the mapping; so an entry is automatically created using the default_factory function which returns an empty list. The list.append() operation then attaches the value to the new list. When keys are encountered again, the look-up proceeds normally (returning the list for that key) and the list.append() operation adds another value to the list. This technique is simpler and faster than
an equivalent technique using `dict.setdefault()`:

```python
>>> d = {}
>>> for k, v in s:
...    d.setdefault(k, []).append(v)
...
>>> list(d.items())
[('blue', [2, 4]), ('red', [1]), ('yellow', [1, 3])]
```

Setting the `default_factory` to `int` makes the `defaultdict` useful for counting (like a bag or multiset in other languages):

```python
>>> s = 'mississippi'
>>> d = defaultdict(int)
>>> for k in s:
...    d[k] += 1
...
>>> list(d.items())
[('i', 4), ('p', 2), ('s', 4), ('m', 1)]
```

When a letter is first encountered, it is missing from the mapping, so the `default_factory` function calls `int()` to supply a default count of zero. The increment operation then builds up the count for each letter.

The function `int()` which always returns zero is just a special case of constant functions. A faster and more flexible way to create constant functions is to use a lambda function which can supply any constant value (not just zero):

```python
>>> def constant_factory(value):
...    return lambda: value

>>> d = defaultdict(constant_factory('<missing>'))
>>> d.update(name='John', action='ran')
```
Setting the `default_factory` to `set` makes the `defaultdict` useful for building a dictionary of sets:

```python
>>> s = [('red', 1), ('blue', 2), ('red', 3), ('blue', 4)]
>>> d = defaultdict(set)
>>> for k, v in s:
...     d[k].add(v)
...  
>>> list(d.items())
[('blue', {2, 4}), ('red', {1, 3})]
```
8.3.5. **namedtuple()** Factory Function for Tuples with Named Fields

Named tuples assign meaning to each position in a tuple and allow for more readable, self-documenting code. They can be used wherever regular tuples are used, and they add the ability to access fields by name instead of position index.

`collections.namedtuple(typename, field_names, verbose=False, rename=False)`

Returns a new tuple subclass named `typename`. The new subclass is used to create tuple-like objects that have fields accessible by attribute lookup as well as being indexable and iterable. Instances of the subclass also have a helpful docstring (with `typename` and `field_names`) and a helpful `__repr__()` method which lists the tuple contents in a name=value format.

The `field_names` are a single string with each fieldname separated by whitespace and/or commas, for example 'x y' or 'x, y'. Alternatively, `field_names` can be a sequence of strings such as ['x', 'y'].

Any valid Python identifier may be used for a fieldname except for names starting with an underscore. Valid identifiers consist of letters, digits, and underscores but do not start with a digit or underscore and cannot be a keyword such as `class`, `for`, `return`, `global`, `pass`, or `raise`.

If `rename` is true, invalid fieldnames are automatically replaced with positional names. For example, ['abc', 'def', 'ghi', 'abc'] is converted to ['abc', '_1', 'ghi', '_3'],
eliminating the keyword def and the duplicate fieldname abc.

If verbose is true, the class definition is printed after it is built. This option is outdated; instead, it is simpler to print the _source attribute.

Named tuple instances do not have per-instance dictionaries, so they are lightweight and require no more memory than regular tuples.

*Changed in version 3.1:* Added support for rename.

```python
>>> # Basic example
>>> Point = namedtuple('Point', ['x', 'y'])
>>> p = Point(11, y=22)    # instantiate with positional arguments
>>> p[0] + p[1]            # indexable like the plain tuple (11, 22)
33
>>> x, y = p               # unpack like a regular tuple
>>> x, y
(11, 22)
>>> p.x + p.y              # fields also accessible by name
33
>>> p                     # readable __repr__ with named fields
Point(x=11, y=22)
```

Named tuples are especially useful for assigning field names to result tuples returned by the csv or sqlite3 modules:

```python
EmployeeRecord = namedtuple('EmployeeRecord', 'name,
import csv
for emp in map(EmployeeRecord._make, csv.reader(open
    print(emp.name, emp.title)
import sqlite3
```
In addition to the methods inherited from tuples, named tuples support three additional methods and two attributes. To prevent conflicts with field names, the method and attribute names start with an underscore.

**classname** `somenamedtuple._make(iterable)`

Class method that makes a new instance from an existing sequence or iterable.

```python
>>> t = [11, 22]
>>> Point._make(t)
Point(x=11, y=22)
```

**somenamedtuple._asdict()**

Return a new `OrderedDict` which maps field names to their corresponding values:

```python
>>> p = Point(x=11, y=22)
>>> p._asdict()
OrderedDict([('x', 11), ('y', 22)])
```

*Changed in version 3.1:* Returns an `OrderedDict` instead of a regular `dict`.

**somenamedtuple._replace(kwargs)**

Return a new instance of the named tuple replacing specified fields with new values:
>>> p = Point(x=11, y=22)
>>> p._replace(x=33)
Point(x=33, y=22)

>>> for partnum, record in inventory.items():
...     inventory[partnum] = record._replace(price=somenamedtuple._source.
A string with the pure Python source code used to create the
tuple class. The source makes the named tuple self-
documenting. It can be printed, executed using `exec()`, or saved
to a file and imported.

*New in version 3.3.*

somenamedtuple._fields

Tuple of strings listing the field names. Useful for introspection and
for creating new named tuple types from existing named tuples.

>>> p._fields # view the field names
('x', 'y')

>>> Color = namedtuple('Color', 'red green blue')
>>> Pixel = namedtuple('Pixel', Point._fields + Color._fields)
>>> Pixel(11, 22, 128, 255, 0)
Pixel(x=11, y=22, red=128, green=255, blue=0)

To retrieve a field whose name is stored in a string, use the
`getattr()` function:

>>> getattr(p, 'x')
11
To convert a dictionary to a named tuple, use the double-star-operator (as described in Unpacking Argument Lists):

```python
>>> d = {'x': 11, 'y': 22}
>>> Point(**d)
Point(x=11, y=22)
```

Since a named tuple is a regular Python class, it is easy to add or change functionality with a subclass. Here is how to add a calculated field and a fixed-width print format:

```python
>>> class Point(namedtuple('Point', 'x y')):
    __slots__ = ()
    @property
def hypot(self):
        return (self.x ** 2 + self.y ** 2) ** 0.5
    def __str__(self):
        return 'Point: x=%6.3f  y=%6.3f  hypot=%6.3f'
```

```python
>>> for p in Point(3, 4), Point(14, 5/7):
    print(p)
Point: x= 3.000  y= 4.000  hypot= 5.000
Point: x=14.000  y= 0.714  hypot=14.018
```

The subclass shown above sets __slots__ to an empty tuple. This helps keep memory requirements low by preventing the creation of instance dictionaries.

Subclassing is not useful for adding new, stored fields. Instead, simply create a new named tuple type from the _fields attribute:

```python
>>> Point3D = namedtuple('Point3D', Point._fields +
```
Docstrings can be customized by making direct assignments to the __doc__ fields:

```python
>> Book = namedtuple('Book', ['id', 'title', 'authors'])
>>> Book.__doc__ += ' : Hardcover book in active collection'
>>> Book.id.__doc__ = '13-digit ISBN'
>>> Book.title.__doc__ = 'Title of first printing'
>>> Book.authors.__doc__ = 'List of authors sorted by last name'
```

Default values can be implemented by using _replace() to customize a prototype instance:

```python
>>> Account = namedtuple('Account', 'owner balance transaction_count')
>>> default_account = Account('<owner name>', 0.0, 0)
>>> johns_account = default_account._replace(owner='John')
>>> janes_account = default_account._replace(owner='Jane')
```

See also:

- Recipe for named tuple abstract base class with a metaclass mix-in by Jan Kaliszewski. Besides providing an abstract base class for named tuples, it also supports an alternate metaclass-based constructor that is convenient for use cases where named tuples are being subclassed.
8.3.6. **OrderedDict** objects

Ordered dictionaries are just like regular dictionaries but they remember the order that items were inserted. When iterating over an ordered dictionary, the items are returned in the order their keys were first added.

```python
class collections.OrderedDict([items])
```

Return an instance of a dict subclass, supporting the usual `dict` methods. An `OrderedDict` is a dict that remembers the order that keys were first inserted. If a new entry overwrites an existing entry, the original insertion position is left unchanged. Deleting an entry and reinserting it will move it to the end.

*New in version 3.1.*

**popitem**(last=True)

The `popitem()` method for ordered dictionaries returns and removes a (key, value) pair. The pairs are returned in LIFO order if `last` is true or FIFO order if false.

**move_to_end**(key, last=True)

Move an existing key to either end of an ordered dictionary. The item is moved to the right end if `last` is true (the default) or to the beginning if `last` is false. Raises `KeyError` if the key does not exist:

```python
>>> d = OrderedDict.fromkeys('abcde')
>>> d.move_to_end('b')
>>> ''.join(d.keys())
'acdeb'
>>> d.move_to_end('b', last=False)
```
In addition to the usual mapping methods, ordered dictionaries also support reverse iteration using `reversed()`.

Equality tests between `OrderedDict` objects are order-sensitive and are implemented as `list(od1.items())==list(od2.items())`. Equality tests between `OrderedDict` objects and other `Mapping` objects are order-insensitive like regular dictionaries. This allows `OrderedDict` objects to be substituted anywhere a regular dictionary is used.

The `OrderedDict` constructor and `update()` method both accept keyword arguments, but their order is lost because Python's function call semantics pass in keyword arguments using a regular unordered dictionary.

`Changed in version 3.5`: The items, keys, and values views of `OrderedDict` now support reverse iteration using `reversed()`.

### 8.3.6.1. `OrderedDict` Examples and Recipes

Since an ordered dictionary remembers its insertion order, it can be used in conjunction with sorting to make a sorted dictionary:

```python
>>> # regular unsorted dictionary
>>> d = {'banana': 3, 'apple':4, 'pear': 1, 'orange': 2}

>>> # dictionary sorted by key
>>> OrderedDict(sorted(d.items(), key=lambda t: t[0])
```
OrderedDict([('apple', 4), ('banana', 3), ('orange', 2), ('pear', 1)]

>>> # dictionary sorted by value
>>> OrderedDict(sorted(d.items(), key=lambda t: t[1])
OrderedDict([('pear', 1), ('orange', 2), ('banana', 3), ('apple', 4)]

>>> # dictionary sorted by length of the key string
>>> OrderedDict(sorted(d.items(), key=lambda t: len(t[0]))
OrderedDict([('pear', 1), ('apple', 4), ('orange', 2), ('banana', 3)]

The new sorted dictionaries maintain their sort order when entries are deleted. But when new keys are added, the keys are appended to the end and the sort is not maintained.

It is also straight-forward to create an ordered dictionary variant that remembers the order the keys were last inserted. If a new entry overwrites an existing entry, the original insertion position is changed and moved to the end:

class LastUpdatedOrderedDict(OrderedDict):  
    'Store items in the order the keys were last added'

        def __setitem__(self, key, value):
            if key in self:
                del self[key]
            OrderedDict.__setitem__(self, key, value)

An ordered dictionary can be combined with the Counter class so that the counter remembers the order elements are first encountered:

class OrderedCounter(Counter, OrderedDict):  
    'Counter that remembers the order elements are first encountered'

    def __repr__(self):
```python
def __reduce__(self):
    return self.__class__, (OrderedDict(self),)
```
8.3.7. **UserDict** objects

The class, **UserDict** acts as a wrapper around dictionary objects. The need for this class has been partially supplanted by the ability to subclass directly from **dict**; however, this class can be easier to work with because the underlying dictionary is accessible as an attribute.

```python
class collections.UserDict([initialdata])
```

Class that simulates a dictionary. The instance’s contents are kept in a regular dictionary, which is accessible via the **data** attribute of **UserDict** instances. If **initialdata** is provided, **data** is initialized with its contents; note that a reference to **initialdata** will not be kept, allowing it be used for other purposes.

In addition to supporting the methods and operations of mappings, **UserDict** instances provide the following attribute:

**data**

A real dictionary used to store the contents of the **UserDict** class.
8.3.8. **UserList** objects

This class acts as a wrapper around list objects. It is a useful base class for your own list-like classes which can inherit from them and override existing methods or add new ones. In this way, one can add new behaviors to lists.

The need for this class has been partially supplanted by the ability to subclass directly from `list`; however, this class can be easier to work with because the underlying list is accessible as an attribute.

```python
class collections.UserList(list):
    Class that simulates a list. The instance’s contents are kept in a regular list, which is accessible via the data attribute of UserList instances. The instance’s contents are initially set to a copy of list, defaulting to the empty list[]. list can be any iterable, for example a real Python list or a UserList object.

    In addition to supporting the methods and operations of mutable sequences, UserList instances provide the following attribute:

    data
    A real list object used to store the contents of the UserList class.

Subclassing requirements: Subclasses of UserList are expected to offer a constructor which can be called with either no arguments or one argument. List operations which return a new sequence attempt to create an instance of the actual implementation class. To do so, it assumes that the constructor can be called with a single parameter, which is a sequence object used as a data source.
If a derived class does not wish to comply with this requirement, all of the special methods supported by this class will need to be overridden; please consult the sources for information about the methods which need to be provided in that case.
8.3.9. **UserString** objects

The class, **UserString** acts as a wrapper around string objects. The need for this class has been partially supplanted by the ability to subclass directly from **str**; however, this class can be easier to work with because the underlying string is accessible as an attribute.

```python
class collections.UserString([sequence])
```

Class that simulates a string or a Unicode string object. The instance's content is kept in a regular string object, which is accessible via the data attribute of **UserString** instances. The instance's contents are initially set to a copy of `sequence`. The `sequence` can be an instance of **bytes**, **str**, **UserString** (or a subclass) or an arbitrary sequence which can be converted into a string using the built-in **str()** function.

*Changed in version 3.5:* New methods `__getnewargs__`, `__rmod__`, `casefold`, `format_map`, `isprintable`, and `maketrans`. 
8.4. `collections.abc` — Abstract Base Classes for Containers

*New in version 3.3:* Formerly, this module was part of the `collections` module.

**Source code:** `Lib/_collections_abc.py`

This module provides `abstract base classes` that can be used to test whether a class provides a particular interface; for example, whether it is hashable or whether it is a mapping.
The collections module offers the following **ABCs**:

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<tr>
<td>MutableMapping</td>
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</table>

```python
class collections.abc.Container
class collections.abc.Hashable
class collections.abc.Sized
class collections.abc.Callable
```
ABCs for classes that provide respectively the methods `__contains__`, `__hash__`, `__len__`, and `__call__`.

```python
class collections.abc.Iterable
```
ABC for classes that provide the `__iter__` method. See also the definition of iterable.

```python
class collections.abc.Iterator
```
ABC for classes that provide the `__iter__` and `__next__` methods. See also the definition of iterator.

```python
class collections.abc.Generator
```
ABC for generator classes that implement the protocol defined in PEP 342 that extends iterators with the `send()`, `throw()` and `close()` methods. See also the definition of generator.

*New in version 3.5.*

```python
class collections.abc.Sequence
class collections.abc.MutableSequence
```
ABCs for read-only and mutable sequences.
Implementation note: Some of the mixin methods, such as `__iter__()`, `__reversed__()`, and `index()`, make repeated calls to the underlying `__getitem__()` method. Consequently, if `__getitem__()` is implemented with constant access speed, the mixin methods will have linear performance; however, if the underlying method is linear (as it would be with a linked list), the mixins will have quadratic performance and will likely need to be overridden.

*Changed in version 3.5:* The `index()` method added support for `stop` and `start` arguments.

```python
class collections.abc.Set
class collections.abc.MutableSet
    ABCs for read-only and mutable sets.

class collections.abc.Mapping
class collections.abc.MutableMapping
    ABCs for read-only and mutable mappings.

class collections.abc.MappingView
class collections.abc.ItemsView
class collections.abc.KeysView
class collections.abc.ValuesView
    ABCs for mapping, items, keys, and values views.

class collections.abc.Awaitable
    ABC for `awaitable` objects, which can be used in `await` expressions. Custom implementations must provide the `__await__()` method.

*Coroutine* objects and instances of the *Coroutine* ABC are all instances of this ABC.
Note: In CPython, generator-based coroutines (generators decorated with `types.coroutine()` or `asyncio.coroutine()`) are *awaitables*, even though they do not have an `__await__()` method. Using `isinstance(gencoro, Awaitable)` for them will return False. Use `inspect.isawaitable()` to detect them.

*New in version 3.5.*

```python
class collections.abc.Coroutine
```
ABC for coroutine compatible classes. These implement the following methods, defined in `Coroutine Objects`: `send()`, `throw()`, and `close()`. Custom implementations must also implement `__await__()`. All `Coroutine` instances are also instances of `Awaitable`. See also the definition of `coroutine`.

```python
Note: In CPython, generator-based coroutines (generators decorated with `types.coroutine()` or `asyncio.coroutine()`) are *awaitables*, even though they do not have an `__await__()` method. Using `isinstance(gencoro, Coroutine)` for them will return False. Use `inspect.isawaitable()` to detect them.

*New in version 3.5.*

```python
class collections.abc.AsyncIterable
```
ABC for classes that provide `__aiter__` method. See also the definition of `asynchronous iterable`.

*New in version 3.5.*

```python
class collections.abc.AsyncIterator
```
ABC for classes that provide __aiter__ and __anext__ methods. See also the definition of asynchronous iterator.

New in version 3.5.

These ABCs allow us to ask classes or instances if they provide particular functionality, for example:

```python
size = None
if isinstance(myvar, collections.abc.Sized):
    size = len(myvar)
```

Several of the ABCs are also useful as mixins that make it easier to develop classes supporting container APIs. For example, to write a class supporting the full Set API, it is only necessary to supply the three underlying abstract methods: __contains__(), __iter__(), and __len__(). The ABC supplies the remaining methods such as __and__() and isdisjoint():

```python
class ListBasedSet(collections.abc.Set):
    ''' Alternate set implementation favoring space and not requiring the set elements to be hashable.'''
    def __init__(self, iterable):
        self.elements = lst = []
        for value in iterable:
            if value not in lst:
                lst.append(value)
    def __iter__(self):
        return iter(self.elements)
    def __contains__(self, value):
        return value in self.elements
    def __len__(self):
        return len(self.elements)

s1 = ListBasedSet('abcdef')
```
s2 = ListBasedSet('defghi')
overlap = s1 & s2  # The __and__() method

Notes on using **Set** and **MutableSet** as a mixin:

1. Since some set operations create new sets, the default mixin methods need a way to create new instances from an iterable. The class constructor is assumed to have a signature in the form `ClassName(iterable)`. That assumption is factored-out to an internal classmethod called `_from_iterable()` which calls `cls(iterable)` to produce a new set. If the **Set** mixin is being used in a class with a different constructor signature, you will need to override `_from_iterable()` with a classmethod that can construct new instances from an iterable argument.

2. To override the comparisons (presumably for speed, as the semantics are fixed), redefine `__le__()` and `__ge__()`, then the other operations will automatically follow suit.

3. The **Set** mixin provides a `_hash()` method to compute a hash value for the set; however, `__hash__()` is not defined because not all sets are hashable or immutable. To add set hashability using mixins, inherit from both **Set()** and **Hashable()**, then define `__hash__ = Set._hash`.

**See also:**

- **OrderedSet recipe** for an example built on **MutableSet**.
- For more about ABCs, see the **abc** module and **PEP 3119**.
8.5. **heapq — Heap queue algorithm**

**Source code:** [Lib/heapq.py](#)

This module provides an implementation of the heap queue algorithm, also known as the priority queue algorithm.

Heaps are binary trees for which every parent node has a value less than or equal to any of its children. This implementation uses arrays for which \( \text{heap}[k] \leq \text{heap}[2*k+1] \) and \( \text{heap}[k] \leq \text{heap}[2*k+2] \) for all \( k \), counting elements from zero. For the sake of comparison, non-existing elements are considered to be infinite. The interesting property of a heap is that its smallest element is always the root, \( \text{heap}[0] \).

The API below differs from textbook heap algorithms in two aspects: (a) We use zero-based indexing. This makes the relationship between the index for a node and the indexes for its children slightly less obvious, but is more suitable since Python uses zero-based indexing. (b) Our pop method returns the smallest item, not the largest (called a “min heap” in textbooks; a “max heap” is more common in texts because of its suitability for in-place sorting).

These two make it possible to view the heap as a regular Python list without surprises: \( \text{heap}[0] \) is the smallest item, and \( \text{heap.sort()} \) maintains the heap invariant!

To create a heap, use a list initialized to [], or you can transform a populated list into a heap via function **heapify**().
The following functions are provided:

`heapq.heappush(heap, item)`
- Push the value `item` onto the `heap`, maintaining the heap invariant.

`heapq.heappop(heap)`
- Pop and return the smallest item from the `heap`, maintaining the heap invariant. If the heap is empty, `IndexError` is raised. To access the smallest item without popping it, use `heap[0]`.

`heapq.heappushpop(heap, item)`
- Push `item` on the heap, then pop and return the smallest item from the `heap`. The combined action runs more efficiently than `heappush()` followed by a separate call to `heappop()`.

`heapq.heapify(x)`
- Transform list `x` into a heap, in-place, in linear time.

`heapq.heappreplace(heap, item)`
- Pop and return the smallest item from the `heap`, and also push the new `item`. The heap size doesn’t change. If the heap is empty, `IndexError` is raised.

This one step operation is more efficient than a `heappop()` followed by `heappush()` and can be more appropriate when using a fixed-size heap. The pop/push combination always returns an element from the heap and replaces it with `item`.

The value returned may be larger than the `item` added. If that isn’t desired, consider using `heappushpop()` instead. Its push/pop combination returns the smaller of the two values, leaving the larger value on the heap.
The module also offers three general purpose functions based on heaps.

**heapq.merge(*iterables, key=None, reverse=False)**

Merge multiple sorted inputs into a single sorted output (for example, merge timestamped entries from multiple log files). Returns an iterator over the sorted values.

Similar to `sorted(itertools.chain(*iterables))` but returns an iterable, does not pull the data into memory all at once, and assumes that each of the input streams is already sorted (smallest to largest).

Has two optional arguments which must be specified as keyword arguments.

- `key` specifies a key function of one argument that is used to extract a comparison key from each input element. The default value is `None` (compare the elements directly).

- `reverse` is a boolean value. If set to `True`, then the input elements are merged as if each comparison were reversed.

  *Changed in version 3.5:* Added the optional `key` and `reverse` parameters.

**heapq.nlargest(n, iterable, key=None)**

Return a list with the `n` largest elements from the dataset defined by `iterable`. `key`, if provided, specifies a function of one argument that is used to extract a comparison key from each element in the iterable: `key=str.lower` Equivalent to: `sorted(iterable, key=key, reverse=True)[n]`
heapq.nsmallest\(n, \text{iterable}, \text{key}=\text{None}\)

Return a list with the \(n\) smallest elements from the dataset defined by \textit{iterable}. \textit{key}, if provided, specifies a function of one argument that is used to extract a comparison key from each element in the iterable: \textit{key}=\text{str.lower} Equivalent to: \text{sorted(\text{iterable}, key=\text{key})[:n]}

The latter two functions perform best for smaller values of \(n\). For larger values, it is more efficient to use the \texttt{sorted()} function. Also, when \(n==1\), it is more efficient to use the built-in \texttt{min()} and \texttt{max()} functions. If repeated usage of these functions is required, consider turning the iterable into an actual heap.
8.5.1. Basic Examples

A `heapsort` can be implemented by pushing all values onto a heap and then popping off the smallest values one at a time:

```python
>>> def heapsort(iterable):
...     h = []
...     for value in iterable:
...         heappush(h, value)
...     return [heappop(h) for i in range(len(h))]
... >>> heapsort([1, 3, 5, 7, 9, 2, 4, 6, 8, 0])
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

This is similar to `sorted(iterable)`, but unlike `sorted()`, this implementation is not stable.

Heap elements can be tuples. This is useful for assigning comparison values (such as task priorities) alongside the main record being tracked:

```python
>>> h = []
>>> heappush(h, (5, 'write code'))
>>> heappush(h, (7, 'release product'))
>>> heappush(h, (1, 'write spec'))
>>> heappush(h, (3, 'create tests'))
>>> heappop(h)
(1, 'write spec')
```
8.5.2. Priority Queue Implementation

Notes

A priority queue is common use for a heap, and it presents several implementation challenges:

- Sort stability: how do you get two tasks with equal priorities to be returned in the order they were originally added?
- Tuple comparison breaks for (priority, task) pairs if the priorities are equal and the tasks do not have a default comparison order.
- If the priority of a task changes, how do you move it to a new position in the heap?
- Or if a pending task needs to be deleted, how do you find it and remove it from the queue?

A solution to the first two challenges is to store entries as 3-element list including the priority, an entry count, and the task. The entry count serves as a tie-breaker so that two tasks with the same priority are returned in the order they were added. And since no two entry counts are the same, the tuple comparison will never attempt to directly compare two tasks.

The remaining challenges revolve around finding a pending task and making changes to its priority or removing it entirely. Finding a task can be done with a dictionary pointing to an entry in the queue.

Removing the entry or changing its priority is more difficult because it would break the heap structure invariants. So, a possible solution is to mark the entry as removed and add a new entry with the revised priority:

```python
pq = []  # list of entries arranged in a heap
entry_finder = {}  # mapping of tasks to indices in pq
```
REMOVED = '<removed-task>'  # placeholder for a removed task

counter = itertools.count()  # unique sequence counter

def add_task(task, priority=0):
    'Add a new task or update the priority of an existing task.'
    if task in entry_finder:
        remove_task(task)
    count = next(counter)
    entry = [priority, count, task]
    entry_finder[task] = entry
    heappush(pq, entry)

def remove_task(task):
    'Mark an existing task as REMOVED. Raise KeyError if not found.'
    entry = entry_finder.pop(task)
    entry[-1] = REMOVED

def pop_task():
    'Remove and return the lowest priority task. Raise KeyError if empty.'
    while pq:
        priority, count, task = heappop(pq)
        if task is not REMOVED:
            del entry_finder[task]
            return task
    raise KeyError('pop from an empty priority queue')
8.5.3. Theory

Heaps are arrays for which \( a[k] \leq a[2k+1] \) and \( a[k] \leq a[2k+2] \) for all \( k \), counting elements from 0. For the sake of comparison, non-existing elements are considered to be infinite. The interesting property of a heap is that \( a[0] \) is always its smallest element.

The strange invariant above is meant to be an efficient memory representation for a tournament. The numbers below are \( k \), not \( a[k] \):

\[
\begin{array}{cccccccccccc}
0 & 1 & 2 & 3 & 4 & 5 & 7 & 8 & 9 & 10 & 11 & 12 & 13 \\
\end{array}
\]

In the tree above, each cell \( k \) is topping \( 2k+1 \) and \( 2k+2 \). In an usual binary tournament we see in sports, each cell is the winner over the two cells it tops, and we can trace the winner down the tree to see all opponents s/he had. However, in many computer applications of such tournaments, we do not need to trace the history of a winner. To be more memory efficient, when a winner is promoted, we try to replace it by something else at a lower level, and the rule becomes that a cell and the two cells it tops contain three different items, but the top cell “wins” over the two topped cells.

If this heap invariant is protected at all time, index 0 is clearly the
overall winner. The simplest algorithmic way to remove it and find the “next” winner is to move some loser (let’s say cell 30 in the diagram above) into the 0 position, and then percolate this new 0 down the tree, exchanging values, until the invariant is re-established. This is clearly logarithmic on the total number of items in the tree. By iterating over all items, you get an O(n log n) sort.

A nice feature of this sort is that you can efficiently insert new items while the sort is going on, provided that the inserted items are not “better” than the last 0’th element you extracted. This is especially useful in simulation contexts, where the tree holds all incoming events, and the “win” condition means the smallest scheduled time. When an event schedules other events for execution, they are scheduled into the future, so they can easily go into the heap. So, a heap is a good structure for implementing schedulers (this is what I used for my MIDI sequencer :-).

Various structures for implementing schedulers have been extensively studied, and heaps are good for this, as they are reasonably speedy, the speed is almost constant, and the worst case is not much different than the average case. However, there are other representations which are more efficient overall, yet the worst cases might be terrible.

Heaps are also very useful in big disk sorts. You most probably all know that a big sort implies producing “runs” (which are pre-sorted sequences, whose size is usually related to the amount of CPU memory), followed by a merging passes for these runs, which merging is often very cleverly organised [1]. It is very important that the initial sort produces the longest runs possible. Tournaments are a good way to achieve that. If, using all the memory available to hold a tournament, you replace and percolate items that happen to fit the current run, you’ll produce runs which are twice the size of the memory for random input, and much better for input fuzzily ordered.
Moreover, if you output the 0'th item on disk and get an input which may not fit in the current tournament (because the value “wins” over the last output value), it cannot fit in the heap, so the size of the heap decreases. The freed memory could be cleverly reused immediately for progressively building a second heap, which grows at exactly the same rate the first heap is melting. When the first heap completely vanishes, you switch heaps and start a new run. Clever and quite effective!

In a word, heaps are useful memory structures to know. I use them in a few applications, and I think it is good to keep a ‘heap’ module around. :-)
8.6. **bisect** — Array bisection algorithm

**Source code:** Lib/bisect.py

This module provides support for maintaining a list in sorted order without having to sort the list after each insertion. For long lists of items with expensive comparison operations, this can be an improvement over the more common approach. The module is called **bisect** because it uses a basic bisection algorithm to do its work. The source code may be most useful as a working example of the algorithm (the boundary conditions are already right!).

The following functions are provided:

**bisect.bisect_left**(*a, x, lo=0, hi=len(a)*)

Locate the insertion point for *x* in *a* to maintain sorted order. The parameters *lo* and *hi* may be used to specify a subset of the list which should be considered; by default the entire list is used. If *x* is already present in *a*, the insertion point will be before (to the left of) any existing entries. The return value is suitable for use as the first parameter to `list.insert()` assuming that *a* is already sorted.

The returned insertion point *i* partitions the array *a* into two halves so that `all(val < x for val in a[lo:i])` for the left side and `all(val >= x for val in a[i:hi])` for the right side.

**bisect.bisect_right**(*a, x, lo=0, hi=len(a)*)

**bisect.bisect**(*a, x, lo=0, hi=len(a)*)

Similar to `bisect_left()`, but returns an insertion point which
comes after (to the right of) any existing entries of \( x \) in \( a \).

The returned insertion point \( i \) partitions the array \( a \) into two halves so that \( \text{all}(\text{val} \leq x \text{ for } \text{val in } a[\text{lo}:i]) \) for the left side and \( \text{all}(\text{val} > x \text{ for } \text{val in } a[i:hi]) \) for the right side.

\[ \text{bisect.insert} \left( a, x, \text{lo}=0, \text{hi}=\text{len}(a) \right) \]

Insert \( x \) in \( a \) in sorted order. This is equivalent to \( a.insert(\text{bisect.bisect} \left( a, x, \text{lo}, \text{hi} \right), x) \) assuming that \( a \) is already sorted. Keep in mind that the \( O(\log n) \) search is dominated by the slow \( O(n) \) insertion step.

\[ \text{bisect.insert} \left( a, x, \text{lo}=0, \text{hi}=\text{len}(a) \right) \]
\[ \text{bisect.insert} \left( a, x, \text{lo}=0, \text{hi}=\text{len}(a) \right) \]

Similar to \( \text{insert} \left( \text{left}() \right) \), but inserting \( x \) in \( a \) after any existing entries of \( x \).

**See also:** [SortedCollection recipe](https://docs.python.org/3/library/bisect.html) that uses bisect to build a full-featured collection class with straight-forward search methods and support for a key-function. The keys are precomputed to save unnecessary calls to the key function during searches.
8.6.1. Searching Sorted Lists

The above `bisect()` functions are useful for finding insertion points but can be tricky or awkward to use for common searching tasks. The following five functions show how to transform them into the standard lookups for sorted lists:

```python
def index(a, x):
    'Locate the leftmost value exactly equal to x'
    i = bisect_left(a, x)
    if i != len(a) and a[i] == x:
        return i
    raise ValueError

def find_lt(a, x):
    'Find rightmost value less than x'
    i = bisect_left(a, x)
    if i:
        return a[i-1]
    raise ValueError

def find_le(a, x):
    'Find rightmost value less than or equal to x'
    i = bisect_right(a, x)
    if i:
        return a[i-1]
    raise ValueError

def find_gt(a, x):
    'Find leftmost value greater than x'
    i = bisect_right(a, x)
    if i != len(a):
        return a[i]
    raise ValueError
```
def find_ge(a, x):
    'Find leftmost item greater than or equal to x'
    i = bisect_left(a, x)
    if i != len(a):
        return a[i]
    raise ValueError
The `bisect()` function can be useful for numeric table lookups. This example uses `bisect()` to look up a letter grade for an exam score (say) based on a set of ordered numeric breakpoints: 90 and up is an ‘A’, 80 to 89 is a ‘B’, and so on:

```python
>>> def grade(score, breakpoints=[60, 70, 80, 90],
...           grades=['F', 'D', 'C', 'B', 'A'])
...     i = bisect(breakpoints, score)
...     return grades[i]
...
>>> [grade(score) for score in [33, 99, 77, 70, 89, 90]]
['F', 'C', 'C', 'B', 'A', 'A']
```

Unlike the `sorted()` function, it does not make sense for the `bisect()` functions to have `key` or `reversed` arguments because that would lead to an inefficient design (successive calls to bisect functions would not “remember” all of the previous key lookups).

Instead, it is better to search a list of precomputed keys to find the index of the record in question:

```python
>>> data = [('red', 5), ('blue', 1), ('yellow', 8), ('black', 0)]
>>> data.sort(key=lambda r: r[1])
>>> keys = [r[1] for r in data]  # precompute
>>> data[bisect_left(keys, 0)]
('black', 0)
>>> data[bisect_left(keys, 1)]
('blue', 1)
>>> data[bisect_left(keys, 5)]
('red', 5)
>>> data[bisect_left(keys, 8)]
('yellow', 8)
```
8.7. `array` — Efficient arrays of numeric values

This module defines an object type which can compactly represent an array of basic values: characters, integers, floating point numbers. Arrays are sequence types and behave very much like lists, except that the type of objects stored in them is constrained. The type is specified at object creation time by using a *type code*, which is a single character. The following type codes are defined:

<table>
<thead>
<tr>
<th>Type code</th>
<th>C Type</th>
<th>Python Type</th>
<th>Minimum size in bytes</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>'b'</td>
<td>signed char</td>
<td>int</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>'B'</td>
<td>unsigned char</td>
<td>int</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>'u'</td>
<td>Py_UNICODE</td>
<td>Unicode character</td>
<td>2</td>
<td>(1)</td>
</tr>
<tr>
<td>'h'</td>
<td>signed short</td>
<td>int</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>'H'</td>
<td>unsigned short</td>
<td>int</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>'i'</td>
<td>signed int</td>
<td>int</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>'I'</td>
<td>unsigned int</td>
<td>int</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>'l'</td>
<td>signed long</td>
<td>int</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>'L'</td>
<td>unsigned long</td>
<td>int</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>'q'</td>
<td>signed long long</td>
<td>int</td>
<td>8</td>
<td>(2)</td>
</tr>
<tr>
<td>'Q'</td>
<td>unsigned long long</td>
<td>int</td>
<td>8</td>
<td>(2)</td>
</tr>
<tr>
<td>'f'</td>
<td>float</td>
<td>float</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>
Notes:

1. The 'u' type code corresponds to Python’s obsolete unicode character (Py_UNICODE which is wchar_t). Depending on the platform, it can be 16 bits or 32 bits.
   
   'u' will be removed together with the rest of the Py_UNICODE API.
   
   *Deprecated since version 3.3, will be removed in version 4.0.*

2. The 'q' and 'Q' type codes are available only if the platform C compiler used to build Python supports C long long, or, on Windows, __int64.

   *New in version 3.3.*

The actual representation of values is determined by the machine architecture (strictly speaking, by the C implementation). The actual size can be accessed through the itemsize attribute.

The module defines the following type:

```
class array.array(typecode[, initializer])
```

A new array whose items are restricted by typecode, and initialized from the optional initializer value, which must be a list, a bytes-like object, or iterable over elements of the appropriate type.

If given a list or string, the initializer is passed to the new array's fromlist(), frombytes(), or fromunicode() method (see below) to add initial items to the array. Otherwise, the iterable
initializer is passed to the `extend()` method.

array.`typecodes`
A string with all available type codes.

Array objects support the ordinary sequence operations of indexing, slicing, concatenation, and multiplication. When using slice assignment, the assigned value must be an array object with the same type code; in all other cases, `TypeError` is raised. Array objects also implement the buffer interface, and may be used wherever `bytes-like objects` are supported.

The following data items and methods are also supported:

array.`typecode`
The typecode character used to create the array.

array.`itemsize`
The length in bytes of one array item in the internal representation.

array.`append(x)`
Append a new item with value x to the end of the array.

array.`buffer_info()`
Return a tuple `(address, length)` giving the current memory address and the length in elements of the buffer used to hold array's contents. The size of the memory buffer in bytes can be computed as `array.buffer_info()[1] * array.itemsize`. This is occasionally useful when working with low-level (and inherently unsafe) I/O interfaces that require memory addresses, such as certain `ioctl()` operations. The returned numbers are valid as long as the array exists and no length-changing operations are applied to it.
Note: When using array objects from code written in C or C++ (the only way to effectively make use of this information), it makes more sense to use the buffer interface supported by array objects. This method is maintained for backward compatibility and should be avoided in new code. The buffer interface is documented in Buffer Protocol.

array.byteswap()

"Byteswap" all items of the array. This is only supported for values which are 1, 2, 4, or 8 bytes in size; for other types of values, RuntimeError is raised. It is useful when reading data from a file written on a machine with a different byte order.

array.count(x)

Return the number of occurrences of x in the array.

array.extend(iterable)

Append items from iterable to the end of the array. If iterable is another array, it must have exactly the same type code; if not, TypeError will be raised. If iterable is not an array, it must be iterable and its elements must be the right type to be appended to the array.

array.frombytes(s)

Appends items from the string, interpreting the string as an array of machine values (as if it had been read from a file using the fromfile() method).

New in version 3.2: fromstring() is renamed to frombytes() for clarity.

array.fromfile(f, n)
Read \( n \) items (as machine values) from the file object \( f \) and append them to the end of the array. If less than \( n \) items are available, \texttt{EOFError} is raised, but the items that were available are still inserted into the array. \( f \) must be a real built-in file object; something else with a \texttt{read()} method won’t do.

\texttt{array.fromlist(list)}

Append items from the list. This is equivalent to \texttt{for x in list: a.append(x)} except that if there is a type error, the array is unchanged.

\texttt{array.fromstring()}

Deprecated alias for \texttt{frombytes()}.  

\texttt{array.fromunicode(s)}

Extends this array with data from the given unicode string. The array must be a type 'u' array; otherwise a \texttt{ValueError} is raised. Use \texttt{array.frombytes(unicodestring.encode(enc))} to append Unicode data to an array of some other type.

\texttt{array.index(x)}

Return the smallest \( i \) such that \( i \) is the index of the first occurrence of \( x \) in the array.

\texttt{array.insert(i, x)}

Insert a new item with value \( x \) in the array before position \( i \). Negative values are treated as being relative to the end of the array.

\texttt{array.pop([i])}

Removes the item with the index \( i \) from the array and returns it.
The optional argument defaults to -1, so that by default the last item is removed and returned.

array.remove(x)
Remove the first occurrence of x from the array.

array.reverse()
Reverse the order of the items in the array.

array.tobytes()
Convert the array to an array of machine values and return the bytes representation (the same sequence of bytes that would be written to a file by the tofile() method.)

New in version 3.2: tostring() is renamed to tobytes() for clarity.

array.tofile(f)
Write all items (as machine values) to the file object f.

array.tolist()
Convert the array to an ordinary list with the same items.

array.tostring()
Deprecated alias for tobytes().

array.tounicode()
Convert the array to a unicode string. The array must be a type 'u' array; otherwise a ValueError is raised. Use array.tobytes().decode(enc) to obtain a unicode string from an array of some other type.

When an array object is printed or converted to a string, it is
represented as `array(typecode, initializer)`. The `initializer` is omitted if the array is empty, otherwise it is a string if the `typecode` is 'u', otherwise it is a list of numbers. The string is guaranteed to be able to be converted back to an array with the same type and value using `eval()`, so long as the `array()` function has been imported using from `array import array`. Examples:

```python
array('l')
array('u', 'hello \u2641')
array('l', [1, 2, 3, 4, 5])
array('d', [1.0, 2.0, 3.14])
```

**See also:**

**Module struct**

Packing and unpacking of heterogeneous binary data.

**Module xdrlib**

Packing and unpacking of External Data Representation (XDR) data as used in some remote procedure call systems.

**The Numerical Python Documentation**

The `weakref` module allows the Python programmer to create *weak references* to objects.

In the following, the term *referent* means the object which is referred to by a weak reference.

A weak reference to an object is not enough to keep the object alive: when the only remaining references to a referent are weak references, *garbage collection* is free to destroy the referent and reuse its memory for something else. However, until the object is actually destroyed the weak reference may return the object even if there are no strong references to it.

A primary use for weak references is to implement caches or mappings holding large objects, where it's desired that a large object not be kept alive solely because it appears in a cache or mapping.

For example, if you have a number of large binary image objects, you may wish to associate a name with each. If you used a Python dictionary to map names to images, or images to names, the image objects would remain alive just because they appeared as values or keys in the dictionaries. The `WeakKeyDictionary` and `WeakValueDictionary` classes supplied by the `weakref` module are an alternative, using weak references to construct mappings that don't keep objects alive solely because they appear in the mapping objects. If, for example, an image object is a value in a `WeakValueDictionary`, then when the last remaining references to
that image object are the weak references held by weak mappings, garbage collection can reclaim the object, and its corresponding entries in weak mappings are simply deleted.

**WeakKeyDictionary** and **WeakValueDictionary** use weak references in their implementation, setting up callback functions on the weak references that notify the weak dictionaries when a key or value has been reclaimed by garbage collection. **WeakSet** implements the **set** interface, but keeps weak references to its elements, just like a **WeakKeyDictionary** does.

**finalize** provides a straight forward way to register a cleanup function to be called when an object is garbage collected. This is simpler to use than setting up a callback function on a raw weak reference, since the module automatically ensures that the finalizer remains alive until the object is collected.

Most programs should find that using one of these weak container types or **finalize** is all they need – it’s not usually necessary to create your own weak references directly. The low-level machinery is exposed by the **weakref** module for the benefit of advanced uses.

Not all objects can be weakly referenced; those objects which can include class instances, functions written in Python (but not in C), instance methods, sets, frozensets, some **file objects**, **generators**, type objects, sockets, arrays, deques, regular expression pattern objects, and code objects.

*Changed in version 3.2:* Added support for thread.lock, threading.Lock, and code objects.

Several built-in types such as **list** and **dict** do not directly support weak references but can add support through subclassing:
```python
class Dict(dict):
    pass

obj = Dict(red=1, green=2, blue=3)  # this object is weak referenceable
```

Other built-in types such as `tuple` and `int` do not support weak references even when subclassed (This is an implementation detail and may be different across various Python implementations.).

Extension types can easily be made to support weak references; see `Weak Reference Support`.

```python
class weakref.ref(object[, callback])
```

Return a weak reference to `object`. The original object can be retrieved by calling the reference object if the referent is still alive; if the referent is no longer alive, calling the reference object will cause `None` to be returned. If `callback` is provided and not `None`, and the returned weakref object is still alive, the callback will be called when the object is about to be finalized; the weak reference object will be passed as the only parameter to the callback; the referent will no longer be available.

It is allowable for many weak references to be constructed for the same object. Callbacks registered for each weak reference will be called from the most recently registered callback to the oldest registered callback.

Exceptions raised by the callback will be noted on the standard error output, but cannot be propagated; they are handled in exactly the same way as exceptions raised from an object's `__del__()` method.
Weak references are hashable if the object is hashable. They will maintain their hash value even after the object was deleted. If hash() is called the first time only after the object was deleted, the call will raise TypeError.

Weak references support tests for equality, but not ordering. If the referents are still alive, two references have the same equality relationship as their referents (regardless of the callback). If either referent has been deleted, the references are equal only if the reference objects are the same object.

This is a subclassable type rather than a factory function.

__callback__

This read-only attribute returns the callback currently associated to the weakref. If there is no callback or if the referent of the weakref is no longer alive then this attribute will have value None.

Changed in version 3.4: Added the __callback__ attribute.

weakref.proxy(object[, callback])

Return a proxy to object which uses a weak reference. This supports use of the proxy in most contexts instead of requiring the explicit dereferencing used with weak reference objects. The returned object will have a type of either ProxyType or CallableProxyType, depending on whether object is callable. Proxy objects are not hashable regardless of the referent; this avoids a number of problems related to their fundamentally mutable nature, and prevent their use as dictionary keys. callback is the same as the parameter of the same name to the ref() function.
weakref.getweakrefcount(object)

Return the number of weak references and proxies which refer to object.

weakref.getweakrefs(object)

Return a list of all weak reference and proxy objects which refer to object.

class weakref.WeakKeyDictionary([dict])

Mapping class that references keys weakly. Entries in the dictionary will be discarded when there is no longer a strong reference to the key. This can be used to associate additional data with an object owned by other parts of an application without adding attributes to those objects. This can be especially useful with objects that override attribute accesses.

Note: Caution: Because a WeakKeyDictionary is built on top of a Python dictionary, it must not change size when iterating over it. This can be difficult to ensure for a WeakKeyDictionary because actions performed by the program during iteration may cause items in the dictionary to vanish “by magic” (as a side effect of garbage collection).

WeakKeyDictionary objects have the following additional methods. These expose the internal references directly. The references are not guaranteed to be “live” at the time they are used, so the result of calling the references needs to be checked before being used. This can be used to avoid creating references that will cause the garbage collector to keep the keys around longer than needed.

weakref.WeakKeyDictionary.keyrefs()

Return an iterable of the weak references to the keys.
**class weakref.WeakValueDictionary([dict])**

Mapping class that references values weakly. Entries in the dictionary will be discarded when no strong reference to the value exists any more.

**Note:** Caution: Because a **WeakValueDictionary** is built on top of a Python dictionary, it must not change size when iterating over it. This can be difficult to ensure for a **WeakValueDictionary** because actions performed by the program during iteration may cause items in the dictionary to vanish “by magic” (as a side effect of garbage collection).

**WeakValueDictionary** objects have the following additional methods. These method have the same issues as the and **keyrefs()** method of **WeakKeyDictionary** objects.

**WeakValueDictionary.valuerefs()**

Return an iterable of the weak references to the values.

**class weakref.WeakSet([elements])**

Set class that keeps weak references to its elements. An element will be discarded when no strong reference to it exists any more.

**class weakref.WeakMethod(method)**

A custom **ref** subclass which simulates a weak reference to a bound method (i.e., a method defined on a class and looked up on an instance). Since a bound method is ephemeral, a standard weak reference cannot keep hold of it. **WeakMethod** has special code to recreate the bound method until either the object or the original function dies:
>> class C:
    ...    def method(self):
    ...        print("method called!")
    ...
>>> c = C()
>>> r = weakref.ref(c.method)
>>> r()
>>> r = weakref.WeakMethod(c.method)
>>> r()
<bound method C.method of <__main__.C object at 0x7fc859830220>>
>>> r()()
method called!
>>> del c
>>> gc.collect()
0
>>> r()

New in version 3.4.

class weakref.**finalize**(obj, func, *args, **kwargs)

Return a callable finalizer object which will be called when obj is
garbage collected. Unlike an ordinary weak reference, a finalizer
will always survive until the reference object is collected, greatly
simplifying lifecycle management.

A finalizer is considered alive until it is called (either explicitly or at
garbage collection), and after that it is dead. Calling a live finalizer
returns the result of evaluating func(*arg, **kwargs), whereas calling a dead finalizer returns None.

Exceptions raised by finalizer callbacks during garbage collection
will be shown on the standard error output, but cannot be propagated. They are handled in the same way as exceptions
raised from an object's \_\_del\_\_ () method or a weak reference's callback.

When the program exits, each remaining live finalizer is called unless its \_atexit\_ attribute has been set to false. They are called in reverse order of creation.

A finalizer will never invoke its callback during the later part of the interpreter shutdown when module globals are liable to have been replaced by \_\_\_None\_\_\_.

\_\_call\_\_ ()
If \_self\_ is alive then mark it as dead and return the result of calling \_\_func\_\_ (*\_\_args\_, **\_\_kwargs\_)\. If \_self\_ is dead then return \_\_None\_\_.

\_detach\_()
If \_self\_ is alive then mark it as dead and return the tuple (\_\_obj\_, \_\_func\_, \_\_args\_, \_\_kwargs\_)\. If \_self\_ is dead then return \_\_None\_\_.

\_peek\_()
If \_self\_ is alive then return the tuple (\_\_obj\_, \_\_func\_, \_\_args\_, \_\_kwargs\_)\. If \_self\_ is dead then return \_\_None\_\_.

\_alive\_
Property which is true if the finalizer is alive, false otherwise.

\_atexit\_
A writable boolean property which by default is true. When the program exits, it calls all remaining live finalizers for which \_atexit\_ is true. They are called in reverse order of creation.
Note: It is important to ensure that `func`, `args` and `kwargs` do not own any references to `obj`, either directly or indirectly, since otherwise `obj` will never be garbage collected. In particular, `func` should not be a bound method of `obj`.

*New in version 3.4.*

`weakref.ReferenceType`

The type object for weak references objects.

`weakref.ProxyType`

The type object for proxies of objects which are not callable.

`weakref_callableproxytype`

The type object for proxies of callable objects.

`weakref.ProxyTypes`

Sequence containing all the type objects for proxies. This can make it simpler to test if an object is a proxy without being dependent on naming both proxy types.

`exception weakref.ReferenceError`

Exception raised when a proxy object is used but the underlying object has been collected. This is the same as the standard `ReferenceError` exception.

**See also:**

**PEP 0205 - Weak References**

The proposal and rationale for this feature, including links to earlier implementations and information about similar features in other languages.
8.8.1. Weak Reference Objects

Weak reference objects have no methods and no attributes besides `ref.__callback__`. A weak reference object allows the referent to be obtained, if it still exists, by calling it:

```python
>>> import weakref
>>> class Object:
...     pass
...>>> o = Object()
>>> r = weakref.ref(o)
>>> o2 = r()
>>> o is o2
True
```

If the referent no longer exists, calling the reference object returns `None`:

```python
>>> del o, o2
>>> print(r())
None
```

Testing that a weak reference object is still live should be done using the expression `ref() is not None`. Normally, application code that needs to use a reference object should follow this pattern:

```python
# r is a weak reference object
o = r()
if o is None:
    # referent has been garbage collected
    print("Object has been deallocated; can't frobniate.
else:
    print("Object is still live!")
```
Using a separate test for “liveness” creates race conditions in threaded applications; another thread can cause a weak reference to become invalidated before the weak reference is called; the idiom shown above is safe in threaded applications as well as single-threaded applications.

Specialized versions of `ref` objects can be created through subclassing. This is used in the implementation of the `WeakValueDictionary` to reduce the memory overhead for each entry in the mapping. This may be most useful to associate additional information with a reference, but could also be used to insert additional processing on calls to retrieve the referent.

This example shows how a subclass of `ref` can be used to store additional information about an object and affect the value that’s returned when the referent is accessed:

```python
import weakref

class ExtendedRef(weakref.ref):
    def __init__(self, ob, callback=None, **annotations):
        super(ExtendedRef, self).__init__(ob, callback)
        self.__counter = 0
        for k, v in annotations.items():
            setattr(self, k, v)

    def __call__(self):
        """Return a pair containing the referent and the number of times the reference has been called."
        ob = super(ExtendedRef, self).__call__()
        if ob is not None:
```
self.__counter += 1
ob = (ob, self.__counter)

return ob
8.8.2. Example

This simple example shows how an application can use objects IDs to retrieve objects that it has seen before. The IDs of the objects can then be used in other data structures without forcing the objects to remain alive, but the objects can still be retrieved by ID if they do.

```python
import weakref

_id2obj_dict = weakref.WeakValueDictionary()

def remember(obj):
    oid = id(obj)
    _id2obj_dict[oid] = obj
    return oid

def id2obj(oid):
    return _id2obj_dict[oid]
```
8.8.3. Finalizer Objects

The main benefit of using `finalize` is that it makes it simple to register a callback without needing to preserve the returned finalizer object. For instance

```python
>>> import weakref
>>> class Object:
    ...
    pass
...
>>> kenny = Object()
>>> weakref.finalize(kenny, print, "You killed Kenny"
<finalizer object at ...; for 'Object' at ...>
>>> del kenny
You killed Kenny!
```

The finalizer can be called directly as well. However the finalizer will invoke the callback at most once.

```python
>>> def callback(x, y, z):
    ...
    print("CALLBACK")
    ...
    return x + y + z
...
>>> obj = Object()
>>> f = weakref.finalize(obj, callback, 1, 2, z=3)
>>> assert f.alive
>>> assert f() == 6
CALLBACK
>>> assert not f.alive
>>> f() # callback not called because finalizer dead
>>> del obj # callback not called because finalizer dead
```

You can unregister a finalizer using its `detach()` method. This kills
the finalizer and returns the arguments passed to the constructor when it was created.

```python
>>> obj = Object()
>>> f = weakref.finalize(obj, callback, 1, 2, z=3)
>>> f.detach()
(<__main__.Object object ...>, <function callback ...>,
 >>> newobj, func, args, kwargs = _
 >>> assert not f.alive
 >>> assert newobj is obj
 >>> assert func(*args, **kwargs) == 6
```

CALLBACK

Unless you set the `atexit` attribute to `False`, a finalizer will be called when the program exits if it is still alive. For instance

```python
>>> obj = Object()
>>> weakref.finalize(obj, print, "obj dead or exiting",
<finalize object at ...; for 'Object' at ...>
>>> exit()
obj dead or exiting
```
8.8.4. Comparing finalizers with \texttt{\_\_del\_\_()} methods

Suppose we want to create a class whose instances represent temporary directories. The directories should be deleted with their contents when the first of the following events occurs:

- the object is garbage collected,
- the object's \texttt{remove()} method is called, or
- the program exits.

We might try to implement the class using a \texttt{\_\_del\_\_()} method as follows:

```python
class TempDir:
    def \_\_init\_\_(self):
        self.name = tempfile.mkdtemp()

    def remove(self):
        if self.name \texttt{is not None}:
            shutil.rmtree(self.name)
        self.name = \texttt{None}

    @property
    def removed(self):
        return self.name \texttt{is None}

    def \_\_del\_\_(self):
        self.remove()
```

Starting with Python 3.4, \texttt{\_\_del\_\_()} methods no longer prevent reference cycles from being garbage collected, and module globals are no longer forced to \texttt{None} during interpreter shutdown. So this code
should work without any issues on CPython.

However, handling of `__del__()` methods is notoriously implementation specific, since it depends on internal details of the interpreter's garbage collector implementation.

A more robust alternative can be to define a finalizer which only references the specific functions and objects that it needs, rather than having access to the full state of the object:

```python
class TempDir:
    def __init__(self):
        self.name = tempfile.mkdtemp()
        self._finalizer = weakref.finalize(self, shutil.rmtree(self.name))

    def remove(self):
        self._finalizer()  # Remove the temporary directory

@property
def removed(self):
    return not self._finalizer.alive
```

Defined like this, our finalizer only receives a reference to the details it needs to clean up the directory appropriately. If the object never gets garbage collected the finalizer will still be called at exit.

The other advantage of weakref based finalizers is that they can be used to register finalizers for classes where the definition is controlled by a third party, such as running code when a module is unloaded:

```python
import weakref, sys
def unloading_module():
    # implicit reference to the module globals from
    weakref.finalize(sys.modules[__name__], unloading_module)
```
**Note:** If you create a finalizer object in a daemonic thread just as the program exits then there is the possibility that the finalizer does not get called at exit. However, in a daemonic thread
\[\texttt{atexit.register()}, \texttt{try: ... finally: ... and with: ... do not guarantee that cleanup occurs either.}\]
8.9. **types** — Dynamic type creation and names for built-in types

**Source code: Lib/types.py**

This module defines utility function to assist in dynamic creation of new types.

It also defines names for some object types that are used by the standard Python interpreter, but not exposed as builtins like `int` or `str` are.

Finally, it provides some additional type-related utility classes and functions that are not fundamental enough to be builtins.
8.9.1. Dynamic Type Creation

types.new_class(name, bases=(), kwds=None, exec_body=None)

Creates a class object dynamically using the appropriate metaclass.

The first three arguments are the components that make up a class definition header: the class name, the base classes (in order), the keyword arguments (such as metaclass).

The exec_body argument is a callback that is used to populate the freshly created class namespace. It should accept the class namespace as its sole argument and update the namespace directly with the class contents. If no callback is provided, it has the same effect as passing in lambda ns: ns.

New in version 3.3.


types.prepare_class(name, bases=(), kwds=None)

Calculates the appropriate metaclass and creates the class namespace.

The arguments are the components that make up a class definition header: the class name, the base classes (in order) and the keyword arguments (such as metaclass).

The return value is a 3-tuple: metaclass, namespace, kwds

metaclass is the appropriate metaclass, namespace is the prepared class namespace and kwds is an updated copy of the passed in kwds argument with any 'metaclass' entry removed.
If no `kwds` argument is passed in, this will be an empty dict.

*New in version 3.3.*

**See also:**

- Customizing class creation
  Full details of the class creation process supported by these functions
- PEP 3115 - Metaclasses in Python 3000
  Introduced the `__prepare__` namespace hook
8.9.2. Standard Interpreter Types

This module provides names for many of the types that are required to implement a Python interpreter. It deliberately avoids including some of the types that arise only incidentally during processing such as the listiterator type.

Typical use of these names is for `isinstance()` or `issubclass()` checks.

Standard names are defined for the following types:

- **types.FunctionType**
  The type of user-defined functions and functions created by `lambda` expressions.

- **types.LambdaType**
  The type of `generator`-iterator objects, created by generator functions.

- **types.GeneratorType**
  The type of `generator` objects, created by `async def` functions.

  New in version 3.5.

- **types.CodeType**
  The type for code objects such as returned by `compile()`.

- **types.MethodType**
  The type of methods of user-defined class instances.

- **types.BuiltinFunctionType**
types. `BuiltInMethodType`
The type of built-in functions like `len()` or `sys.exit()`, and methods of built-in classes. (Here, the term “built-in” means “written in C”.)

class types. `ModuleType`(
    name, doc=None)
The type of modules. Constructor takes the name of the module to be created and optionally its docstring.

**Note:** Use `importlib.util.module_from_spec()` to create a new module if you wish to set the various import-controlled attributes.

`__doc__`
The docstring of the module. Defaults to None.

`__loader__`
The loader which loaded the module. Defaults to None.

*Changed in version 3.4:* Defaults to None. Previously the attribute was optional.

`__name__`
The name of the module.

`__package__`
Which package a module belongs to. If the module is top-level (i.e. not a part of any specific package) then the attribute should be set to '', else it should be set to the name of the package (which can be `__name__` if the module is a package itself). Defaults to None.

*Changed in version 3.4:* Defaults to None. Previously the
attribute was optional.

types.TracebackType

The type of traceback objects such as found in sys.exc_info()[2].

types.FrameType

The type of frame objects such as found in tb.tb_frame if tb is a traceback object.

types.GetSetDescriptorType

The type of objects defined in extension modules with PyGetSetDef, such as FrameType.f_locals or array.array.typecode. This type is used as descriptor for object attributes; it has the same purpose as the property type, but for classes defined in extension modules.

types.MemberDescriptorType

The type of objects defined in extension modules with PyMemberDef, such as datetime.timedelta.days. This type is used as descriptor for simple C data members which use standard conversion functions; it has the same purpose as the property type, but for classes defined in extension modules.

**CPython implementation detail:** In other implementations of Python, this type may be identical to GetSetDescriptorType.

class types.MappingProxyType(mapping)

Read-only proxy of a mapping. It provides a dynamic view on the mapping’s entries, which means that when the mapping changes, the view reflects these changes.

*New in version 3.3.*
**key in proxy**
Return True if the underlying mapping has a key key, else False.

**proxy[key]**
Return the item of the underlying mapping with key key. Raises a KeyError if key is not in the underlying mapping.

**iter(proxy)**
Return an iterator over the keys of the underlying mapping. This is a shortcut for iter(proxy.keys()).

**len(proxy)**
Return the number of items in the underlying mapping.

**copy()**
Return a shallow copy of the underlying mapping.

**get(key[, default])**
Return the value for key if key is in the underlying mapping, else default. If default is not given, it defaults to None, so that this method never raises a KeyError.

**items()**
Return a new view of the underlying mapping's items ((key, value) pairs).

**keys()**
Return a new view of the underlying mapping's keys.

**values()**
Return a new view of the underlying mapping's values.
8.9.3. Additional Utility Classes and Functions

class types.SimpleNamespace

A simple object subclass that provides attribute access to its namespace, as well as a meaningful repr.

Unlike object, with SimpleNamespace you can add and remove attributes. If a SimpleNamespace object is initialized with keyword arguments, those are directly added to the underlying namespace.

The type is roughly equivalent to the following code:

class SimpleNamespace:
    def __init__(self, **kwargs):
        self.__dict__.update(kwargs)
    def __repr__(self):
        keys = sorted(self.__dict__)
        items = ("{}={!r}".format(k, self.__dict__
        return "{}({})".format(type(self).__name_
    def __eq__(self, other):
        return self.__dict__ == other.__dict__

SimpleNamespace may be useful as a replacement for class NS: pass. However, for a structured record type use namedtuple() instead.

New in version 3.3.

types.DynamicClassAttribute(fget=None, fset=None, fdel=None, doc=None)

Route attribute access on a class to __getattr__.
This is a descriptor, used to define attributes that act differently when accessed through an instance and through a class. Instance access remains normal, but access to an attribute through a class will be routed to the class’s `__getattr__` method; this is done by raising `AttributeError`.

This allows one to have properties active on an instance, and have virtual attributes on the class with the same name (see `Enum` for an example).

*New in version 3.4.*
8.9.4. Coroutine Utility Functions

`types.coroutine(gen_func)`

This function transforms a generator function into a coroutine function which returns a generator-based coroutine. The generator-based coroutine is still a generator iterator, but is also considered to be a coroutine object and is awaitable. However, it may not necessarily implement the `__await__() `method.

If `gen_func` is a generator function, it will be modified in-place.

If `gen_func` is not a generator function, it will be wrapped. If it returns an instance of `collections.abc.Generator`, the instance will be wrapped in an awaitable proxy object. All other types of objects will be returned as is.

*New in version 3.5.*
8.10. **copy** — Shallow and deep copy operations

Assignment statements in Python do not copy objects, they create bindings between a target and an object. For collections that are mutable or contain mutable items, a copy is sometimes needed so one can change one copy without changing the other. This module provides generic shallow and deep copy operations (explained below).

Interface summary:

- `copy.copy(x)`
  Return a shallow copy of `x`.

- `copy.deepcopy(x)`
  Return a deep copy of `x`.

- `exception copy.error`
  Raised for module specific errors.

The difference between shallow and deep copying is only relevant for compound objects (objects that contain other objects, like lists or class instances):

- A **shallow copy** constructs a new compound object and then (to the extent possible) inserts *references* into it to the objects found in the original.
- A **deep copy** constructs a new compound object and then, recursively, inserts *copies* into it of the objects found in the original.

Two problems often exist with deep copy operations that don’t exist
with shallow copy operations:

- Recursive objects (compound objects that, directly or indirectly, contain a reference to themselves) may cause a recursive loop.
- Because deep copy copies *everything* it may copy too much, e.g., administrative data structures that should be shared even between copies.

The `deepcopy()` function avoids these problems by:

- keeping a “memo” dictionary of objects already copied during the current copying pass; and
- letting user-defined classes override the copying operation or the set of components copied.

This module does not copy types like module, method, stack trace, stack frame, file, socket, window, array, or any similar types. It does “copy” functions and classes (shallow and deeply), by returning the original object unchanged; this is compatible with the way these are treated by the `pickle` module.

Shallow copies of dictionaries can be made using `dict.copy()`, and of lists by assigning a slice of the entire list, for example, `copied_list = original_list[:]`.

Classes can use the same interfaces to control copying that they use to control pickling. See the description of module `pickle` for information on these methods. In fact, the `copy` module uses the registered pickle functions from the `copyreg` module.

In order for a class to define its own copy implementation, it can define special methods `__copy__()` and `__deepcopy__()`. The former is called to implement the shallow copy operation; no additional arguments are passed. The latter is called to implement the deep copy
operation; it is passed one argument, the memo dictionary. If the
__deepcopy__() implementation needs to make a deep copy of a
component, it should call the deepcopy() function with the
component as first argument and the memo dictionary as second
argument.

See also:

Module pickle
Discussion of the special methods used to support object state
retrieval and restoration.
8.11. `pprint` — Data pretty printer

Source code: `Lib/pprint.py`

The `pprint` module provides a capability to “pretty-print” arbitrary Python data structures in a form which can be used as input to the interpreter. If the formatted structures include objects which are not fundamental Python types, the representation may not be loadable. This may be the case if objects such as files, sockets or classes are included, as well as many other objects which are not representable as Python literals.

The formatted representation keeps objects on a single line if it can, and breaks them onto multiple lines if they don’t fit within the allowed width. Construct `PrettyPrinter` objects explicitly if you need to adjust the width constraint.

Dictionaries are sorted by key before the display is computed.

The `pprint` module defines one class:

```python
class pprint.PrettyPrinter(indent=1, width=80, depth=None, stream=None, *, compact=False)
```

Construct a `PrettyPrinter` instance. This constructor understands several keyword parameters. An output stream may be set using the `stream` keyword; the only method used on the stream object is the file protocol’s `write()` method. If not specified, the `PrettyPrinter` adopts `sys.stdout`. The amount of indentation added for each recursive level is specified by `indent`; the default is one. Other values can cause output to look a little
odd, but can make nesting easier to spot. The number of levels which may be printed is controlled by `depth`; if the data structure being printed is too deep, the next contained level is replaced by .... By default, there is no constraint on the depth of the objects being formatted. The desired output width is constrained using the `width` parameter; the default is 80 characters. If a structure cannot be formatted within the constrained width, a best effort will be made. If `compact` is false (the default) each item of a long sequence will be formatted on a separate line. If `compact` is true, as many items as will fit within the `width` will be formatted on each output line.

*Changed in version 3.4:* Added the `compact` parameter.

```python
>>> import pprint
>>> stuff = ['spam', 'eggs', 'lumberjack', 'knights', 'ni']
>>> stuff.insert(0, stuff[:])
>>> pp = pprint.PrettyPrinter(indent=4)
>>> pp.pprint(stuff)
['spam', 'eggs', 'lumberjack', 'knights', 'ni']
>>> pp = pprint.PrettyPrinter(width=41, compact=True)
>>> pp.pprint(stuff)
['spam', 'eggs', 'lumberjack', 'knights', 'ni']
>>> tup = ('spam', ('eggs', ('lumberjack', ('knights', ('ni'))))),
... ('parrot', ('fresh fruit',))))))
>>> pp = pprint.PrettyPrinter(depth=6)
>>> pp.pprint(tup)
```
The **pprint** module also provides several shortcut functions:

```python
pprint.pformat(object, indent=1, width=80, depth=None, *, compact=False)
```

Return the formatted representation of `object` as a string. `indent`, `width`, `depth` and `compact` will be passed to the `PrettyPrinter` constructor as formatting parameters.

*Changed in version 3.4:* Added the `compact` parameter.

```python
pprint.pprint(object, stream=None, indent=1, width=80, depth=None, *, compact=False)
```

Prints the formatted representation of `object` on `stream`, followed by a newline. If `stream` is None, `sys.stdout` is used. This may be used in the interactive interpreter instead of the `print()` function for inspecting values (you can even reassign `print = pprint.pprint` for use within a scope). `indent`, `width`, `depth` and `compact` will be passed to the `PrettyPrinter` constructor as formatting parameters.

*Changed in version 3.4:* Added the `compact` parameter.

```python
>>> import pprint
>>> stuff = ['spam', 'eggs', 'lumberjack', 'knights', 'ni
<Recursion on list with id=...>,
'spam',
'eggs',
'lumberjack',
'knights',
```
pprint.isreadable(object)
Determine if the formatted representation of object is “readable,” or can be used to reconstruct the value using eval(). This always returns False for recursive objects.

```python
>>> pprint.isreadable(stuff)
False
```

pprint.isrecursive(object)
Determine if object requires a recursive representation.

One more support function is also defined:

pprint.saferepr(object)
Return a string representation of object, protected against recursive data structures. If the representation of object exposes a recursive entry, the recursive reference will be represented as <Recursion on typename with id=number>. The representation is not otherwise formatted.

```python
>>> pprint.saferepr(stuff)
"[<Recursion on list with id=...>, 'spam', 'eggs', 'ni']"
```
8.11.1. PrettyPrinter Objects

PrettyPrinter instances have the following methods:

PrettyPrinter.\texttt{pformat}(object)

Return the formatted representation of \textit{object}. This takes into account the options passed to the \texttt{PrettyPrinter} constructor.

PrettyPrinter.\texttt{pprint}(object)

Print the formatted representation of \textit{object} on the configured stream, followed by a newline.

The following methods provide the implementations for the corresponding functions of the same names. Using these methods on an instance is slightly more efficient since new PrettyPrinter objects don’t need to be created.

PrettyPrinter.\texttt{isreadable}(object)

Determine if the formatted representation of the object is “readable,” or can be used to reconstruct the value using \texttt{eval()}. Note that this returns False for recursive objects. If the \textit{depth} parameter of the \texttt{PrettyPrinter} is set and the object is deeper than allowed, this returns False.

PrettyPrinter.\texttt{isrecursive}(object)

Determine if the object requires a recursive representation.

This method is provided as a hook to allow subclasses to modify the way objects are converted to strings. The default implementation uses the internals of the \texttt{saferepr()} implementation.

PrettyPrinter.\texttt{format}(object, context, maxlevels, level)
Returns three values: the formatted version of object as a string, a flag indicating whether the result is readable, and a flag indicating whether recursion was detected. The first argument is the object to be presented. The second is a dictionary which contains the id() of objects that are part of the current presentation context (direct and indirect containers for object that are affecting the presentation) as the keys; if an object needs to be presented which is already represented in context, the third return value should be True. Recursive calls to the format() method should add additional entries for containers to this dictionary. The third argument, maxlevels, gives the requested limit to recursion; this will be 0 if there is no requested limit. This argument should be passed unmodified to recursive calls. The fourth argument, level, gives the current level; recursive calls should be passed a value less than that of the current call.
8.11.2. Example

To demonstrate several uses of the `pprint()` function and its parameters, let’s fetch information about a project from PyPI:

```python
>>> import json
>>> import pprint
>>> from urllib.request import urlopen
>>> with urlopen('http://pypi.python.org/pypi/Twisted/json') as url:
    http_info = url.info()
    raw_data = url.read().decode(http_info.get_content_charset())
>>> project_info = json.loads(raw_data)
```

In its basic form, `pprint()` shows the whole object:

```python
>>> pprint.pprint(project_info)
{'info': {'_pypi_hidden': False,
           '_pypi_ordering': 125,
           'author': 'Glyph Lefkowitz',
           'author_email': 'glyph@twistedmatrix.com',
           'bugtrack_url': '',
           'cheesecake_code_kwalitee_id': None,
           'cheesecake_documentation_id': None,
           'cheesecake_installability_id': None,
           'classifiers': ['Programming Language :: Python :: 2.6',
                           'Programming Language :: Python :: 2.7',
                           'Programming Language :: Python :: 2 :: Only'],
           'description': 'An extensible framework for event-based network programming with special focus on protocol integration.',
           'docs_url': '',
           'download_url': 'UNKNOWN',
           'home_page': 'http://twistedmatrix.com/'},
```
The result can be limited to a certain depth (ellipsis is used for deeper contents):
Additionally, maximum character width can be suggested. If a long object cannot be split, the specified width will be exceeded:

```python
>>> pprint.pprint(project_info, depth=2, width=50)
{'info': {'_pypi_hidden': False,
         '_pypi_ordering': 125,
         'author': 'Glyph Lefkowitz',
         'author_email': 'glyph@twistedmatrix.com',
         'bugtrack_url': '',
         'cheesecake_code_kwalitee_id': None,
         'cheesecake_documentation_id': None,
         'cheesecake_installability_id': None,
         'classifiers': [...],
         'description': 'An extensible framework for
                        special focus
                        on event-based network pro
                        'integration.',
         'docs_url': '',
         'download_url': 'UNKNOWN',
         'home_page': 'http://twistedmatrix.com/',
         'keywords': '',
         'license': 'MIT',
         'maintainer': '',
         'maintainer_email': '',
         'name': 'Twisted',
         'package_url': 'http://pypi.python.org/pypi/Twisted',
         'platform': 'UNKNOWN',
         'release_url': 'http://pypi.python.org/pypi/Twisted',
         'requires_python': None,
         'stable_version': None,
         'summary': 'An asynchronous networking fr
         'version': '12.3.0',
         'urls': [{...}, {...}]}
```
8.12. reprlib — Alternate repr() implementation

Source code: Lib/reprlib.py

The reprlib module provides a means for producing object representations with limits on the size of the resulting strings. This is used in the Python debugger and may be useful in other contexts as well.

This module provides a class, an instance, and a function:

class reprlib.Repr

Class which provides formatting services useful in implementing functions similar to the built-in repr(); size limits for different object types are added to avoid the generation of representations which are excessively long.

reprlib.aRepr

This is an instance of Repr which is used to provide the repr() function described below. Changing the attributes of this object will affect the size limits used by repr() and the Python debugger.

reprlib.repr(obj)

This is the repr() method of aRepr. It returns a string similar to that returned by the built-in function of the same name, but with limits on most sizes.

In addition to size-limiting tools, the module also provides a decorator for detecting recursive calls to __repr__() and substituting a
placeholer string instead.

@reprlib.recursive_repr(fillvalue="...")

Decorator for __repr__() methods to detect recursive calls within the same thread. If a recursive call is made, the fillvalue is returned, otherwise, the usual __repr__() call is made. For example:

```python
>>> class MyList(list):
...     @recursive_repr()
...     def __repr__(self):
...         return '<' + '|'.join(map(repr, self))
...

>>> m = MyList('abc')
>>> m.append(m)
>>> m.append('x')
>>> print(m)
<a'|'b'|'c'|...'|'x'>
```

New in version 3.2.
8.12.1. Repr Objects

Repr instances provide several attributes which can be used to provide size limits for the representations of different object types, and methods which format specific object types.

Repr.\texttt{maxlevel}

Depth limit on the creation of recursive representations. The default is 6.

Repr.\texttt{maxdict}
Repr.\texttt{maxlist}
Repr.\texttt{maxtuple}
Repr.\texttt{maxset}
Repr.\texttt{maxfrozenset}
Repr.\texttt{maxdeque}
Repr.\texttt{maxarray}

Limits on the number of entries represented for the named object type. The default is 4 for \texttt{maxdict}, 5 for \texttt{maxarray}, and 6 for the others.

Repr.\texttt{maxlong}

Maximum number of characters in the representation for an integer. Digits are dropped from the middle. The default is 40.

Repr.\texttt{maxstring}

Limit on the number of characters in the representation of the string. Note that the “normal” representation of the string is used as the character source: if escape sequences are needed in the representation, these may be mangled when the representation is shortened. The default is 30.
Repr.\texttt{maxother}

This limit is used to control the size of object types for which no specific formatting method is available on the \texttt{Repr} object. It is applied in a similar manner as \texttt{maxstring}. The default is 20.

Repr.\texttt{repr}(\texttt{obj})

The equivalent to the built-in \texttt{repr()} that uses the formatting imposed by the instance.

Repr.\texttt{repr1}(\texttt{obj, level})

Recursive implementation used by \texttt{repr()}. This uses the type of \texttt{obj} to determine which formatting method to call, passing it \texttt{obj} and \texttt{level}. The type-specific methods should call \texttt{repr1()} to perform recursive formatting, with \texttt{level - 1} for the value of \texttt{level} in the recursive call.

Repr.\texttt{repr\_TYPE}(\texttt{obj, level})

Formatting methods for specific types are implemented as methods with a name based on the type name. In the method name, \texttt{TYPE} is replaced by `'._'.join(type(obj).__name__.split())`. Dispatch to these methods is handled by \texttt{repr1()}. Type-specific methods which need to recursively format a value should call \texttt{self.repr1(subobj, level - 1)}. 
8.12.2. Subclassing Repr Objects

The use of dynamic dispatching by `Repr.repr1()` allows subclasses of `Repr` to add support for additional built-in object types or to modify the handling of types already supported. This example shows how special support for file objects could be added:

```python
import reprlib
import sys

class MyRepr(reprlib.Repr):
    def repr_TextIOWrapper(self, obj, level):
        if obj.name in {'<stdin>', '<stdout>', '<stderr'>:
            return obj.name
        return repr(obj)

aRepr = MyRepr()
print(aRepr.repr(sys.stdin))  # prints '<stdin>'
```

8.13. **enum** — Support for enumerations

*New in version 3.4.*

**Source code:** Lib/enum.py

An enumeration is a set of symbolic names (members) bound to unique, constant values. Within an enumeration, the members can be compared by identity, and the enumeration itself can be iterated over.
8.13.1. Module Contents

This module defines two enumeration classes that can be used to define unique sets of names and values: `Enum` and `IntEnum`. It also defines one decorator, `unique()`.

```python
class enum.Enum
    Base class for creating enumerated constants. See section Functional API for an alternate construction syntax.

class enum.IntEnum
    Base class for creating enumerated constants that are also subclasses of int.

decorator enum.unique()
    Enum class decorator that ensures only one name is bound to any one value.
```
8.13.2. Creating an Enum

Enumerations are created using the class syntax, which makes them easy to read and write. An alternative creation method is described in Functional API. To define an enumeration, subclass Enum as follows:

```python
>>> from enum import Enum
>>> class Color(Enum):
    ...    red = 1
    ...    green = 2
    ...    blue = 3
...
```

**Note:** Nomenclature

- The class Color is an enumeration (or enum)
- The attributes Color.red, Color.green, etc., are enumeration members (or enum members).
- The enum members have names and values (the name of Color.red is red, the value of Color.blue is 3, etc.)

**Note:** Even though we use the class syntax to create Enums, Enums are not normal Python classes. See How are Enums different? for more details.

Enumeration members have human readable string representations:

```python
>>> print(Color.red)
Color.red
```

...while their repr has more information:
>>> print(repr(Color.red))
<Color.red: 1>

The *type* of an enumeration member is the enumeration it belongs to:

>>> type(Color.red)
<enum 'Color'>
>>> isinstance(Color.green, Color)
True

Enum members also have a property that contains just their item name:

>>> print(Color.red.name)
red

Enumerations support iteration, in definition order:

```python
>>> class Shake(Enum):
...     vanilla = 7
...     chocolate = 4
...     cookies = 9
...     mint = 3
...
>>> for shake in Shake:
...     print(shake)
...
Shake.vanilla
Shake.chocolate
Shake.cookies
Shake.mint
```

Enumeration members are hashable, so they can be used in dictionaries and sets:
>>> apples = {}
>>> apples[Color.red] = 'red delicious'
>>> apples[Color.green] = 'granny smith'
>>> apples == {Color.red: 'red delicious', Color.green: 'granny smith'}
True
8.13.3. Programmatic access to enumeration members and their attributes

Sometimes it’s useful to access members in enumerations programmatically (i.e. situations where Color.red won’t do because the exact color is not known at program-writing time). Enum allows such access:

```python
>>> Color(1)
<Color.red: 1>
>>> Color(3)
<Color.blue: 3>
```

If you want to access enum members by *name*, use item access:

```python
>>> Color['red']
<Color.red: 1>
>>> Color['green']
<Color.green: 2>
```

If you have an enum member and need its name or value:

```python
>>> member = Color.red
>>> member.name
'red'
>>> member.value
1
```
8.13.4. Duplicating enum members and values

Having two enum members with the same name is invalid:

```python
>>> class Shape(Enum):
...    square = 2
...    square = 3
...
Traceback (most recent call last):
...
TypeError: Attempted to reuse key: 'square'
```

However, two enum members are allowed to have the same value. Given two members A and B with the same value (and A defined first), B is an alias to A. By-value lookup of the value of A and B will return A. By-name lookup of B will also return A:

```python
>>> class Shape(Enum):
...    square = 2
...    diamond = 1
...    circle = 3
...    alias_for_square = 2
...
>>> Shape.square
<Shape.square: 2>
>>> Shape.alias_for_square
<Shape.square: 2>
>>> Shape(2)
<Shape.square: 2>
```

**Note:** Attempting to create a member with the same name as an already defined attribute (another member, a method, etc.) or
attempting to create an attribute with the same name as a member is not allowed.
8.13.5. Ensuring unique enumeration values

By default, enumerations allow multiple names as aliases for the same value. When this behavior isn’t desired, the following decorator can be used to ensure each value is used only once in the enumeration:

@enum.unique

A class decorator specifically for enumerations. It searches an enumeration’s __members__ gathering any aliases it finds; if any are found ValueError is raised with the details:

```python
>>> from enum import Enum, unique
>>> @unique
... class Mistake(Enum):
...     one = 1
...     two = 2
...     three = 3
...     four = 3
...
Traceback (most recent call last):
...
ValueError: duplicate values found in <enum 'Mistake'>: four -> three
```
8.13.6. Iteration

Iterating over the members of an enum does not provide the aliases:

```python
>>> list(Shape)
[<Shape.square: 2>, <Shape.diamond: 1>, <Shape.circle: 3>]
```

The special attribute `__members__` is an ordered dictionary mapping names to members. It includes all names defined in the enumeration, including the aliases:

```python
>>> for name, member in Shape.__members__.items():
    ...     print(name, member)
    ...
('square', <Shape.square: 2>)
('diamond', <Shape.diamond: 1>)
('circle', <Shape.circle: 3>)
('alias_for_square', <Shape.square: 2>)
```

The `__members__` attribute can be used for detailed programmatic access to the enumeration members. For example, finding all the aliases:

```python
>>> [name for name, member in Shape.__members__.items() if name.startswith('alias')]
['alias_for_square']
```
8.13.7. Comparisons

Enumeration members are compared by identity:

```python
>>> Color.red is Color.red
True
>>> Color.red is Color.blue
False
>>> Color.red is not Color.blue
True
```

Ordered comparisons between enumeration values are not supported. Enum members are not integers (but see `IntEnum` below):

```python
>>> Color.red < Color.blue
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unorderable types: Color() < Color()
```

Equality comparisons are defined though:

```python
>>> Color.blue == Color.red
False
>>> Color.blue != Color.red
True
>>> Color.blue == Color.blue
True
```

Comparisons against non-enumeration values will always compare not equal (again, `IntEnum` was explicitly designed to behave differently, see below):

```python
>>> Color.blue == 2
False
```
8.13.8. Allowed members and attributes of enumerations

The examples above use integers for enumeration values. Using integers is short and handy (and provided by default by the Functional API), but not strictly enforced. In the vast majority of use-cases, one doesn’t care what the actual value of an enumeration is. But if the value is important, enumerations can have arbitrary values.

Enumerations are Python classes, and can have methods and special methods as usual. If we have this enumeration:

```python
>>> class Mood(Enum):
...     funky = 1
...     happy = 3
...
...     def describe(self):
...         # self is the member here
...         return self.name, self.value
...
...     def __str__(self):
...         return 'my custom str! {0}'.format(self).
...
...     @classmethod
...     def favorite_mood(cls):
...         # cls here is the enumeration
...         return cls.happy
...
```

Then:

```python
>>> Mood.favorite_mood()  
<Mood.happy: 3>
```
The rules for what is allowed are as follows: names that start and end with a with a single underscore are reserved by enum and cannot be used; all other attributes defined within an enumeration will become members of this enumeration, with the exception of special methods (`__str__(), __add__(), etc.) and descriptors (methods are also descriptors).

Note: if your enumeration defines `__new__() and/or `__init__()` then whatever value(s) were given to the enum member will be passed into those methods. See Planet for an example.
8.13.9. Restricted subclassing of enumerations

Subclassing an enumeration is allowed only if the enumeration does not define any members. So this is forbidden:

```python
>>> class MoreColor(Color):
...    pink = 17
...
Traceback (most recent call last):
... TypeError: Cannot extend enumerations
```

But this is allowed:

```python
>>> class Foo(Enum):
...    def some_behavior(self):
...        pass
...
>>> class Bar(Foo):
...    happy = 1
...    sad = 2
```

Allowing subclassing of enums that define members would lead to a violation of some important invariants of types and instances. On the other hand, it makes sense to allow sharing some common behavior between a group of enumerations. (See `OrderedEnum` for an example.)
8.13.10. Pickling

Enumerations can be pickled and unpickled:

```python
>>> from test.test_enum import Fruit
>>> from pickle import dumps, loads
>>> Fruit.tomato is loads(dumps(Fruit.tomato))
True
```

The usual restrictions for pickling apply: picklable enums must be defined in the top level of a module, since unpickling requires them to be importable from that module.

**Note:** With pickle protocol version 4 it is possible to easily pickle enums nested in other classes.

It is possible to modify how Enum members are pickled/unpickled by defining `__reduce_ex__(...)` in the enumeration class.
8.13.11. Functional API

The `Enum` class is callable, providing the following functional API:

```python
>>> Animal = Enum('Animal', 'ant bee cat dog')
>>> Animal
<enum 'Animal'>
>>> Animal.ant
<Animal.ant: 1>
>>> Animal.ant.value
1
>>> list(Animal)
```

The semantics of this API resemble `namedtuple`. The first argument of the call to `Enum` is the name of the enumeration.

The second argument is the source of enumeration member names. It can be a whitespace-separated string of names, a sequence of names, a sequence of 2-tuples with key/value pairs, or a mapping (e.g. dictionary) of names to values. The last two options enable assigning arbitrary values to enumerations; the others auto-assign increasing integers starting with 1 (use the `start` parameter to specify a different starting value). A new class derived from `Enum` is returned. In other words, the above assignment to `Animal` is equivalent to:

```python
>>> class Animal(Enum):
    ...    ant = 1
    ...    bee = 2
    ...    cat = 3
    ...    dog = 4
```
The reason for defaulting to 1 as the starting number and not 0 is that 0 is False in a boolean sense, but enum members all evaluate to True.

Pickling enums created with the functional API can be tricky as frame stack implementation details are used to try and figure out which module the enumeration is being created in (e.g. it will fail if you use a utility function in separate module, and also may not work on IronPython or Jython). The solution is to specify the module name explicitly as follows:

```python
>>> Animal = Enum('Animal', 'ant bee cat dog', module='...')
```

**Warning:** If module is not supplied, and Enum cannot determine what it is, the new Enum members will not be unpicklable; to keep errors closer to the source, pickling will be disabled.

The new pickle protocol 4 also, in some circumstances, relies on __qualname__ being set to the location where pickle will be able to find the class. For example, if the class was made available in class SomeData in the global scope:

```python
>>> Animal = Enum('Animal', 'ant bee cat dog', qualname='...')
```

The complete signature is:

```
Enum(value='NewEnumName', names=<...>, *, module='...')
```
What the new Enum class will record as its name.

**names:**

The Enum members. This can be a whitespace or comma separated string (values will start at 1 unless otherwise specified):

- `'red green blue'` |
- `'red,green,blue'` |
- `'red,green,blue'` |

or an iterator of names:

- `['red', 'green', 'blue']`

or an iterator of (name, value) pairs:

- `[('cyan', 4), ('magenta', 5), ('yellow', , ]`

or a mapping:

- `{'chartreuse': 7, 'sea_green': 11, 'rosemary'`

<table>
<thead>
<tr>
<th>module:</th>
<th>name of module where new Enum class can be found.</th>
</tr>
</thead>
<tbody>
<tr>
<td>qualname:</td>
<td>where in module new Enum class can be found.</td>
</tr>
<tr>
<td>type:</td>
<td>type to mix in to new Enum class.</td>
</tr>
<tr>
<td>start:</td>
<td>number to start counting at if only names are passed in.</td>
</tr>
</tbody>
</table>

*Changed in version 3.5:* The *start* parameter was added.
8.13.12. Derived Enumerations

8.13.12.1. IntEnum

A variation of `Enum` is provided which is also a subclass of `int`. Members of an `IntEnum` can be compared to integers; by extension, integer enumerations of different types can also be compared to each other:

```python
>>> from enum import IntEnum
>>> class Shape(IntEnum):
...     circle = 1
...     square = 2
... 
>>> class Request(IntEnum):
...     post = 1
...     get = 2
... 
>>> Shape == 1
False
>>> Shape.circle == 1
True
>>> Shape.circle == Request.post
True
```

However, they still can’t be compared to standard `Enum` enumerations:

```python
>>> class Shape(IntEnum):
...     circle = 1
...     square = 2
... 
>>> class Color(Enum):
...     red = 1
...     green = 2
```
... >>> Shape.circle == Color.red False

`IntEnum` values behave like integers in other ways you'd expect:

```python
>>> int(Shape.circle) 1
>>> ['a', 'b', 'c'][Shape.circle] 'b'
>>> [i for i in range(Shape.square)] [0, 1]
```

For the vast majority of code, `Enum` is strongly recommended, since `IntEnum` breaks some semantic promises of an enumeration (by being comparable to integers, and thus by transitivity to other unrelated enumerations). It should be used only in special cases where there's no other choice; for example, when integer constants are replaced with enumerations and backwards compatibility is required with code that still expects integers.

**8.13.12.2. Others**

While `IntEnum` is part of the `enum` module, it would be very simple to implement independently:

```python
class IntEnum(int, Enum):
    pass
```

This demonstrates how similar derived enumerations can be defined; for example a `StrEnum` that mixes in `str` instead of `int`.

Some rules:
1. When subclassing `Enum`, mix-in types must appear before `Enum` itself in the sequence of bases, as in the `IntEnum` example above.

2. While `Enum` can have members of any type, once you mix in an additional type, all the members must have values of that type, e.g. `int` above. This restriction does not apply to mix-ins which only add methods and don’t specify another data type such as `int` or `str`.

3. When another data type is mixed in, the value attribute is *not the same* as the enum member itself, although it is equivalent and will compare equal.

4. `%`-style formatting: `%s` and `%r` call `Enum`'s `__str__()` and `__repr__()` respectively; other codes (such as `%i` or `%h` for `IntEnum`) treat the enum member as its mixed-in type.

5. `str.__format__()` (or `format()`) will use the mixed-in type's `__format__()`. If the `Enum`'s `str()` or `repr()` is desired use the `!s` or `!r str` format codes.
8.13.13. Interesting examples

While Enum and IntEnum are expected to cover the majority of use-cases, they cannot cover them all. Here are recipes for some different types of enumerations that can be used directly, or as examples for creating one's own.

8.13.13.1. AutoNumber

Avoids having to specify the value for each enumeration member:

```python
>>> class AutoNumber(Enum):
...     def __new__(cls):
...         value = len(cls.__members__) + 1
...         obj = object.__new__(cls)
...         obj._value_ = value
...         return obj
...
>>> class Color(AutoNumber):
...     red = ()
...     green = ()
...     blue = ()
...
>>> Color.green.value == 2
True
```

Note: The __new__() method, if defined, is used during creation of the Enum members; it is then replaced by Enum’s __new__() which is used after class creation for lookup of existing members.

8.13.13.2. OrderedEnum
An ordered enumeration that is not based on `IntEnum` and so maintains the normal `Enum` invariants (such as not being comparable to other enumerations):

```python
>>> class OrderedEnum(Enum):
    ...     def __ge__(self, other):
    ...         if self.__class__ is other.__class__:
    ...             return self.value >= other.value
    ...     def __gt__(self, other):
    ...         if self.__class__ is other.__class__:
    ...             return self.value > other.value
    ...     def __le__(self, other):
    ...         if self.__class__ is other.__class__:
    ...             return self.value <= other.value
    ...     def __lt__(self, other):
    ...         if self.__class__ is other.__class__:
    ...             return self.value < other.value

>>> class Grade(OrderedEnum):
    ...     A = 5
    ...     B = 4
    ...     C = 3
    ...     D = 2
    ...     F = 1

>>> Grade.C < Grade.A
True
```

8.13.13.3. DuplicateFreeEnum

Raises an error if a duplicate member name is found instead of
creating an alias:

```python
>>> class DuplicateFreeEnum(Enum):
...    def __init__(self, *args):
...        cls = self.__class__
...        if any(self.value == e.value for e in cls):
...            a = self.name
...            e = cls(self.value).name
...            raise ValueError(
...                "aliases not allowed in DuplicateFreeEnum:		%r	-->	%r"
...                % (a, e))

>>> class Color(DuplicateFreeEnum):
...    red = 1
...    green = 2
...    blue = 3
...    grene = 2

Traceback (most recent call last):
...
ValueError: aliases not allowed in DuplicateFreeEnum:

Note: This is a useful example for subclassing Enum to add or change other behaviors as well as disallowing aliases. If the only desired change is disallowing aliases, the `unique()` decorator can be used instead.

8.13.13.4. Planet

If `__new__()` or `__init__()` is defined the value of the enum member will be passed to those methods:

```python
>>> class Planet(Enum):
...    MERCURY = (3.303e+23, 2.4397e6)
```
VENUS = (4.869e+24, 6.0518e6)
EARTH = (5.976e+24, 6.37814e6)
MARS = (6.421e+23, 3.3972e6)
JUPITER = (1.9e+27, 7.1492e7)
SATURN = (5.688e+26, 6.0268e7)
URANUS = (8.686e+25, 2.5559e7)
NEPTUNE = (1.024e+26, 2.4746e7)

```
def __init__(self, mass, radius):
    self.mass = mass  # in kilograms
    self.radius = radius  # in meters

@property
    def surface_gravity(self):
        # universal gravitational constant  (m^3 kg^{-1} s^{-2})
        G = 6.67300E-11
        return G * self.mass / (self.radius * self massa)}
```
8.13.14. How are Enums different?

Enums have a custom metaclass that affects many aspects of both derived Enum classes and their instances (members).


The EnumMeta metaclass is responsible for providing the \_\_contains\_\_(), \_\_dir\_\_(), \_\_iter\_\_() and other methods that allow one to do things with an Enum class that fail on a typical class, such as \texttt{list(Color)} or \texttt{some\_var in Color}. EnumMeta is responsible for ensuring that various other methods on the final Enum class are correct (such as \_\_new\_\_(), \_\_getnewargs\_\_(), \_\_str\_\_() and \_\_repr\_\_()).

8.13.14.2. Enum Members (aka instances)

The most interesting thing about Enum members is that they are singletons. EnumMeta creates them all while it is creating the Enum class itself, and then puts a custom \_\_new\_\_() in place to ensure that no new ones are ever instantiated by returning only the existing member instances.

8.13.14.3. Finer Points

Enum members are instances of an Enum class, and even though they are accessible as \texttt{EnumClass.member}, they should not be accessed directly from the member as that lookup may fail or, worse, return something besides the Enum member you looking for:
```python
>>> class FieldTypes(Enum):
...    name = 0
...    value = 1
...    size = 2

>>> FieldTypes.value.size
<FieldTypes.size: 2>
>>> FieldTypes.size.value
2
```

*Changed in version 3.5.*

The `__members__` attribute is only available on the class.

If you give your `Enum` subclass extra methods, like the `Planet` class above, those methods will show up in a `dir()` of the member, but not of the class:

```python
>>> dir(Planet)
['EARTH', 'JUPITER', 'MARS', 'MERCURY', 'NEPTUNE', ...

>>> dir(Planet.EARTH)
['__class__', '__doc__', '__module__', 'name', 'surface_gravity', ...
```

The `__new__()` method will only be used for the creation of the `Enum` members – after that it is replaced. Any custom `__new__()` method must create the object and set the `_value_` attribute appropriately.

If you wish to change how `Enum` members are looked up you should either write a helper function or a `classmethod()` for the `Enum` subclass.
9. Numeric and Mathematical Modules

The modules described in this chapter provide numeric and math-related functions and data types. The `numbers` module defines an abstract hierarchy of numeric types. The `math` and `cmath` modules contain various mathematical functions for floating-point and complex numbers. The `decimal` module supports exact representations of decimal numbers, using arbitrary precision arithmetic.

The following modules are documented in this chapter:

- **9.1. numbers — Numeric abstract base classes**
  - 9.1.1. The numeric tower
  - 9.1.2. Notes for type implementors
    - 9.1.2.1. Adding More Numeric ABCs
    - 9.1.2.2. Implementing the arithmetic operations

- **9.2. math — Mathematical functions**
  - 9.2.1. Number-theoretic and representation functions
  - 9.2.2. Power and logarithmic functions
  - 9.2.3. Trigonometric functions
  - 9.2.4. Angular conversion
  - 9.2.5. Hyperbolic functions
  - 9.2.6. Special functions
  - 9.2.7. Constants

- **9.3. cmath — Mathematical functions for complex numbers**
  - 9.3.1. Conversions to and from polar coordinates
  - 9.3.2. Power and logarithmic functions
  - 9.3.3. Trigonometric functions
  - 9.3.4. Hyperbolic functions
  - 9.3.5. Classification functions
9.3.6. Constants
9.4. decimal — Decimal fixed point and floating point arithmetic
  9.4.1. Quick-start Tutorial
  9.4.2. Decimal objects
    9.4.2.1. Logical operands
  9.4.3. Context objects
  9.4.4. Constants
  9.4.5. Rounding modes
  9.4.6. Signals
  9.4.7. Floating Point Notes
    9.4.7.1. Mitigating round-off error with increased precision
    9.4.7.2. Special values
  9.4.8. Working with threads
  9.4.9. Recipes
  9.4.10. Decimal FAQ
9.5. fractions — Rational numbers
9.6. random — Generate pseudo-random numbers
  9.6.1. Notes on Reproducibility
  9.6.2. Examples and Recipes
9.7. statistics — Mathematical statistics functions
  9.7.1. Averages and measures of central location
  9.7.2. Measures of spread
  9.7.3. Function details
  9.7.4. Exceptions
9.1. numbers — Numeric abstract base classes

The numbers module (PEP 3141) defines a hierarchy of numeric abstract base classes which progressively define more operations. None of the types defined in this module can be instantiated.

class numbers.Number

    The root of the numeric hierarchy. If you just want to check if an argument \( x \) is a number, without caring what kind, use \( \text{isinstance}(x, \text{Number}) \).
9.1.1. The numeric tower

class numbers.Complex

Subclasses of this type describe complex numbers and include the operations that work on the built-in complex type. These are: conversions to complex and bool, real, imag, +, -, *, /, abs(), conjugate(), ==, and !=. All except - and != are abstract.

real

Abstract. Retrieves the real component of this number.

imag

Abstract. Retrieves the imaginary component of this number.

conjugate()

Abstract. Returns the complex conjugate. For example, (1+3j).conjugate() == (1-3j).

class numbers.Real

To Complex, Real adds the operations that work on real numbers.

In short, those are: a conversion to float, math.trunc(), round(), math.floor(), math.ceil(), divmod(), //, %, <, <=, >, and >=.

Real also provides defaults for complex(), real, imag, and conjugate().

class numbers.Rational

Subtypes Real and adds numerator and denominator properties, which should be in lowest terms. With these, it provides
a default for `float()`.

**numerator**
Abstract.

**denominator**
Abstract.

*class* numbers. **Integral**
Subtypes **Rational** and adds a conversion to `int`. Provides defaults for `float()`, **numerator**, and **denominator**. Adds abstract methods for ** and bit-string operations: `<<, >>, &, ^, |, ~`. 
9.1.2. Notes for type implementors

Implementors should be careful to make equal numbers equal and hash them to the same values. This may be subtle if there are two different extensions of the real numbers. For example, `fractions.Fraction` implements `hash()` as follows:

```python
def __hash__(self):
    if self.denominator == 1:
        # Get integers right.
        return hash(self.numerator)
    # Expensive check, but definitely correct.
    if self == float(self):
        return hash(float(self))
    else:
        # Use tuple's hash to avoid a high collision rate on
        # simple fractions.
        return hash((self.numerator, self.denominator))
```

9.1.2.1. Adding More Numeric ABCs

There are, of course, more possible ABCs for numbers, and this would be a poor hierarchy if it precluded the possibility of adding those. You can add `MyFoo` between `Complex` and `Real` with:

```python
class MyFoo(Complex): ...
MyFoo.register(Real)
```

9.1.2.2. Implementing the arithmetic operations

We want to implement the arithmetic operations so that mixed-mode
operations either call an implementation whose author knew about the types of both arguments, or convert both to the nearest built in type and do the operation there. For subtypes of `Integral`, this means that `__add__()` and `__radd__()` should be defined as:

```python
class MyIntegral(Integral):
    def __add__(self, other):
        if isinstance(other, MyIntegral):
            return do_my_adding_stuff(self, other)
        elif isinstance(other, OtherTypeIKnowAbout):
            return do_my_other_adding_stuff(self, other)
        else:
            return NotImplemented

    def __radd__(self, other):
        if isinstance(other, MyIntegral):
            return do_my_adding_stuff(other, self)
        elif isinstance(other, OtherTypeIKnowAbout):
            return do_my_other_adding_stuff(other, self)
        elif isinstance(other, Integral):
            return int(other) + int(self)
        elif isinstance(other, Real):
            return float(other) + float(self)
        elif isinstance(other, Complex):
            return complex(other) + complex(self)
        else:
            return NotImplemented
```

There are 5 different cases for a mixed-type operation on subclasses of `Complex`. I'll refer to all of the above code that doesn't refer to `MyIntegral` and `OtherTypeIKnowAbout` as “boilerplate”. `a` will be an instance of `A`, which is a subtype of `Complex` (`a : A <: Complex`), and `b : B <: Complex`. I'll consider `a + b`:
1. If A defines an `__add__()` which accepts b, all is well.
2. If A falls back to the boilerplate code, and it were to return a
   value from `__add__()`, we’d miss the possibility that B
   defines a more intelligent `__radd__()`, so the boilerplate
   should return `NotImplemented` from `__add__()`. (Or A
   may not implement `__add__()` at all.)
3. Then B’s `__radd__()` gets a chance. If it accepts a, all is
   well.
4. If it falls back to the boilerplate, there are no more possible
   methods to try, so this is where the default implementation
   should live.
5. If B <: A, Python tries B.__radd__ before A.__add__.
   This is ok, because it was implemented with knowledge of A,
   so it can handle those instances before delegating to
   `Complex`.

If A <: Complex and B <: Real without sharing any other
knowledge, then the appropriate shared operation is the one involving
the built in `complex`, and both `__radd__()` s land there, so a+b ==
b+a.

Because most of the operations on any given type will be very similar,
it can be useful to define a helper function which generates the
forward and reverse instances of any given operator. For example,
`fractions.Fraction` uses:
else:
    return NotImplemented
forward.__name__ = '__' + fallback_operator.__name__
forward.__doc__ = monomorphic_operator.__doc__

    def reverse(b, a):
        if isinstance(a, Rational):
            # Includes ints.
            return monomorphic_operator(a, b)
        elif isinstance(a, numbers.Real):
            return fallback_operator(float(a), float(b))
        elif isinstance(a, numbers.Complex):
            return fallback_operator(complex(a), complex(b))
        else:
            return NotImplemented
reverse.__name__ = '__r' + fallback_operator.__name__
reverse.__doc__ = monomorphic_operator.__doc__
        return forward, reverse

    def __add__(a, b):
        """a + b""
        return Fraction(a.numerator * b.denominator +
                        b.numerator * a.denominator,
                        a.denominator * b.denominator)
__add__, __radd__ = _operator_fallbacks(__add__, operator
# ...
This module is always available. It provides access to the mathematical functions defined by the C standard.

These functions cannot be used with complex numbers; use the functions of the same name from the `cmath` module if you require support for complex numbers. The distinction between functions which support complex numbers and those which don't is made since most users do not want to learn quite as much mathematics as required to understand complex numbers. Receiving an exception instead of a complex result allows earlier detection of the unexpected complex number used as a parameter, so that the programmer can determine how and why it was generated in the first place.

The following functions are provided by this module. Except when explicitly noted otherwise, all return values are floats.
9.2.1. Number-theoretic and representation functions

**math.ceil(x)**

Return the ceiling of $x$, the smallest integer greater than or equal to $x$. If $x$ is not a float, delegates to $x.__ceil__()$, which should return an `Integral` value.

**math.copysign(x, y)**

Return a float with the magnitude (absolute value) of $x$ but the sign of $y$. On platforms that support signed zeros, `copysign(1.0, -0.0)` returns `-1.0`.

**math.fabs(x)**

Return the absolute value of $x$.

**math.factorial(x)**

Return $x$ factorial. Raises `ValueError` if $x$ is not integral or is negative.

**math.floor(x)**

Return the floor of $x$, the largest integer less than or equal to $x$. If $x$ is not a float, delegates to $x.__floor__()$, which should return an `Integral` value.

**math.fmod(x, y)**

Return $\text{fmod}(x, y)$, as defined by the platform C library. Note that the Python expression $x \% y$ may not return the same result. The intent of the C standard is that $\text{fmod}(x, y)$ be exactly (mathematically; to infinite precision) equal to $x - n \times y$ for some
integer $n$ such that the result has the same sign as $x$ and magnitude less than $\text{abs}(y)$. Python’s $x \% y$ returns a result with the sign of $y$ instead, and may not be exactly computable for float arguments. For example, $\text{fmod}(-1e-100, 1e100)$ is $-1e-100$, but the result of Python’s $-1e-100 \% 1e100$ is $1e100-1e-100$, which cannot be represented exactly as a float, and rounds to the surprising $1e100$. For this reason, function $\text{fmod}()$ is generally preferred when working with floats, while Python’s $x \% y$ is preferred when working with integers.

\texttt{math.frexp}(x)

Return the mantissa and exponent of $x$ as the pair $(m, e)$. $m$ is a float and $e$ is an integer such that $x == m \times 2**e$ exactly. If $x$ is zero, returns $(0.0, 0)$, otherwise $0.5 \leq \text{abs}(m) < 1$. This is used to “pick apart” the internal representation of a float in a portable way.

\texttt{math.fsum(iterable)}

Return an accurate floating point sum of values in the iterable. Avoids loss of precision by tracking multiple intermediate partial sums:

```python
>>> sum([.1, .1, .1, .1, .1, .1, .1, .1, .1])
0.9999999999999999
>>> fsum([.1, .1, .1, .1, .1, .1, .1, .1, .1])
1.0
```

The algorithm’s accuracy depends on IEEE-754 arithmetic guarantees and the typical case where the rounding mode is half-even. On some non-Windows builds, the underlying C library uses extended precision addition and may occasionally double-round an intermediate sum causing it to be off in its least significant bit.
For further discussion and two alternative approaches, see the ASPN cookbook recipes for accurate floating point summation.

\[ \text{math.gcd}(a, b) \]

Return the greatest common divisor of the integers \( a \) and \( b \). If either \( a \) or \( b \) is nonzero, then the value of \( \text{gcd}(a, b) \) is the largest positive integer that divides both \( a \) and \( b \). \( \text{gcd}(0, 0) \) returns 0.

*New in version 3.5.*

\[ \text{math.isclose}(a, b, *, rel_tol=1e-09, abs_tol=0.0) \]

Return True if the values \( a \) and \( b \) are close to each other and False otherwise.

Whether or not two values are considered close is determined according to given absolute and relative tolerances.

\( rel\_tol \) is the relative tolerance – it is the maximum allowed difference between \( a \) and \( b \), relative to the larger absolute value of \( a \) or \( b \). For example, to set a tolerance of 5%, pass \( rel\_tol=0.05 \). The default tolerance is 1e-09, which assures that the two values are the same within about 9 decimal digits. \( rel\_tol \) must be greater than zero.

\( abs\_tol \) is the minimum absolute tolerance – useful for comparisons near zero. \( abs\_tol \) must be at least zero.

If no errors occur, the result will be: \( \text{abs}(a-b) \leq \max(rel\_tol \times \max(\text{abs}(a), \text{abs}(b)), abs\_tol) \).

The IEEE 754 special values of NaN, inf, and -inf will be handled according to IEEE rules. Specifically, NaN is not
considered close to any other value, including NaN. inf and -inf are only considered close to themselves.

*New in version 3.5.*

**See also:** PEP 485 – A function for testing approximate equality

```python
math.isfinite(x)
```

Return True if $x$ is neither an infinity nor a NaN, and False otherwise. (Note that 0.0 is considered finite.)

*New in version 3.2.*

```python
math.isinf(x)
```

Return True if $x$ is a positive or negative infinity, and False otherwise.

```python
math.isnan(x)
```

Return True if $x$ is a NaN (not a number), and False otherwise.

```python
math.ldexp(x, i)
```

Return $x \times (2**i)$. This is essentially the inverse of function `frexp()`.

```python
math.modf(x)
```

Return the fractional and integer parts of $x$. Both results carry the sign of $x$ and are floats.

```python
math.trunc(x)
```

Return the **Real** value $x$ truncated to an **Integral** (usually an integer). Delegates to $x.__trunc__()$. 
Note that \texttt{frexp()} and \texttt{modf()} have a different call/return pattern than their C equivalents: they take a single argument and return a pair of values, rather than returning their second return value through an ‘output parameter’ (there is no such thing in Python).

For the \texttt{ceil()}, \texttt{floor()}, and \texttt{modf()} functions, note that all floating-point numbers of sufficiently large magnitude are exact integers. Python floats typically carry no more than 53 bits of precision (the same as the platform C double type), in which case any float \( x \) with \( \text{abs}(x) \geq 2^{*52} \) necessarily has no fractional bits.
9.2.2. Power and logarithmic functions

**math.exp(x)**

Return $e^{**x}$.

**math.expm1(x)**

Return $e^{**x} - 1$. For small floats $x$, the subtraction in exp(x) - 1 can result in a significant loss of precision; the expm1() function provides a way to compute this quantity to full precision:

```python
>>> from math import exp, expm1
>>> exp(1e-5) - 1  # gives result accurate to 11 places
1.000005000069649e-05
>>> expm1(1e-5)    # result accurate to full precision
1.0000050000166668e-05
```

New in version 3.2.

**math.log(x[, base])**

With one argument, return the natural logarithm of $x$ (to base $e$).

With two arguments, return the logarithm of $x$ to the given $base$, calculated as log($x$)/log($base$).

**math.log1p(x)**

Return the natural logarithm of $1+x$ (base $e$). The result is calculated in a way which is accurate for $x$ near zero.

**math.log2(x)**

Return the base-2 logarithm of $x$. This is usually more accurate than log($x$, 2).
New in version 3.3.

See also: `int.bit_length()` returns the number of bits necessary to represent an integer in binary, excluding the sign and leading zeros.

**math.log10(x)**

Return the base-10 logarithm of x. This is usually more accurate than `log(x, 10)`.

**math.pow(x, y)**

Return x raised to the power y. Exceptional cases follow Annex ‘F’ of the C99 standard as far as possible. In particular, `pow(1.0, x)` and `pow(x, 0.0)` always return 1.0, even when x is a zero or a NaN. If both x and y are finite, x is negative, and y is not an integer then `pow(x, y)` is undefined, and raises `ValueError`.

Unlike the built-in ** operator, `math.pow()` converts both its arguments to type **float**. Use ** or the built-in `pow()` function for computing exact integer powers.

**math.sqrt(x)**

Return the square root of x.
9.2.3. Trigonometric functions

\texttt{math.acos(x)}

Return the arc cosine of \( x \), in radians.

\texttt{math.asin(x)}

Return the arc sine of \( x \), in radians.

\texttt{math.atan(x)}

Return the arc tangent of \( x \), in radians.

\texttt{math.atan2(y, x)}

Return \( \arctan(y / x) \), in radians. The result is between \(-\pi\) and \(\pi\). The vector in the plane from the origin to point \((x, y)\) makes this angle with the positive X axis. The point of \texttt{atan2()} is that the signs of both inputs are known to it, so it can compute the correct quadrant for the angle. For example, \(\arctan(1)\) and \(\arctan2(1, 1)\) are both \(\pi/4\), but \(\arctan2(-1, -1)\) is \(-3\pi/4\).

\texttt{math.cos(x)}

Return the cosine of \( x \) radians.

\texttt{math.hypot(x, y)}

Return the Euclidean norm, \(\sqrt{x^2 + y^2}\). This is the length of the vector from the origin to point \((x, y)\).

\texttt{math.sin(x)}

Return the sine of \( x \) radians.

\texttt{math.tan(x)}

Return the tangent of \( x \) radians.
9.2.4. Angular conversion

\texttt{math.degrees(x)}

Convert angle \(x\) from radians to degrees.

\texttt{math.radians(x)}

Convert angle \(x\) from degrees to radians.
9.2.5. Hyperbolic functions

Hyperbolic functions are analogs of trigonometric functions that are based on hyperbolas instead of circles.

- math.acosh(x)
  Return the inverse hyperbolic cosine of x.

- math.asinh(x)
  Return the inverse hyperbolic sine of x.

- math.atanh(x)
  Return the inverse hyperbolic tangent of x.

- math.cosh(x)
  Return the hyperbolic cosine of x.

- math.sinh(x)
  Return the hyperbolic sine of x.

- math.tanh(x)
  Return the hyperbolic tangent of x.
9.2.6. Special functions

math.\texttt{erf}(x)

Return the \textit{error function} at $x$.

The \texttt{erf()} function can be used to compute traditional statistical functions such as the \textit{cumulative standard normal distribution}:

\begin{verbatim}
def phi(x):
    'Cumulative distribution function for the standard normal distribution'
    return (1.0 + erf(x / sqrt(2.0))) / 2.0
\end{verbatim}

\textit{New in version 3.2.}

math.\texttt{erfc}(x)

Return the \textit{complementary error function} at $x$. The \textit{complementary error function} is defined as $1.0 - \text{erf}(x)$. It is used for large values of $x$ where a subtraction from one would cause a \textit{loss of significance}.

\textit{New in version 3.2.}

math.\texttt{gamma}(x)

Return the \textit{Gamma function} at $x$.

\textit{New in version 3.2.}

math.\texttt{lgamma}(x)

Return the natural logarithm of the absolute value of the Gamma function at $x$.

\textit{New in version 3.2.}
9.2.7. Constants

math.pi
The mathematical constant \( \pi = 3.141592... \), to available precision.

math.e
The mathematical constant \( e = 2.718281... \), to available precision.

math.inf
A floating-point positive infinity. (For negative infinity, use \(-math.inf\).) Equivalent to the output of \( \text{float('inf')} \).

*New in version 3.5.*

math.nan
A floating-point “not a number” (NaN) value. Equivalent to the output of \( \text{float('nan')} \).

*New in version 3.5.*

**CPython implementation detail:** The `math` module consists mostly of thin wrappers around the platform C math library functions. Behavior in exceptional cases follows Annex F of the C99 standard where appropriate. The current implementation will raise `ValueError` for invalid operations like `sqrt(-1.0)` or `log(0.0)` (where C99 Annex F recommends signaling invalid operation or divide-by-zero), and `OverflowError` for results that overflow (for example, `exp(1000.0)`). A NaN will not be returned from any of the functions above unless one or more of the input arguments was a NaN; in that case, most functions will return a NaN, but (again following C99 Annex F) there are some exceptions to this rule, for example `pow(float('nan'), 0.0)` or `hypot(float('nan'),
float('inf')).

Note that Python makes no effort to distinguish signaling NaNs from quiet NaNs, and behavior for signaling NaNs remains unspecified. Typical behavior is to treat all NaNs as though they were quiet.

**See also:**

**Module cmath**

Complex number versions of many of these functions.
9.3. **cmath** — Mathematical functions for complex numbers

This module is always available. It provides access to mathematical functions for complex numbers. The functions in this module accept integers, floating-point numbers or complex numbers as arguments. They will also accept any Python object that has either a `__complex__()` or a `__float__()` method: these methods are used to convert the object to a complex or floating-point number, respectively, and the function is then applied to the result of the conversion.

**Note:** On platforms with hardware and system-level support for signed zeros, functions involving branch cuts are continuous on *both* sides of the branch cut: the sign of the zero distinguishes one side of the branch cut from the other. On platforms that do not support signed zeros the continuity is as specified below.
**9.3.1. Conversions to and from polar coordinates**

A Python complex number $z$ is stored internally using *rectangular* or *Cartesian* coordinates. It is completely determined by its *real part* $z\text{.real}$ and its *imaginary part* $z\text{.imag}$. In other words:

$$z == z\text{.real} + z\text{.imag}*1j$$

*Polar coordinates* give an alternative way to represent a complex number. In polar coordinates, a complex number $z$ is defined by the modulus $r$ and the phase angle $\phi$. The modulus $r$ is the distance from $z$ to the origin, while the phase $\phi$ is the counterclockwise angle, measured in radians, from the positive $x$-axis to the line segment that joins the origin to $z$.

The following functions can be used to convert from the native rectangular coordinates to polar coordinates and back.

**cmath.phase(x)**

Return the phase of $x$ (also known as the *argument* of $x$), as a float. `phase(x)` is equivalent to `math.atan2(x.imag, x.real)`. The result lies in the range $[-\pi, \pi]$, and the branch cut for this operation lies along the negative real axis, continuous from above. On systems with support for signed zeros (which includes most systems in current use), this means that the sign of the result is the same as the sign of $x\text{.imag}$, even when $x\text{.imag}$ is zero:

```python
>>> phase(complex(-1.0, 0.0))
3.141592653589793
>>> phase(complex(-1.0, -0.0))
-3.141592653589793
```
Note: The modulus (absolute value) of a complex number \( x \) can be computed using the built-in \( \text{abs()} \) function. There is no separate \texttt{cmath} module function for this operation.

cmath.\texttt{polar}(x)

Return the representation of \( x \) in polar coordinates. Returns a pair \((r, \phi)\) where \( r \) is the modulus of \( x \) and \( \phi \) is the phase of \( x \). \texttt{polar}(x) is equivalent to \((\text{abs}(x), \text{phase}(x))\).

cmath.\texttt{rect}(r, \phi)

Return the complex number \( x \) with polar coordinates \( r \) and \( \phi \). Equivalent to \( r \ast (\text{math.cos}(\phi) + \text{math.sin}(\phi)\ast\text{1j}) \).
9.3.2. Power and logarithmic functions

cmath.**exp**(x)
Return the exponential value e**x**.

cmath.**log**(x[, base])
Returns the logarithm of x to the given base. If the base is not specified, returns the natural logarithm of x. There is one branch cut, from 0 along the negative real axis to -∞, continuous from above.

cmath.**log10**(x)
Return the base-10 logarithm of x. This has the same branch cut as **log**(.)

cmath.**sqrt**(x)
Return the square root of x. This has the same branch cut as **log**(.)
9.3.3. Trigonometric functions

cmath.\texttt{acos}(x)

Return the arc cosine of \(x\). There are two branch cuts: One extends right from 1 along the real axis to \(\infty\), continuous from below. The other extends left from -1 along the real axis to \(-\infty\), continuous from above.

cmath.\texttt{asin}(x)

Return the arc sine of \(x\). This has the same branch cuts as \texttt{acos()}.

cmath.\texttt{atan}(x)

Return the arc tangent of \(x\). There are two branch cuts: One extends from 1\(j\) along the imaginary axis to \(\infty j\), continuous from the right. The other extends from -1\(j\) along the imaginary axis to \(-\infty j\), continuous from the left.

cmath.\texttt{cos}(x)

Return the cosine of \(x\).

cmath.\texttt{sin}(x)

Return the sine of \(x\).

cmath.\texttt{tan}(x)

Return the tangent of \(x\).
9.3.4. Hyperbolic functions

cmath.\texttt{acosh}(x)

Return the inverse hyperbolic cosine of $x$. There is one branch cut, extending left from 1 along the real axis to $-\infty$, continuous from above.

cmath.\texttt{asinh}(x)

Return the inverse hyperbolic sine of $x$. There are two branch cuts: One extends from $1j$ along the imaginary axis to $\infty j$, continuous from the right. The other extends from $-1j$ along the imaginary axis to $-\infty j$, continuous from the left.

cmath.\texttt{atanh}(x)

Return the inverse hyperbolic tangent of $x$. There are two branch cuts: One extends from 1 along the real axis to $\infty$, continuous from below. The other extends from $-1$ along the real axis to $-\infty$, continuous from above.

cmath.\texttt{cosh}(x)

Return the hyperbolic cosine of $x$.

cmath.\texttt{sinh}(x)

Return the hyperbolic sine of $x$.

cmath.\texttt{tanh}(x)

Return the hyperbolic tangent of $x$. 
9.3.5. Classification functions

cmath.\texttt{isfinite}(x)

Return True if both the real and imaginary parts of $x$ are finite, and False otherwise.

\textit{New in version 3.2.}

cmath.\texttt{isinf}(x)

Return True if either the real or the imaginary part of $x$ is an infinity, and False otherwise.

cmath.\texttt{isnan}(x)

Return True if either the real or the imaginary part of $x$ is a NaN, and False otherwise.

cmath.\texttt{isclose}(a, b, *, rel\_tol=1e-09, abs\_tol=0.0)

Return True if the values $a$ and $b$ are close to each other and False otherwise.

Whether or not two values are considered close is determined according to given absolute and relative tolerances.

\textit{rel\_tol} is the relative tolerance – it is the maximum allowed difference between $a$ and $b$, relative to the larger absolute value of $a$ or $b$. For example, to set a tolerance of 5\%, pass \textit{rel\_tol}=0.05. The default tolerance is 1e-09, which assures that the two values are the same within about 9 decimal digits. \textit{rel\_tol} must be greater than zero.

\textit{abs\_tol} is the minimum absolute tolerance – useful for comparisons near zero. \textit{abs\_tol} must be at least zero.
If no errors occur, the result will be: $\text{abs}(a - b) \leq \max(\text{rel\_tol} \times \max(\text{abs}(a), \text{abs}(b)), \text{abs\_tol})$.

The IEEE 754 special values of NaN, inf, and -inf will be handled according to IEEE rules. Specifically, NaN is not considered close to any other value, including NaN. inf and -inf are only considered close to themselves.

*New in version 3.5.*

**See also:** [PEP 485](#) – A function for testing approximate equality
9.3.6. Constants

cmath.pi

The mathematical constant \(\pi\), as a float.

cmath.e

The mathematical constant \(e\), as a float.

Note that the selection of functions is similar, but not identical, to that in module math. The reason for having two modules is that some users aren’t interested in complex numbers, and perhaps don’t even know what they are. They would rather have math.sqrt(-1) raise an exception than return a complex number. Also note that the functions defined in cmath always return a complex number, even if the answer can be expressed as a real number (in which case the complex number has an imaginary part of zero).

A note on branch cuts: They are curves along which the given function fails to be continuous. They are a necessary feature of many complex functions. It is assumed that if you need to compute with complex functions, you will understand about branch cuts. Consult almost any (not too elementary) book on complex variables for enlightenment. For information of the proper choice of branch cuts for numerical purposes, a good reference should be the following:

9.4. **decimal** — Decimal fixed point and floating point arithmetic

**Source code:** Lib/decimal.py

The `decimal` module provides support for fast correctly-rounded decimal floating point arithmetic. It offers several advantages over the `float` datatype:

- Decimal “is based on a floating-point model which was designed with people in mind, and necessarily has a paramount guiding principle – computers must provide an arithmetic that works in the same way as the arithmetic that people learn at school.” – excerpt from the decimal arithmetic specification.

- Decimal numbers can be represented exactly. In contrast, numbers like `1.1` and `2.2` do not have exact representations in binary floating point. End users typically would not expect `1.1 + 2.2` to display as `3.3000000000000003` as it does with binary floating point.

- The exactness carries over into arithmetic. In decimal floating point, `0.1 + 0.1 + 0.1 - 0.3` is exactly equal to zero. In binary floating point, the result is `5.5511151231257827e-017`. While near to zero, the differences prevent reliable equality testing and differences can accumulate. For this reason, decimal is preferred in accounting applications which have strict equality invariants.

- The decimal module incorporates a notion of significant places so
that $1.30 + 1.20$ is $2.50$. The trailing zero is kept to indicate significance. This is the customary presentation for monetary applications. For multiplication, the “schoolbook” approach uses all the figures in the multiplicands. For instance, $1.3 \times 1.2$ gives $1.56$ while $1.30 \times 1.20$ gives $1.5600$.

- Unlike hardware based binary floating point, the decimal module has a user alterable precision (defaulting to 28 places) which can be as large as needed for a given problem:

```python
>>> from decimal import *
>>> getcontext().prec = 6
>>> Decimal(1) / Decimal(7)
Decimal('0.142857')
>>> getcontext().prec = 28
>>> Decimal(1) / Decimal(7)
Decimal('0.1428571428571428571428571429')
```

- Both binary and decimal floating point are implemented in terms of published standards. While the built-in float type exposes only a modest portion of its capabilities, the decimal module exposes all required parts of the standard. When needed, the programmer has full control over rounding and signal handling. This includes an option to enforce exact arithmetic by using exceptions to block any inexact operations.

- The decimal module was designed to support “without prejudice, both exact unrounded decimal arithmetic (sometimes called fixed-point arithmetic) and rounded floating-point arithmetic.” – excerpt from the decimal arithmetic specification.

The module design is centered around three concepts: the decimal number, the context for arithmetic, and signals.
A decimal number is immutable. It has a sign, coefficient digits, and an exponent. To preserve significance, the coefficient digits do not truncate trailing zeros. Decimals also include special values such as Infinity, -Infinity, and NaN. The standard also differentiates -0 from +0.

The context for arithmetic is an environment specifying precision, rounding rules, limits on exponents, flags indicating the results of operations, and trap enablers which determine whether signals are treated as exceptions. Rounding options include ROUND_CEILING, ROUND_DOWN, ROUND_FLOOR, ROUND_HALF_DOWN, ROUND_HALF_EVEN, ROUND_HALF_UP, ROUND_UP, and ROUND_05UP.

Signals are groups of exceptional conditions arising during the course of computation. Depending on the needs of the application, signals may be ignored, considered as informational, or treated as exceptions. The signals in the decimal module are: Clamped, InvalidOperation, DivisionByZero, Inexact, Rounded, Subnormal, Overflow, Underflow and FloatOperation.

For each signal there is a flag and a trap enabler. When a signal is encountered, its flag is set to one, then, if the trap enabler is set to one, an exception is raised. Flags are sticky, so the user needs to reset them before monitoring a calculation.

See also:

9.4.1. Quick-start Tutorial

The usual start to using decimals is importing the module, viewing the current context with `getcontext()` and, if necessary, setting new values for precision, rounding, or enabled traps:

```python
>>> from decimal import *
>>> getcontext()
Context(prec=28, rounding=ROUND_HALF_EVEN, Emin=-999999, Emax=999999,
capitals=1, clamp=0, flags=[], traps=[Overflow, DivisionByZero, InvalidOperation])
```

```python
>>> getcontext().prec = 7  # Set a new precision
```

Decimal instances can be constructed from integers, strings, floats, or tuples. Construction from an integer or a float performs an exact conversion of the value of that integer or float. Decimal numbers include special values such as `NaN` which stands for “Not a number”, positive and negative Infinity, and -0:

```python
>>> getcontext().prec = 28
>>> Decimal(10)
Decimal('10')
>>> Decimal('3.14')
Decimal('3.14')
>>> Decimal(3.14)
Decimal('3.14')
>>> Decimal((0, (3, 1, 4), -2))
Decimal('3.14')
>>> Decimal(str(2.0 ** 0.5))
Decimal('1.4142135623730951')
>>> Decimal(2) ** Decimal('0.5')
Decimal('1.414213562373095048801688724')
```
If the **FloatOperation** signal is trapped, accidental mixing of decimals and floats in constructors or ordering comparisons raises an exception:

```python
>>> c = getcontext()
>>> c.traps[FloatOperation] = True
>>> Decimal(3.14)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
decimal.FloatOperation: [<class 'decimal.FloatOperation'>]
>>> Decimal('3.5') < 3.7
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
decimal.FloatOperation: [<class 'decimal.FloatOperation'>]
>>> Decimal('3.5') == 3.5
True
```

*New in version 3.3.*

The significance of a new Decimal is determined solely by the number of digits input. Context precision and rounding only come into play during arithmetic operations.

```python
>>> getcontext().prec = 6
>>> Decimal('3.0')
Decimal('3.0')
>>> Decimal('3.1415926535')
Decimal('3.1415926535')
>>> Decimal('3.1415926535') + Decimal('2.7182818285')
```
If the internal limits of the C version are exceeded, constructing a decimal raises :exc:`InvalidOperation`:

```python
>>> Decimal("1e9999999999999999999")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
decimal.InvalidOperation: [<class 'decimal.InvalidOperation'>]
```

*Changed in version 3.3.*

Decimals interact well with much of the rest of Python. Here is a small decimal floating point flying circus:

```python
>>> data = list(map(Decimal, '1.34 1.87 3.45 2.35 1.00 0.03 9.25'))
>>> max(data)
Decimal('9.25')
>>> min(data)
Decimal('0.03')
>>> sorted(data)
[Decimal('0.03'), Decimal('1.00'), Decimal('1.34'), Decimal('2.35'), Decimal('3.45'), Decimal('9.25')]
>>> sum(data)
Decimal('19.29')
>>> a,b,c = data[:3]
>>> str(a)
'1.34'
>>> float(a)
1.34
>>> round(a, 1)
Decimal('1.3')
```
And some mathematical functions are also available to Decimal:

```python
>>> getcontext().prec = 28
>>> Decimal(2).sqrt()
Decimal('1.4142135623730950488017991455')
>>> Decimal(1).exp()
Decimal('2.718281828459045235360287471')
>>> Decimal('10').ln()
Decimal('2.302585092994045684017991455')
>>> Decimal('10').log10()
Decimal('1')
```

The `quantize()` method rounds a number to a fixed exponent. This method is useful for monetary applications that often round results to a fixed number of places:

```python
>>> Decimal('7.325').quantize(Decimal('.01'), rounding=rounding_DOWN)
Decimal('7.32')
>>> Decimal('7.325').quantize(Decimal('1.'), rounding=rounding_DOWN)
Decimal('8')
```

As shown above, the `getcontext()` function accesses the current context and allows the settings to be changed. This approach meets the needs of most applications.
For more advanced work, it may be useful to create alternate contexts using the `Context()` constructor. To make an alternate active, use the `setcontext()` function.

In accordance with the standard, the `decimal` module provides two ready to use standard contexts, `BasicContext` and `ExtendedContext`. The former is especially useful for debugging because many of the traps are enabled:

```python
>>> myothercontext = Context(prec=60, rounding=ROUND_HALF_DOWN)
>>> setcontext(myothercontext)
>>> Decimal(1) / Decimal(7)
Decimal('0.142857142857142857142857142857142857142857142857142857142857')

>>> ExtendedContext(prec=9, rounding=ROUND_HALF_EVEN, Emin=-999999, capitals=1, clamp=0, flags=[], traps=[])]
>>> setcontext(ExtendedContext)
>>> Decimal(1) / Decimal(7)
Decimal('0.142857143')
>>> Decimal(42) / Decimal(0)
Decimal('Infinity')

>>> setcontext(BasicContext)
>>> Decimal(42) / Decimal(0)
Traceback (most recent call last):
  File "<pyshell#143>", line 1, in -toplevel-
    Decimal(42) / Decimal(0)
DivisionByZero: x / 0
```

Contexts also have signal flags for monitoring exceptional conditions encountered during computations. The flags remain set until explicitly cleared, so it is best to clear the flags before each set of monitored computations by using the `clear_flags()` method.
The `flags` entry shows that the rational approximation to Pi was rounded (digits beyond the context precision were thrown away) and that the result is inexact (some of the discarded digits were non-zero). Individual traps are set using the dictionary in the `traps` field of a context:

```
>>> setcontext(ExtendedContext)
>>> Decimal(1) / Decimal(0)
Decimal('Infinity')
>>> getcontext().traps[DivisionByZero] = 1
>>> Decimal(1) / Decimal(0)
Traceback (most recent call last):
  File "<pyshell#112>", line 1, in -toplevel-
    Decimal(1) / Decimal(0)
DivisionByZero: x / 0
```

Most programs adjust the current context only once, at the beginning of the program. And, in many applications, data is converted to `Decimal` with a single cast inside a loop. With context set and decimals created, the bulk of the program manipulates the data no differently than with other Python numeric types.
9.4.2. Decimal objects

```python
class decimal.Decimal(value=\"0\", context=None)
```

Construct a new `Decimal` object based from `value`.

`value` can be an integer, string, tuple, `float`, or another `Decimal` object. If no `value` is given, returns `Decimal(\"0\")`. If `value` is a string, it should conform to the decimal numeric string syntax after leading and trailing whitespace characters are removed:

```
sign ::= \'+\' | \'-\'
digit ::= \'0\' | \'1\' | \'2\' | \'3\' | \'4\' |
indicator ::= \'e\' | \'E\'
digits ::= digit [digit]...
decimal-part ::= digits \'.\' [digits] | [\'.\'] digits
exponent-part ::= indicator [sign] digits
infinity ::= \'Infinity\' | \'Inf\'
nan ::= \'NaN\' [digits] | \'sNaN\' [digits]
numeric-value ::= decimal-part [exponent-part]
numeric-string ::= [sign] numeric-value | [sign]
```

Other Unicode decimal digits are also permitted where `digit` appears above. These include decimal digits from various other alphabets (for example, Arabic-Indic and Devanāgarī digits) along with the fullwidth digits '\uff10' through '\uff19'.

If `value` is a `tuple`, it should have three components, a sign (0 for positive or 1 for negative), a `tuple` of digits, and an integer exponent. For example, `Decimal((\0, (1, 4, 1, 4), -3))` returns `Decimal('1.414')`.

If `value` is a `float`, the binary floating point value is losslessly
converted to its exact decimal equivalent. This conversion can often require 53 or more digits of precision. For example, `Decimal(float('1.1'))` converts to `Decimal('1.10000000000000008881784197001252323389

The context precision does not affect how many digits are stored. That is determined exclusively by the number of digits in `value`. For example, `Decimal('3.00000')` records all five zeros even if the context precision is only three.

The purpose of the context argument is determining what to do if `value` is a malformed string. If the context traps `InvalidOperation`, an exception is raised; otherwise, the constructor returns a new Decimal with the value of NaN.

Once constructed, `Decimal` objects are immutable.

*Changed in version 3.2:* The argument to the constructor is now permitted to be a `float` instance.

*Changed in version 3.3:* `float` arguments raise an exception if the `FloatOperation` trap is set. By default the trap is off.

Decimal floating point objects share many properties with the other built-in numeric types such as `float` and `int`. All of the usual math operations and special methods apply. Likewise, decimal objects can be copied, pickled, printed, used as dictionary keys, used as set elements, compared, sorted, and coerced to another type (such as `float` or `int`).

There are some small differences between arithmetic on Decimal objects and arithmetic on integers and floats. When the remainder operator `%` is applied to Decimal objects, the sign of the result is the
sign of the *dividend* rather than the sign of the divisor:

```python
>>> (-7) % 4
1
>>> Decimal(-7) % Decimal(4)
Decimal('-3')
```

The integer division operator `//` behaves analogously, returning the integer part of the true quotient (truncating towards zero) rather than its floor, so as to preserve the usual identity `x == (x // y) * y + x % y`:

```python
>>> -7 // 4
-2
>>> Decimal(-7) // Decimal(4)
Decimal('-1')
```

The `%` and `//` operators implement the remainder and divide-integer operations (respectively) as described in the specification.

Decimal objects cannot generally be combined with floats or instances of `fractions.Fraction` in arithmetic operations: an attempt to add a `Decimal` to a `float`, for example, will raise a `TypeError`. However, it is possible to use Python's comparison operators to compare a `Decimal` instance `x` with another number `y`. This avoids confusing results when doing equality comparisons between numbers of different types.

*Changed in version 3.2:* Mixed-type comparisons between `Decimal` instances and other numeric types are now fully supported.
In addition to the standard numeric properties, decimal floating point objects also have a number of specialized methods:

**adjusted()**

Return the adjusted exponent after shifting out the coefficient's rightmost digits until only the lead digit remains: Decimal('321e+5').adjusted() returns seven. Used for determining the position of the most significant digit with respect to the decimal point.

**as_tuple()**

Return a **named tuple** representation of the number: DecimalTuple(sign, digits, exponent).

**canonical()**

Return the canonical encoding of the argument. Currently, the encoding of a Decimal instance is always canonical, so this operation returns its argument unchanged.

**compare(other, context=None)**

Compare the values of two Decimal instances. compare() returns a Decimal instance, and if either operand is a NaN then the result is a NaN:

```
a or b is a NaN  ==>  Decimal('NaN')
a < b           ==>  Decimal('-1')
a == b           ==>  Decimal('0')
a > b            ==>  Decimal('1')
```

**compare_signal(other, context=None)**

This operation is identical to the compare() method, except that all NaNs signal. That is, if neither operand is a signaling
NaN then any quiet NaN operand is treated as though it were signaling NaN.

**compare_total**(other, context=None)

Compare two operands using their abstract representation rather than their numerical value. Similar to the `compare()` method, but the result gives a total ordering on `Decimal` instances. Two `Decimal` instances with the same numeric value but different representations compare unequal in this ordering:

```python
>>> Decimal('12.0').compare_total(Decimal('12'))
Decimal('-1')
```

Quiet and signaling NaNs are also included in the total ordering. The result of this function is `Decimal('0')` if both operands have the same representation, `Decimal('-1')` if the first operand is lower in the total order than the second, and `Decimal('1')` if the first operand is higher in the total order than the second operand. See the specification for details of the total order.

This operation is unaffected by context and is quiet: no flags are changed and no rounding is performed. As an exception, the C version may raise `InvalidOperation` if the second operand cannot be converted exactly.

**compare_total_mag**(other, context=None)

Compare two operands using their abstract representation rather than their value as in `compare_total()`, but ignoring the sign of each operand. `x.compare_total_mag(y)` is equivalent to
\[ x.\text{copy\_abs()} \cdot \text{compare\_total}(y.\text{copy\_abs()}) \].

This operation is unaffected by context and is quiet: no flags are changed and no rounding is performed. As an exception, the C version may raise \text{InvalidOperation} if the second operand cannot be converted exactly.

**conjugate()**

Just returns self, this method is only to comply with the Decimal Specification.

**copy\_abs()**

Return the absolute value of the argument. This operation is unaffected by the context and is quiet: no flags are changed and no rounding is performed.

**copy\_negate()**

Return the negation of the argument. This operation is unaffected by the context and is quiet: no flags are changed and no rounding is performed.

**copy\_sign(other, context=None)**

Return a copy of the first operand with the sign set to be the same as the sign of the second operand. For example:

```python
>>> \text{Decimal('2.3').copy\_sign(Decimal('-1.5'))}
\text{Decimal('-2.3')}
```

This operation is unaffected by context and is quiet: no flags are changed and no rounding is performed. As an exception, the C version may raise \text{InvalidOperation} if the second operand cannot be converted exactly.
exp(context=None)
Return the value of the (natural) exponential function \( e^{x} \) at the given number. The result is correctly rounded using the `ROUND_HALF_EVEN` rounding mode.

```python
>>> Decimal(1).exp()
Decimal('2.718281828459045235360287471')
>>> Decimal(321).exp()
Decimal('2.561702493119680037517373933E+139')
```

from_float()
Classmethod that converts a float to a decimal number, exactly.

Note `Decimal.from_float(0.1)` is not the same as `Decimal('0.1')`. Since 0.1 is not exactly representable in binary floating point, the value is stored as the nearest representable value which is 0x1.9999999999999ap-4. That equivalent value in decimal is 0.10000000000000000555111512312578270211815834045410

**Note:** From Python 3.2 onwards, a `Decimal` instance can also be constructed directly from a `float`.

```python
>>> Decimal.from_float(0.1)
Decimal('0.10000000000000000555111512312578270211815834045410')
>>> Decimal.from_float(float('nan'))
Decimal('NaN')
>>> Decimal.from_float(float('inf'))
Decimal('Infinity')
>>> Decimal.from_float(float('-inf'))
Decimal('-Infinity')
```

New in version 3.1.
**fma**(other, third, context=None)

Fused multiply-add. Return self*other+third with no rounding of the intermediate product self*other.

```python
>>> Decimal(2).fma(3, 5)
Decimal('11')
```

**is_canonical()**

Return True if the argument is canonical and False otherwise. Currently, a Decimal instance is always canonical, so this operation always returns True.

**is_finite()**

Return True if the argument is a finite number, and False if the argument is an infinity or a NaN.

**is_infinite()**

Return True if the argument is either positive or negative infinity and False otherwise.

**is_nan()**

Return True if the argument is a (quiet or signaling) NaN and False otherwise.

**is_normal**(context=None)

Return True if the argument is a normal finite number. Return False if the argument is zero, subnormal, infinite or a NaN.

**is_qnan()**

Return True if the argument is a quiet NaN, and False otherwise.
is_signed()  
Return True if the argument has a negative sign and False otherwise. Note that zeros and NaNs can both carry signs.

is_snan()  
Return True if the argument is a signaling NaN and False otherwise.

is_subnormal(context=None)  
Return True if the argument is subnormal, and False otherwise.

is_zero()  
Return True if the argument is a (positive or negative) zero and False otherwise.

ln(context=None)  
Return the natural (base e) logarithm of the operand. The result is correctly rounded using the ROUND_HALF_EVEN rounding mode.

log10(context=None)  
Return the base ten logarithm of the operand. The result is correctly rounded using the ROUND_HALF_EVEN rounding mode.

logb(context=None)  
For a nonzero number, return the adjusted exponent of its operand as a Decimal instance. If the operand is a zero then Decimal('-Infinity') is returned and the DivisionByZero flag is raised. If the operand is an infinity then Decimal('Infinity') is returned.
**logical_and**(other, context=None)

*logical_and()* is a logical operation which takes two *logical operands* (see *Logical operands*). The result is the digit-wise and of the two operands.

**logical_invert**(context=None)

*logical_invert()* is a logical operation. The result is the digit-wise inversion of the operand.

**logical_or**(other, context=None)

*logical_or()* is a logical operation which takes two *logical operands* (see *Logical operands*). The result is the digit-wise or of the two operands.

**logical_xor**(other, context=None)

*logical_xor()* is a logical operation which takes two *logical operands* (see *Logical operands*). The result is the digit-wise exclusive or of the two operands.

**max**(other, context=None)

Like *max(self, other)* except that the context rounding rule is applied before returning and that NaN values are either signaled or ignored (depending on the context and whether they are signaling or quiet).

**max_mag**(other, context=None)

Similar to the *max()* method, but the comparison is done using the absolute values of the operands.

**min**(other, context=None)

Like *min(self, other)* except that the context rounding rule is applied before returning and that NaN values are either
signaled or ignored (depending on the context and whether they are signaling or quiet).

**min_mag**(other, context=None)
Similar to the **min()** method, but the comparison is done using the absolute values of the operands.

**next_minus**(context=None)
Return the largest number representable in the given context (or in the current thread's context if no context is given) that is smaller than the given operand.

**next_plus**(context=None)
Return the smallest number representable in the given context (or in the current thread's context if no context is given) that is larger than the given operand.

**next_toward**(other, context=None)
If the two operands are unequal, return the number closest to the first operand in the direction of the second operand. If both operands are numerically equal, return a copy of the first operand with the sign set to be the same as the sign of the second operand.

**normalize**(context=None)
Normalize the number by stripping the rightmost trailing zeros and converting any result equal to **Decimal('0')** to **Decimal('0e0')**. Used for producing canonical values for attributes of an equivalence class. For example, **Decimal('32.100')** and **Decimal('0.321000e+2')** both normalize to the equivalent value **Decimal('32.1')**.
number_class(context=None)

Return a string describing the class of the operand. The returned value is one of the following ten strings.

- "-Infinity", indicating that the operand is negative infinity.
- "-Normal", indicating that the operand is a negative normal number.
- "-Subnormal", indicating that the operand is negative and subnormal.
- "-Zero", indicating that the operand is a negative zero.
- "+Zero", indicating that the operand is a positive zero.
- "+Subnormal", indicating that the operand is positive and subnormal.
- "+Normal", indicating that the operand is a positive normal number.
- "+Infinity", indicating that the operand is positive infinity.
- "NaN", indicating that the operand is a quiet NaN (Not a Number).
- "sNaN", indicating that the operand is a signaling NaN.

quantize(exp, rounding=None, context=None)

Return a value equal to the first operand after rounding and having the exponent of the second operand.

```python
>>> Decimal('1.41421356').quantize(Decimal('1.0'))
Decimal('1.414')
```

Unlike other operations, if the length of the coefficient after the quantize operation would be greater than precision, then an InvalidOperation is signaled. This guarantees that, unless
there is an error condition, the quantized exponent is always equal to that of the right-hand operand.

Also unlike other operations, quantize never signals Underflow, even if the result is subnormal and inexact.

If the exponent of the second operand is larger than that of the first then rounding may be necessary. In this case, the rounding mode is determined by the rounding argument if given, else by the given context argument; if neither argument is given the rounding mode of the current thread's context is used.

An error is returned whenever the resulting exponent is greater than Emax or less than Etiny.

**radix()**

Return Decimal(10), the radix (base) in which the Decimal class does all its arithmetic. Included for compatibility with the specification.

**remainder_near**(other, context=None)

Return the remainder from dividing self by other. This differs from self % other in that the sign of the remainder is chosen so as to minimize its absolute value. More precisely, the return value is self - n * other where n is the integer nearest to the exact value of self / other, and if two integers are equally near then the even one is chosen.

If the result is zero then its sign will be the sign of self.

```python
>>> Decimal(18).remainder_near(Decimal(10))
Decimal('-2')
>>> Decimal(25).remainder_near(Decimal(10))
```
\begin{verbatim}
>>> Decimal('5').remainder_near(Decimal('10'))
Decimal('-5')
\end{verbatim}

**rotate**(other, context=None)

Return the result of rotating the digits of the first operand by an amount specified by the second operand. The second operand must be an integer in the range \(-\text{precision}\) through \text{precision}. The absolute value of the second operand gives the number of places to rotate. If the second operand is positive then rotation is to the left; otherwise rotation is to the right. The coefficient of the first operand is padded on the left with zeros to length \text{precision} if necessary. The sign and exponent of the first operand are unchanged.

**same_quantum**(other, context=None)

Test whether self and other have the same exponent or whether both are NaN.

This operation is unaffected by context and is quiet: no flags are changed and no rounding is performed. As an exception, the C version may raise \text{InvalidOperation} if the second operand cannot be converted exactly.

**scaleb**(other, context=None)

Return the first operand with exponent adjusted by the second. Equivalently, return the first operand multiplied by \(10^{\text{other}}\). The second operand must be an integer.

**shift**(other, context=None)

Return the result of shifting the digits of the first operand by an amount specified by the second operand. The second operand must be an integer in the range \(-\text{precision}\) through \text{precision}.\]
The absolute value of the second operand gives the number of places to shift. If the second operand is positive then the shift is to the left; otherwise the shift is to the right. Digits shifted into the coefficient are zeros. The sign and exponent of the first operand are unchanged.

\textbf{sqrt}\textit{(context=\text{None})}

Return the square root of the argument to full precision.

\textbf{to\_eng\_string}\textit{(context=\text{None})}

Convert to an engineering-type string.

Engineering notation has an exponent which is a multiple of 3, so there are up to 3 digits left of the decimal place. For example, converts \texttt{Decimal('123E+1')} to \texttt{Decimal('1.23E+3')}.

\textbf{to\_integral}\textit{(rounding=\text{None}, context=\text{None})}

Identical to the \texttt{to\_integral\_value()} method. The \texttt{to\_integral} name has been kept for compatibility with older versions.

\textbf{to\_integral\_exact}\textit{(rounding=\text{None}, context=\text{None})}

Round to the nearest integer, signaling \texttt{Inexact} or \texttt{Rounded} as appropriate if rounding occurs. The rounding mode is determined by the rounding parameter if given, else by the given context. If neither parameter is given then the rounding mode of the current context is used.

\textbf{to\_integral\_value}\textit{(rounding=\text{None}, context=\text{None})}

Round to the nearest integer without signaling \texttt{Inexact} or \texttt{Rounded}. If given, applies \texttt{rounding}; otherwise, uses the
rounding method in either the supplied context or the current context.

9.4.2.1. Logical operands

The logical_and(), logical_invert(), logical_or(), and logical_xor() methods expect their arguments to be logical operands. A logical operand is a Decimal instance whose exponent and sign are both zero, and whose digits are all either 0 or 1.
9.4.3. Context objects

Contexts are environments for arithmetic operations. They govern precision, set rules for rounding, determine which signals are treated as exceptions, and limit the range for exponents.

Each thread has its own current context which is accessed or changed using the `getcontext()` and `setcontext()` functions:

```python
decimal.getcontext()

Return the current context for the active thread.
```

```python
decimal.setcontext(c)

Set the current context for the active thread to c.
```

You can also use the `with` statement and the `localcontext()` function to temporarily change the active context.

```python
decimal.localcontext(ctx=None)

Return a context manager that will set the current context for the active thread to a copy of ctx on entry to the with-statement and restore the previous context when exiting the with-statement. If no context is specified, a copy of the current context is used.
```

For example, the following code sets the current decimal precision to 42 places, performs a calculation, and then automatically restores the previous context:

```python
from decimal import localcontext

with localcontext() as ctx:
    ctx.prec = 42  # Perform a high precision calculation
    s = calculate_something()
```
New contexts can also be created using the `Context` constructor described below. In addition, the module provides three pre-made contexts:

```python
s = +s  # Round the final result back to the default precision
```

**class decimal.BasicContext**

This is a standard context defined by the General Decimal Arithmetic Specification. Precision is set to nine. Rounding is set to `ROUND_HALF_UP`. All flags are cleared. All traps are enabled (treated as exceptions) except `Inexact`, `Rounded`, and `Subnormal`.

Because many of the traps are enabled, this context is useful for debugging.

**class decimal.ExtendedContext**

This is a standard context defined by the General Decimal Arithmetic Specification. Precision is set to nine. Rounding is set to `ROUND_HALF_EVEN`. All flags are cleared. No traps are enabled (so that exceptions are not raised during computations).

Because the traps are disabled, this context is useful for applications that prefer to have result value of NaN or Infinity instead of raising exceptions. This allows an application to complete a run in the presence of conditions that would otherwise halt the program.

**class decimal.DefaultContext**

This context is used by the `Context` constructor as a prototype for new contexts. Changing a field (such a precision) has the effect of changing the default for new contexts created by the `Context` constructor.
This context is most useful in multi-threaded environments. Changing one of the fields before threads are started has the effect of setting system-wide defaults. Changing the fields after threads have started is not recommended as it would require thread synchronization to prevent race conditions.

In single threaded environments, it is preferable to not use this context at all. Instead, simply create contexts explicitly as described below.

The default values are prec=28, rounding=ROUND_HALF_EVEN, and enabled traps for Overflow, InvalidOperation, and DivisionByZero.

In addition to the three supplied contexts, new contexts can be created with the Context constructor.

class decimal.Context(prec=None, rounding=None, Emin=None, Emax=None, capitals=None, clamp=None, flags=None, traps=None)

 Creates a new context. If a field is not specified or is None, the default values are copied from the DefaultContext. If the flags field is not specified or is None, all flags are cleared.

prec is an integer in the range [1, MAX_PREC] that sets the precision for arithmetic operations in the context.

The rounding option is one of the constants listed in the section Rounding Modes.

The traps and flags fields list any signals to be set. Generally, new contexts should only set traps and leave the flags clear.
The $E_{\text{min}}$ and $E_{\text{max}}$ fields are integers specifying the outer limits allowable for exponents. $E_{\text{min}}$ must be in the range $[\text{MIN\_EMIN}, 0]$, $E_{\text{max}}$ in the range $[0, \text{MAX\_EMAX}]$.

The $\text{capitals}$ field is either 0 or 1 (the default). If set to 1, exponents are printed with a capital E; otherwise, a lowercase e is used: Decimal('6.02e+23').

The $\text{clamp}$ field is either 0 (the default) or 1. If set to 1, the exponent $e$ of a Decimal instance representable in this context is strictly limited to the range $E_{\text{min}} - \text{prec} + 1 \leq e \leq E_{\text{max}} - \text{prec} + 1$. If $\text{clamp}$ is 0 then a weaker condition holds: the adjusted exponent of the Decimal instance is at most $E_{\text{max}}$. When $\text{clamp}$ is 1, a large normal number will, where possible, have its exponent reduced and a corresponding number of zeros added to its coefficient, in order to fit the exponent constraints; this preserves the value of the number but loses information about significant trailing zeros. For example:

```
>>> Context(prec=6, Emax=999, clamp=1).create_decimal('1.23000E+999')
Decimal('1.23000E+999')
```

A $\text{clamp}$ value of 1 allows compatibility with the fixed-width decimal interchange formats specified in IEEE 754.

The Context class defines several general purpose methods as well as a large number of methods for doing arithmetic directly in a given context. In addition, for each of the Decimal methods described above (with the exception of the adjusted() and as_tuple() methods) there is a corresponding Context method. For example, for a Context instance C and Decimal
instance \( x, C.exp(x) \) is equivalent to \( x.exp(context=C) \). Each \texttt{Context} method accepts a Python integer (an instance of \texttt{int}) anywhere that a Decimal instance is accepted.

\begin{description}
\item[\texttt{clear_flags()}:]
Resets all of the flags to 0.
\item[\texttt{clear_traps()}:]
Resets all of the traps to 0.
\end{description}

\textit{New in version 3.3.}

\begin{description}
\item[\texttt{copy()}:]
Return a duplicate of the context.
\item[\texttt{copy_decimal(num)}:]
Return a copy of the Decimal instance \( \texttt{num} \).
\item[\texttt{create_decimal(num)}:]
Creates a new Decimal instance from \( \texttt{num} \) but using \texttt{self} as context. Unlike the \texttt{Decimal} constructor, the context precision, rounding method, flags, and traps are applied to the conversion.
\end{description}

This is useful because constants are often given to a greater precision than is needed by the application. Another benefit is that rounding immediately eliminates unintended effects from digits beyond the current precision. In the following example, using unrounded inputs means that adding zero to a sum can change the result:

\begin{verbatim}
>>> getcontext().prec = 3
>>> Decimal('3.4445') + Decimal('1.0023')
Decimal('4.45')
\end{verbatim}
This method implements the to-number operation of the IBM specification. If the argument is a string, no leading or trailing whitespace is permitted.

**create_decimal_from_float(f)**

Creates a new Decimal instance from a float f but rounding using self as the context. Unlike the `Decimal.from_float()` class method, the context precision, rounding method, flags, and traps are applied to the conversion.

```python
>>> context = Context(prec=5, rounding=ROUND_DOWN)
>>> context.create_decimal_from_float(math.pi)
Decimal('3.1415')
>>> context = Context(prec=5, traps=[Inexact])
>>> context.create_decimal_from_float(math.pi)
Traceback (most recent call last):
  ... 
decimal.Inexact: None
```

*New in version 3.1.*

**Etiny()**

Returns a value equal to Emin - prec + 1 which is the minimum exponent value for subnormal results. When underflow occurs, the exponent is set to Etiny.

**Etop()**

Returns a value equal to Emax - prec + 1.

The usual approach to working with decimals is to create `Decimal`
instances and then apply arithmetic operations which take place within the current context for the active thread. An alternative approach is to use context methods for calculating within a specific context. The methods are similar to those for the Decimal class and are only briefly recounted here.

\texttt{abs}(x)

Returns the absolute value of \( x \).

\texttt{add}(x, y)

Return the sum of \( x \) and \( y \).

\texttt{canonical}(x)

Returns the same Decimal object \( x \).

\texttt{compare}(x, y)

Compares \( x \) and \( y \) numerically.

\texttt{compare\_signal}(x, y)

Compares the values of the two operands numerically.

\texttt{compare\_total}(x, y)

Compares two operands using their abstract representation.

\texttt{compare\_total\_mag}(x, y)

Compares two operands using their abstract representation, ignoring sign.

\texttt{copy\_abs}(x)

Returns a copy of \( x \) with the sign set to 0.

\texttt{copy\_negate}(x)

Returns a copy of \( x \) with the sign inverted.
\textbf{copy\_sign}(x, y) \\
Copies the sign from $y$ to $x$.

\textbf{divide}(x, y) \\
Return $x$ divided by $y$.

\textbf{divide\_int}(x, y) \\
Return $x$ divided by $y$, truncated to an integer.

\textbf{divmod}(x, y) \\
Divides two numbers and returns the integer part of the result.

\textbf{exp}(x) \\
Returns $e \times x$.

\textbf{fma}(x, y, z) \\
Returns $x$ multiplied by $y$, plus $z$.

\textbf{is\_canonical}(x) \\
Returns True if $x$ is canonical; otherwise returns False.

\textbf{is\_finite}(x) \\
Returns True if $x$ is finite; otherwise returns False.

\textbf{is\_infinite}(x) \\
Returns True if $x$ is infinite; otherwise returns False.

\textbf{is\_nan}(x) \\
Returns True if $x$ is a qNaN or sNaN; otherwise returns False.

\textbf{is\_normal}(x) \\
Returns True if $x$ is a normal number; otherwise returns False.
is_qnan(x)
    Returns True if x is a quiet NaN; otherwise returns False.

is_signed(x)
    Returns True if x is negative; otherwise returns False.

is_snan(x)
    Returns True if x is a signaling NaN; otherwise returns False.

is_subnormal(x)
    Returns True if x is subnormal; otherwise returns False.

is_zero(x)
    Returns True if x is a zero; otherwise returns False.

ln(x)
    Returns the natural (base e) logarithm of x.

log10(x)
    Returns the base 10 logarithm of x.

logb(x)
    Returns the exponent of the magnitude of the operand's MSD.

logical_and(x, y)
    Applies the logical operation and between each operand's digits.

logical_invert(x)
    Invert all the digits in x.

logical_or(x, y)
Applies the logical operation or between each operand’s digits.

**logical_xor**\((x, y)\)
Applies the logical operation xor between each operand’s digits.

**max**\((x, y)\)
Compares two values numerically and returns the maximum.

**max_mag**\((x, y)\)
Compares the values numerically with their sign ignored.

**min**\((x, y)\)
Compares two values numerically and returns the minimum.

**min_mag**\((x, y)\)
Compares the values numerically with their sign ignored.

**minus**\((x)\)
Minus corresponds to the unary prefix minus operator in Python.

**multiply**\((x, y)\)
Return the product of \(x\) and \(y\).

**next_minus**\((x)\)
Returns the largest representable number smaller than \(x\).

**next_plus**\((x)\)
Returns the smallest representable number larger than \(x\).

**next_toward**\((x, y)\)
Returns the number closest to \(x\), in direction towards \(y\).
normalize($x$)
Reduces $x$ to its simplest form.

number_class($x$)
Returns an indication of the class of $x$.

plus($x$)
Plus corresponds to the unary prefix plus operator in Python. This operation applies the context precision and rounding, so it is not an identity operation.

power($x, y, \text{modulo}=\text{None}$)
Return $x$ to the power of $y$, reduced modulo modulo if given.

With two arguments, compute $x^{**}y$. If $x$ is negative then $y$ must be integral. The result will be inexact unless $y$ is integral and the result is finite and can be expressed exactly in ‘precision’ digits. The rounding mode of the context is used. Results are always correctly-rounded in the Python version.

Changed in version 3.3: The C module computes power() in terms of the correctly-rounded exp() and ln() functions. The result is well-defined but only “almost always correctly-rounded”.

With three arguments, compute $(x^{**}y) \% \text{modulo}$. For the three argument form, the following restrictions on the arguments hold:

- all three arguments must be integral
- $y$ must be nonnegative
- at least one of $x$ or $y$ must be nonzero
- modulo must be nonzero and have at most ‘precision’
The value resulting from Context.power(x, y, modulo) is equal to the value that would be obtained by computing \((x**y) \mod \text{modulo} \) with unbounded precision, but is computed more efficiently. The exponent of the result is zero, regardless of the exponents of \(x\), \(y\) and \(\text{modulo}\). The result is always exact.

**quantize(x, y)**

Returns a value equal to \(x\) (rounded), having the exponent of \(y\).

**radix()**

Just returns 10, as this is Decimal, :)

**remainder(x, y)**

Returns the remainder from integer division.

The sign of the result, if non-zero, is the same as that of the original dividend.

**remainder_near(x, y)**

Returns \(x - y \times n\), where \(n\) is the integer nearest the exact value of \(x / y\) (if the result is 0 then its sign will be the sign of \(x\)).

**rotate(x, y)**

Returns a rotated copy of \(x\), \(y\) times.

**same_quantum(x, y)**

Returns True if the two operands have the same exponent.

**scaleb(x, y)**
Returns the first operand after adding the second value its exp.

\textbf{shift}(x, y)

Returns a shifted copy of \(x\), \(y\) times.

\textbf{sqrt}(x)

Square root of a non-negative number to context precision.

\textbf{subtract}(x, y)

Return the difference between \(x\) and \(y\).

\textbf{to_eng_string}(x)

Converts a number to a string, using scientific notation.

\textbf{to_integral_exact}(x)

Rounds to an integer.

\textbf{to_sci_string}(x)

Converts a number to a string using scientific notation.
9.4.4. Constants

The constants in this section are only relevant for the C module. They are also included in the pure Python version for compatibility.

<table>
<thead>
<tr>
<th></th>
<th>32-bit</th>
<th>64-bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>decimal.MAX_PREC</td>
<td>4250000000</td>
<td>999999999999999999</td>
</tr>
<tr>
<td>decimal.MAX_EMAX</td>
<td>4250000000</td>
<td>999999999999999999</td>
</tr>
<tr>
<td>decimal.MIN_EMIN</td>
<td>-4250000000</td>
<td>-999999999999999999</td>
</tr>
<tr>
<td>decimal.MIN_ETINY</td>
<td>-849999999</td>
<td>-199999999999999999</td>
</tr>
</tbody>
</table>

**decimal.HAVE_THREADS**

The default value is True. If Python is compiled without threads, the C version automatically disables the expensive thread local context machinery. In this case, the value is False.
9.4.5. Rounding modes

decimal.ROUND_CEILING
    Round towards Infinity.

decimal.ROUND_DOWN
    Round towards zero.

decimal.ROUND_FLOOR
    Round towards -Infinity.

decimal.ROUND_HALF_DOWN
    Round to nearest with ties going towards zero.

decimal.ROUND_HALF_EVEN
    Round to nearest with ties going to nearest even integer.

decimal.ROUND_HALF_UP
    Round to nearest with ties going away from zero.

decimal.ROUND_UP
    Round away from zero.

decimal.ROUND_05UP
    Round away from zero if last digit after rounding towards zero
    would have been 0 or 5; otherwise round towards zero.
9.4.6. Signals

Signals represent conditions that arise during computation. Each corresponds to one context flag and one context trap enabler.

The context flag is set whenever the condition is encountered. After the computation, flags may be checked for informational purposes (for instance, to determine whether a computation was exact). After checking the flags, be sure to clear all flags before starting the next computation.

If the context's trap enabler is set for the signal, then the condition causes a Python exception to be raised. For example, if the DivisionByZero trap is set, then a DivisionByZero exception is raised upon encountering the condition.

```python
class decimal.Clamped
    Altered an exponent to fit representation constraints.

    Typically, clamping occurs when an exponent falls outside the context's Emin and Emax limits. If possible, the exponent is reduced to fit by adding zeros to the coefficient.

class decimal.DecimalException
    Base class for other signals and a subclass of ArithmeticError.

class decimal.DivisionByZero
    Signals the division of a non-infinite number by zero.

    Can occur with division, modulo division, or when raising a number to a negative power. If this signal is not trapped, returns Infinity
```
or -Infinity with the sign determined by the inputs to the calculation.

`class decimal.Inexact`
Indicates that rounding occurred and the result is not exact.

Signals when non-zero digits were discarded during rounding. The rounded result is returned. The signal flag or trap is used to detect when results are inexact.

`class decimal.InvalidOperation`
An invalid operation was performed.

Indicates that an operation was requested that does not make sense. If not trapped, returns NaN. Possible causes include:

```
Infinity - Infinity
0 * Infinity
Infinity / Infinity
x % 0
Infinity % x
sqrt(-x) and x > 0
0 ** 0
x ** (non-integer)
x ** Infinity
```

`class decimal.Overflow`
Numerical overflow.

Indicates the exponent is larger than Emax after rounding has occurred. If not trapped, the result depends on the rounding mode, either pulling inward to the largest representable finite number or rounding outward to Infinity. In either case, `Inexact` and `Rounded` are also signaled.
class decimal.Rounded
Rounding occurred though possibly no information was lost.

Signaled whenever rounding discards digits; even if those digits are zero (such as rounding 5.00 to 5.0). If not trapped, returns the result unchanged. This signal is used to detect loss of significant digits.

class decimal.Subnormal
Exponent was lower than Emin prior to rounding.

Occurs when an operation result is subnormal (the exponent is too small). If not trapped, returns the result unchanged.

class decimal.Underflow
Numerical underflow with result rounded to zero.

Occurs when a subnormal result is pushed to zero by rounding. Inexact and Subnormal are also signaled.

class decimal.FloatOperation
Enable stricter semantics for mixing floats and Decimals.

If the signal is not trapped (default), mixing floats and Decimals is permitted in the Decimal constructor, create_decimal() and all comparison operators. Both conversion and comparisons are exact. Any occurrence of a mixed operation is silently recorded by setting FloatOperation in the context flags. Explicit conversions with from_float() or create_decimal_from_float() do not set the flag.

Otherwise (the signal is trapped), only equality comparisons and explicit conversions are silent. All other mixed operations raise
**FloatOperation.**

The following table summarizes the hierarchy of signals:

<table>
<thead>
<tr>
<th>exceptions.ArithmeticError(exceptions.Exception)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DecimalException</td>
</tr>
<tr>
<td>Clamped</td>
</tr>
<tr>
<td>DivisionByZero(DecimalException, exceptions.</td>
</tr>
<tr>
<td>Inexact</td>
</tr>
<tr>
<td>Overflow(Inexact, Rounded)</td>
</tr>
<tr>
<td>Underflow(Inexact, Rounded, Subnormal)</td>
</tr>
<tr>
<td>InvalidOperation</td>
</tr>
<tr>
<td>Rounded</td>
</tr>
<tr>
<td>Subnormal</td>
</tr>
<tr>
<td>FloatOperation(DecimalException, exceptions.</td>
</tr>
</tbody>
</table>


9.4.7. Floating Point Notes

9.4.7.1. Mitigating round-off error with increased precision

The use of decimal floating point eliminates decimal representation error (making it possible to represent 0.1 exactly); however, some operations can still incur round-off error when non-zero digits exceed the fixed precision.

The effects of round-off error can be amplified by the addition or subtraction of nearly offsetting quantities resulting in loss of significance. Knuth provides two instructive examples where rounded floating point arithmetic with insufficient precision causes the breakdown of the associative and distributive properties of addition:

```python
# Examples from Seminumerical Algorithms, Section 4.
>>> from decimal import Decimal, getcontext
>>> getcontext().prec = 8

>>> u, v, w = Decimal('1111113'), Decimal('-1111111'),
>>> (u + v) + w
Decimal('9.511111')
>>> u + (v + w)
Decimal('10')

>>> u, v, w = Decimal('20000'), Decimal('-6'), Decimal('6.0000003')
>>> (u*v) + (u*w)
Decimal('0.01')
>>> u * (v+w)
Decimal('0.0060000')
```

The `decimal` module makes it possible to restore the identities by
expanding the precision sufficiently to avoid loss of significance:

```python
>>> getcontext().prec = 20
>>> u, v, w = Decimal(11111113), Decimal(-11111111),
>>> (u + v) + w
Decimal('9.51111111')
>>> u + (v + w)
Decimal('9.51111111')
>>> u, v, w = Decimal(20000), Decimal(-6), Decimal('6.0000003')
>>> (u*v) + (u*w)
Decimal('0.0060000')
>>> u * (v+w)
Decimal('0.0060000')
```

### 9.4.7.2. Special values

The number system for the `decimal` module provides special values including `NaN`, `sNaN`, `-Infinity`, `Infinity`, and two zeros, `+0` and `-0`.

Infinities can be constructed directly with: `Decimal('Infinity')`. Also, they can arise from dividing by zero when the `DivisionByZero` signal is not trapped. Likewise, when the `Overflow` signal is not trapped, infinity can result from rounding beyond the limits of the largest representable number.

The infinities are signed (affine) and can be used in arithmetic operations where they get treated as very large, indeterminate numbers. For instance, adding a constant to infinity gives another infinite result.

Some operations are indeterminate and return `NaN`, or if the
InvalidOperation signal is trapped, raise an exception. For example, \(0/0\) returns NaN which means “not a number”. This variety of NaN is quiet and, once created, will flow through other computations always resulting in another NaN. This behavior can be useful for a series of computations that occasionally have missing inputs — it allows the calculation to proceed while flagging specific results as invalid.

A variant is sNaN which signals rather than remaining quiet after every operation. This is a useful return value when an invalid result needs to interrupt a calculation for special handling.

The behavior of Python’s comparison operators can be a little surprising where a NaN is involved. A test for equality where one of the operands is a quiet or signaling NaN always returns False (even when doing Decimal('NaN')==Decimal('NaN')), while a test for inequality always returns True. An attempt to compare two Decimals using any of the \(<\), \(<=\), \(>\) or \(>=\) operators will raise the InvalidOperation signal if either operand is a NaN, and return False if this signal is not trapped. Note that the General Decimal Arithmetic specification does not specify the behavior of direct comparisons; these rules for comparisons involving a NaN were taken from the IEEE 854 standard (see Table 3 in section 5.7). To ensure strict standards-compliance, use the compare() and compare-signal() methods instead.

The signed zeros can result from calculations that underflow. They keep the sign that would have resulted if the calculation had been carried out to greater precision. Since their magnitude is zero, both positive and negative zeros are treated as equal and their sign is informational.
In addition to the two signed zeros which are distinct yet equal, there are various representations of zero with differing precisions yet equivalent in value. This takes a bit of getting used to. For an eye accustomed to normalized floating point representations, it is not immediately obvious that the following calculation returns a value equal to zero:

```python
>>> 1 / Decimal('Infinity')
Decimal('0E-1000026')
```
9.4.8. Working with threads

The `getcontext()` function accesses a different `Context` object for each thread. Having separate thread contexts means that threads may make changes (such as `getcontext().prec=10`) without interfering with other threads.

Likewise, the `setcontext()` function automatically assigns its target to the current thread.

If `setcontext()` has not been called before `getcontext()`, then `getcontext()` will automatically create a new context for use in the current thread.

The new context is copied from a prototype context called `DefaultContext`. To control the defaults so that each thread will use the same values throughout the application, directly modify the `DefaultContext` object. This should be done before any threads are started so that there won’t be a race condition between threads calling `getcontext()`. For example:

```python
# Set applicationwide defaults for all threads about to be launched
DefaultContext.prec = 12
DefaultContext.rounding = ROUND_DOWN
DefaultContext.traps = ExtendedContext.traps.copy()
DefaultContext.traps[InvalidOperation] = 1
setcontext(DefaultContext)

# Afterwards, the threads can be started
t1.start()
t2.start()
t3.start()
...
```
9.4.9. Recipes

Here are a few recipes that serve as utility functions and that demonstrate ways to work with the Decimal class:

```python
def moneyfmt(value, places=2, curr='', sep=' ', dp='.
pos=', neg='-', trailneg=' '):
    """Convert Decimal to a money formatted string.
    places: required number of places after the decimal point
    curr: optional currency symbol before the sign
    sep: optional grouping separator (comma, period, or space)
    dp: decimal point indicator (comma or period)
        only specify as blank when places is zero
    pos: optional sign for positive numbers: '+'
    neg: optional sign for negative numbers: '-'
    trailneg: optional trailing minus indicator: '-'
    >>> d = Decimal('-1234567.8901')
    >>> moneyfmt(d, curr='$')
    '-$1,234,567.89'
    >>> moneyfmt(d, places=0, sep='.', dp='.', neg='')
    '1234568-'
    >>> moneyfmt(d, curr='$', neg='(', trailneg=')')
    '($1,234,567.89)'
    >>> moneyfmt(Decimal(123456789), sep=' ')
    '123 456 789.00'
    >>> moneyfmt(Decimal('-0.02'), neg='<', trailneg='>')
    '<0.02>'
    """

    q = Decimal(10) ** -places  # 2 places --> 2
    sign, digits, exp = value.quantize(q).as_tuple()
    result = []
digits = list(map(str, digits))
```
def pi():
    """Compute Pi to the current precision.\n\n>>> print(pi())
3.141592653589793238462643383\n"""
    getcontext().prec += 2  # extra digits for intermediate steps
    three = Decimal(3)  # substitute "three=3.0" for regular floats
    lasts, t, s, n, na, d, da = 0, three, 3, 1, 0, 0
    while s != lasts:
        lasts = s
        n, na = n+na, na+8
        d, da = d+da, da+32
        t = (t * n) / d
        s += t
    getcontext().prec -= 2
    return s
```python
def exp(x):
    """Return e raised to the power of x. Result type matches input type."
    >>> print(exp(Decimal(1)))
    2.718281828459045235360287471
    >>> print(exp(Decimal(2)))
    7.389056098930650227230427461
    >>> print(exp(2.0))
    7.38905609893
    >>> print(exp(2+0j))
    (7.38905609893+0j)
    """
    getcontext().prec += 2
    i, lasts, s, fact, num = 0, 0, 1, 1, 1
    while s != lasts:
        lasts = s
        i += 1
        fact *= i
        num *= x
        s += num / fact
    getcontext().prec -= 2
    return +s

def cos(x):
    """Return the cosine of x as measured in radians."
    The Taylor series approximation works best for a small value of x.
    For larger values, first compute x = x % (2 * pi)
    >>> print(cos(Decimal('0.5')))
    0.8775825618903727161162815826
    >>> print(cos(0.5))
    0.87758256189
    >>> print(cos(0.5+0j))
```

(0.87758256189+0j)

def sin(x):
    """Return the sine of x as measured in radians.

    The Taylor series approximation works best for a small value of x.
    For larger values, first compute x = x % (2 * pi)
    """
    getcontext().prec += 2
    i, lasts, s, fact, num, sign = 0, 0, 1, 1, 1, 1
    while s != lasts:
        lasts = s
        i += 2
        fact *= i * (i-1)
        num *= x * x
        sign *= -1
        s += num / fact * sign
    getcontext().prec -= 2
    return +s

getcontext().prec += 2
i, lasts, s, fact, num, sign = 1, 0, x, 1, x, 1
while s != lasts:
    lasts = s
    i += 2
    fact *= i * (i-1)
    num *= x * x
    sign *= -1
s += num / fact * sign
getcontext().prec -= 2
return +s
9.4.10. Decimal FAQ

Q. It is cumbersome to type `decimal.Decimal('1234.5')`. Is there a way to minimize typing when using the interactive interpreter?

A. Some users abbreviate the constructor to just a single letter:

```python
>>> D = decimal.Decimal
>>> D('1.23') + D('3.45')
Decimal('4.68')
```

Q. In a fixed-point application with two decimal places, some inputs have many places and need to be rounded. Others are not supposed to have excess digits and need to be validated. What methods should be used?

A. The `quantize()` method rounds to a fixed number of decimal places. If the `Inexact` trap is set, it is also useful for validation:

```python
>>> TWOPLACES = Decimal(10) ** -2  # same as Decimal('0.01')

# Round to two places
>>> Decimal('3.214').quantize(TWOPLACES)
Decimal('3.21')

# Validate that a number does not exceed two places
>>> Decimal('3.21').quantize(TWOPLACES, context=Context)
Decimal('3.21')

>>> Decimal('3.214').quantize(TWOPLACES, context=Context)
Traceback (most recent call last):
...
```
Q. Once I have valid two place inputs, how do I maintain that invariant throughout an application?

A. Some operations like addition, subtraction, and multiplication by an integer will automatically preserve fixed point. Others operations, like division and non-integer multiplication, will change the number of decimal places and need to be followed-up with a `quantize()` step:

```python
>>> a = Decimal('102.72')  # Initial fixed-point values
>>> b = Decimal('3.17')
>>> a + b                   # Addition preserves fixed-point
Decimal('105.89')
>>> a - b                   # Subtraction preserves fixed-point
Decimal('99.55')
>>> a * 42                  # So does integer multiplication
Decimal('4314.24')
>>> (a * b).quantize(TWOPLACES)  # Must quantize non-integer multiplication
Decimal('325.62')
>>> (b / a).quantize(TWOPLACES)  # And quantize division
Decimal('0.03')
```

In developing fixed-point applications, it is convenient to define functions to handle the `quantize()` step:

```python
>>> def mul(x, y, fp=TWOPLACES):
...     return (x * y).quantize(fp)
>>> def div(x, y, fp=TWOPLACES):
...     return (x / y).quantize(fp)
```

```python
>>> mul(a, b)                 # Automatically preserves fixed-point
 Decimal('325.62')
>>> div(b, a)
```
Q. There are many ways to express the same value. The numbers 200, 200.000, 2E2, and 02E+4 all have the same value at various precisions. Is there a way to transform them to a single recognizable canonical value?

A. The normalize() method maps all equivalent values to a single representative:

```python
>>> values = map(Decimal, '200 200.000 2E2 .02E+4'.split)
>>> [v.normalize() for v in values]
[Decimal('2E+2'), Decimal('2E+2'), Decimal('2E+2'), Decimal('2E+2')]
```

Q. Some decimal values always print with exponential notation. Is there a way to get a non-exponential representation?

A. For some values, exponential notation is the only way to express the number of significant places in the coefficient. For example, expressing 5.0E+3 as 5000 keeps the value constant but cannot show the original’s two-place significance.

If an application does not care about tracking significance, it is easy to remove the exponent and trailing zeroes, losing significance, but keeping the value unchanged:

```python
>>> def remove_exponent(d):
...    return d.quantize(Decimal(1)) if d == d.to_integral

>>> remove_exponent(Decimal('5E+3'))
Decimal('5000')
```
Q. Is there a way to convert a regular float to a `Decimal`?

A. Yes, any binary floating point number can be exactly expressed as a Decimal though an exact conversion may take more precision than intuition would suggest:

```
>>> Decimal(math.pi)
Decimal('3.141592653589793115997963468544185161590576171875')
```

Q. Within a complex calculation, how can I make sure that I haven't gotten a spurious result because of insufficient precision or rounding anomalies.

A. The decimal module makes it easy to test results. A best practice is to re-run calculations using greater precision and with various rounding modes. Widely differing results indicate insufficient precision, rounding mode issues, ill-conditioned inputs, or a numerically unstable algorithm.

Q. I noticed that context precision is applied to the results of operations but not to the inputs. Is there anything to watch out for when mixing values of different precisions?

A. Yes. The principle is that all values are considered to be exact and so is the arithmetic on those values. Only the results are rounded. The advantage for inputs is that “what you type is what you get”. A disadvantage is that the results can look odd if you forget that the inputs haven’t been rounded:

```
>>> getcontext().prec = 3
>>> Decimal('3.104') + Decimal('2.104')
Decimal('5.21')
>>> Decimal('3.104') + Decimal('0.000') + Decimal('2
```
The solution is either to increase precision or to force rounding of inputs using the unary plus operation:

```python
>>> getcontext().prec = 3
>>> +Decimal('1.23456789')  # unary plus triggers rounding
Decimal('1.23')
```

Alternatively, inputs can be rounded upon creation using the `Context.create_decimal()` method:

```python
>>> Context(prec=5, rounding=ROUND_DOWN).create_decimal('1.2345')
Decimal('1.2345')
```
The `fractions` module provides support for rational number arithmetic.

A Fraction instance can be constructed from a pair of integers, from another rational number, or from a string.

```python
class fractions.Fraction(numerator=0, denominator=1)
class fractions.Fraction(other_fraction)
class fractions.Fraction(float)
class fractions.Fraction(decimal)
class fractions.Fraction(string)
```

The first version requires that `numerator` and `denominator` are instances of `numbers.Rational` and returns a new `Fraction` instance with value `numerator/denominator`. If `denominator` is 0, it raises a `ZeroDivisionError`. The second version requires that `other_fraction` is an instance of `numbers.Rational` and returns a `Fraction` instance with the same value. The next two versions accept either a `float` or a `decimal.Decimal` instance, and return a `Fraction` instance with exactly the same value. Note that due to the usual issues with binary floating-point (see `Floating Point Arithmetic: Issues and Limitations`), the argument to `Fraction(1.1)` is not exactly equal to 11/10, and so `Fraction(1.1)` does not return `Fraction(11, 10)` as one might expect. (But see the documentation for the
limit_denominator() method below.) The last version of the constructor expects a string or unicode instance. The usual form for this instance is:

```
[sign] numerator [/] denominator
```

where the optional sign may be either ‘+’ or ‘-’ and numerator and denominator (if present) are strings of decimal digits. In addition, any string that represents a finite value and is accepted by the float constructor is also accepted by the Fraction constructor. In either form the input string may also have leading and/or trailing whitespace. Here are some examples:

```
>>> from fractions import Fraction
>>> Fraction(16, -10)
Fraction(-8, 5)
>>> Fraction(123)
Fraction(123, 1)
>>> Fraction()
Fraction(0, 1)
>>> Fraction('3/7')
Fraction(3, 7)
>>> Fraction(' -3/7 ')
Fraction(-3, 7)
>>> Fraction('1.414213 \t\n')
Fraction(1414213, 1000000)
>>> Fraction('- .125')
Fraction(-1, 8)
>>> Fraction('7e-6')
Fraction(7, 10000000)
>>> Fraction(2.25)
Fraction(9, 4)
>>> Fraction(1.1)
Fraction(2476979795053773, 2251799813685248)
>>> from decimal import Decimal
```
The `Fraction` class inherits from the abstract base class `numbers.Rational`, and implements all of the methods and operations from that class. `Fraction` instances are hashable, and should be treated as immutable. In addition, `Fraction` has the following properties and methods:

* **numerator**
  
  Numerator of the `Fraction` in lowest term.

* **denominator**
  
  Denominator of the `Fraction` in lowest term.

* **from_float(flt)**
  
  This class method constructs a `Fraction` representing the exact value of `flt`, which must be a `float`. Beware that `Fraction.from_float(0.3)` is not the same value as `Fraction(3, 10).

  Note: From Python 3.2 onwards, you can also construct a `Fraction` instance directly from a `float`.

* **from_decimal(dec)**
  
  This class method constructs a `Fraction` representing the exact value of `dec`, which must be a `decimal.Decimal` instance.
Note: From Python 3.2 onwards, you can also construct a `Fraction` instance directly from a `decimal.Decimal` instance.

**limit_denominator**(max_denominator=1000000)

Finds and returns the closest `Fraction` to self that has denominator at most max_denominator. This method is useful for finding rational approximations to a given floating-point number:

```python
>>> from fractions import Fraction
>>> Fraction('3.1415926535897932').limit_denominator()
Fraction(355, 113)
```

or for recovering a rational number that's represented as a float:

```python
>>> from math import pi, cos
>>> Fraction(cos(pi / 3))
Fraction(4503599627370497, 9007199254740992)
>>> Fraction(cos(pi / 3)).limit_denominator()
Fraction(1, 2)
>>> Fraction(1.1).limit_denominator()
Fraction(11, 10)
```

**__floor__**( )

Returns the greatest `int` <= self. This method can also be accessed through the `math.floor()` function:

```python
>>> from math import floor
>>> floor(Fraction(355, 113))
3
```

**__ceil__**( )

...
Returns the least \texttt{int} >= \texttt{self}. This method can also be accessed through the \texttt{math.ceil()} function.

\begin{verbatim}
__round__()
__round__(ndigits)
\end{verbatim}

The first version returns the nearest \texttt{int} to \texttt{self}, rounding half to even. The second version rounds \texttt{self} to the nearest multiple of \texttt{Fraction(1, 10**ndigits)} (logically, if \texttt{ndigits} is negative), again rounding half toward even. This method can also be accessed through the \texttt{round()} function.

\texttt{fractions.gcd(a, b)}

Return the greatest common divisor of the integers \texttt{a} and \texttt{b}. If either \texttt{a} or \texttt{b} is nonzero, then the absolute value of \texttt{gcd(a, b)} is the largest integer that divides both \texttt{a} and \texttt{b}. \texttt{gcd(a,b)} has the same sign as \texttt{b} if \texttt{b} is nonzero; otherwise it takes the sign of \texttt{a}. \texttt{gcd(0, 0)} returns 0.

\textit{Deprecated since version 3.5: Use math.gcd()} instead.

\textbf{See also:}

\textbf{Module numbers}

The abstract base classes making up the numeric tower.
This module implements pseudo-random number generators for various distributions.

For integers, there is uniform selection from a range. For sequences, there is uniform selection of a random element, a function to generate a random permutation of a list in-place, and a function for random sampling without replacement.

On the real line, there are functions to compute uniform, normal (Gaussian), lognormal, negative exponential, gamma, and beta distributions. For generating distributions of angles, the von Mises distribution is available.

Almost all module functions depend on the basic function `random()`, which generates a random float uniformly in the semi-open range \([0.0, 1.0)\). Python uses the Mersenne Twister as the core generator. It produces 53-bit precision floats and has a period of \(2^{19937}-1\). The underlying implementation in C is both fast and threadsafe. The Mersenne Twister is one of the most extensively tested random number generators in existence. However, being completely deterministic, it is not suitable for all purposes, and is completely unsuitable for cryptographic purposes.

The functions supplied by this module are actually bound methods of a hidden instance of the `random.Random` class. You can instantiate
your own instances of Random to get generators that don’t share state.

Class Random can also be subclassed if you want to use a different basic generator of your own devising: in that case, override the random(), seed(), getstate(), and setstate() methods. Optionally, a new generator can supply a getrandbits() method — this allows randrange() to produce selections over an arbitrarily large range.

The random module also provides the SystemRandom class which uses the system function os.urandom() to generate random numbers from sources provided by the operating system.

**Warning:** The pseudo-random generators of this module should not be used for security purposes.

Bookkeeping functions:

random.seed(a=None, version=2)

Initialize the random number generator.

If a is omitted or None, the current system time is used. If randomness sources are provided by the operating system, they are used instead of the system time (see the os.urandom() function for details on availability).

If a is an int, it is used directly.

With version 2 (the default), a str, bytes, or bytearray object gets converted to an int and all of its bits are used. With version 1, the hash() of a is used instead.

*Changed in version 3.2:* Moved to the version 2 scheme which
uses all of the bits in a string seed.

random.getstate()

Return an object capturing the current internal state of the generator. This object can be passed to setstate() to restore the state.

random.setstate(state)

state should have been obtained from a previous call to getstate(), and setstate() restores the internal state of the generator to what it was at the time getstate() was called.

random.getrandbits(k)

Returns a Python integer with k random bits. This method is supplied with the MersenneTwister generator and some other generators may also provide it as an optional part of the API. When available, getrandbits() enables randrange() to handle arbitrarily large ranges.

Functions for integers:

random.randrange(stop)

random.randrange(start, stop[, step])

Return a randomly selected element from range(start, stop, step). This is equivalent to choice(range(start, stop, step)), but doesn't actually build a range object.

The positional argument pattern matches that of range(). Keyword arguments should not be used because the function may use them in unexpected ways.

*Changed in version 3.2:* randrange() is more sophisticated
about producing equally distributed values. Formerly it used a style like `int(random() * n)` which could produce slightly uneven distributions.

random.randint(a, b)

Return a random integer \( N \) such that \( a \leq N \leq b \). Alias for `randrange(a, b+1)`.

Functions for sequences:

random.choice(seq)

Return a random element from the non-empty sequence `seq`. If `seq` is empty, raises `IndexError`.

random.shuffle(x[, random])

Shuffle the sequence `x` in place. The optional argument `random` is a 0-argument function returning a random float in \([0.0, 1.0)\); by default, this is the function `random()`.

Note that for even rather small \( \text{len}(x) \), the total number of permutations of \( x \) is larger than the period of most random number generators; this implies that most permutations of a long sequence can never be generated.

random.sample(population, k)

Return a \( k \) length list of unique elements chosen from the population sequence or set. Used for random sampling without replacement.

Returns a new list containing elements from the population while leaving the original population unchanged. The resulting list is in selection order so that all sub-slices will also be valid random
samples. This allows raffle winners (the sample) to be partitioned into grand prize and second place winners (the subslices).

Members of the population need not be hashable or unique. If the population contains repeats, then each occurrence is a possible selection in the sample.

To choose a sample from a range of integers, use an \texttt{range()} object as an argument. This is especially fast and space efficient for sampling from a large population: \texttt{sample(range(10000000), 60)}.

If the sample size is larger than the population size, a \texttt{ValueError} is raised.

The following functions generate specific real-valued distributions. Function parameters are named after the corresponding variables in the distribution’s equation, as used in common mathematical practice; most of these equations can be found in any statistics text.

\texttt{random.random()}

Return the next random floating point number in the range [0.0, 1.0).

\texttt{random.uniform(a, b)}

Return a random floating point number \( N \) such that \( a \leq N \leq b \) for \( a \leq b \) and \( b \leq N \leq a \) for \( b < a \).

The end-point value \( b \) may or may not be included in the range depending on floating-point rounding in the equation \( a + (b-a) \times \texttt{random()} \).

\texttt{random.triangular(low, high, mode)}
Return a random floating point number \( N \) such that \( \text{low} \leq N \leq \text{high} \) and with the specified \( \text{mode} \) between those bounds. The \( \text{low} \) and \( \text{high} \) bounds default to zero and one. The \( \text{mode} \) argument defaults to the midpoint between the bounds, giving a symmetric distribution.

\[
\text{random.}\text{betavariate}(\alpha, \beta)
\]
Beta distribution. Conditions on the parameters are \( \alpha > 0 \) and \( \beta > 0 \). Returned values range between 0 and 1.

\[
\text{random.}\text{expovariate}(\lambda)
\]
Exponential distribution. \( \lambda \) is 1.0 divided by the desired mean. It should be nonzero. (The parameter would be called “lambda”, but that is a reserved word in Python.) Returned values range from 0 to positive infinity if \( \lambda \) is positive, and from negative infinity to 0 if \( \lambda \) is negative.

\[
\text{random.}\text{gammavariate}(\alpha, \beta)
\]
Gamma distribution. (Not the gamma function!) Conditions on the parameters are \( \alpha > 0 \) and \( \beta > 0 \).

The probability distribution function is:
\[
\text{pdf}(x) = \frac{x^{(\alpha - 1)} \times \exp(-x/\beta)}{\Gamma(\alpha) \times \beta^\alpha}
\]

\[
\text{random.}\text{gauss}(\mu, \sigma)
\]
Gaussian distribution. \( \mu \) is the mean, and \( \sigma \) is the standard deviation. This is slightly faster than the \text{normalvariate()} function defined below.

\[
\text{random.}\text{lognormvariate}(\mu, \sigma)
\]
Log normal distribution. If you take the natural logarithm of this distribution, you’ll get a normal distribution with mean \( \mu \) and standard deviation \( \sigma \). \( \mu \) can have any value, and \( \sigma \) must be greater than zero.

```python
random.normalvariate(mu, sigma)
```

Normal distribution. \( \mu \) is the mean, and \( \sigma \) is the standard deviation.

```python
random.vonmisesvariate(mu, kappa)
```

\( \mu \) is the mean angle, expressed in radians between 0 and \( 2\pi \), and \( \kappa \) is the concentration parameter, which must be greater than or equal to zero. If \( \kappa \) is equal to zero, this distribution reduces to a uniform random angle over the range 0 to \( 2\pi \).

```python
random.paretovariate(alpha)
```

Pareto distribution. \( \alpha \) is the shape parameter.

```python
random.weibullvariate(alpha, beta)
```

Weibull distribution. \( \alpha \) is the scale parameter and \( \beta \) is the shape parameter.

Alternative Generator:

```python
class random.SystemRandom([seed])
```

Class that uses the `os.urandom()` function for generating random numbers from sources provided by the operating system. Not available on all systems. Does not rely on software state, and sequences are not reproducible. Accordingly, the `seed()` method has no effect and is ignored. The `getstate()` and `setstate()` methods raise `NotImplementedError` if called.

Complementary-Multiply-with-Carry recipe for a compatible alternative random number generator with a long period and comparatively simple update operations.
9.6.1. Notes on Reproducibility

Sometimes it is useful to be able to reproduce the sequences given by a pseudo random number generator. By re-using a seed value, the same sequence should be reproducible from run to run as long as multiple threads are not running.

Most of the random module’s algorithms and seeding functions are subject to change across Python versions, but two aspects are guaranteed not to change:

- If a new seeding method is added, then a backward compatible seeder will be offered.
- The generator’s `random()` method will continue to produce the same sequence when the compatible seeder is given the same seed.
9.6.2. Examples and Recipes

Basic usage:

```python
>>> random.random()  # Random float, 0.0 <= x < 1.0
0.3744887175646646

>>> random.uniform(1, 10)  # Random float, 1.0 <= x < 10.0
1.1800146073117523

>>> random.randrange(10)  # Integer from 0 to 9
7

>>> random.randrange(0, 101, 2)  # Even integer from 0 to 100
26

>>> random.choice('abcdefghij')  # Single random element
'c'

>>> items = [1, 2, 3, 4, 5, 6, 7]
>>> random.shuffle(items)
>>> items
[7, 3, 2, 5, 6, 4, 1]

>>> random.sample([1, 2, 3, 4, 5], 3)  # Three samples without replacement
[4, 1, 5]
```

A common task is to make a `random.choice()` with weighted probabilities.

If the weights are small integer ratios, a simple technique is to build a sample population with repeats:

```python
>>> weighted_choices = [('Red', 3), ('Blue', 2), ('Yellow', 1)]
>>> random.choice(weighted_choices)
('Red', 3)
```
A more general approach is to arrange the weights in a cumulative distribution with `itertools.accumulate()`, and then locate the random value with `bisect.bisect()`:

```python
>>> choices, weights = zip(*weighted_choices)
>>> cumdist = list(itertools.accumulate(weights))
>>> x = random.random() * cumdist[-1]
>>> choices[bisect.bisect(cumdist, x)]
'Blue'
```
9.7. **statistics** — Mathematical statistics functions

*New in version 3.4.*

**Source code:** Lib/statistics.py

This module provides functions for calculating mathematical statistics of numeric (Real-valued) data.

**Note:** Unless explicitly noted otherwise, these functions support `int`, `float`, `decimal.Decimal` and `fractions.Fraction`. Behaviour with other types (whether in the numeric tower or not) is currently unsupported. Mixed types are also undefined and implementation-dependent. If your input data consists of mixed types, you may be able to use `map()` to ensure a consistent result, e.g. `map(float, input_data).`
9.7.1. Averages and measures of central location

These functions calculate an average or typical value from a population or sample.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean()</td>
<td>Arithmetic mean (“average”) of data.</td>
</tr>
<tr>
<td>median()</td>
<td>Median (middle value) of data.</td>
</tr>
<tr>
<td>median_low()</td>
<td>Low median of data.</td>
</tr>
<tr>
<td>median_high()</td>
<td>High median of data.</td>
</tr>
<tr>
<td>median_grouped()</td>
<td>Median, or 50th percentile, of grouped data.</td>
</tr>
<tr>
<td>mode()</td>
<td>Mode (most common value) of discrete data.</td>
</tr>
</tbody>
</table>
9.7.2. Measures of spread

These functions calculate a measure of how much the population or sample tends to deviate from the typical or average values.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pstdev()</td>
<td>Population standard deviation of data.</td>
</tr>
<tr>
<td>pvariance()</td>
<td>Population variance of data.</td>
</tr>
<tr>
<td>stdev()</td>
<td>Sample standard deviation of data.</td>
</tr>
<tr>
<td>variance()</td>
<td>Sample variance of data.</td>
</tr>
</tbody>
</table>
9.7.3. Function details

Note: The functions do not require the data given to them to be sorted. However, for reading convenience, most of the examples show sorted sequences.

`statistics.mean(data)`

Return the sample arithmetic mean of `data`, a sequence or iterator of real-valued numbers.

The arithmetic mean is the sum of the data divided by the number of data points. It is commonly called “the average”, although it is only one of many different mathematical averages. It is a measure of the central location of the data.

If `data` is empty, `StatisticsError` will be raised.

Some examples of use:

```python
>>> mean([1, 2, 3, 4, 4])
2.8
>>> mean([-1.0, 2.5, 3.25, 5.75])
2.625
>>> from fractions import Fraction as F
>>> mean([F(3, 7), F(1, 21), F(5, 3), F(1, 3)])
Fraction(13, 21)
>>> from decimal import Decimal as D
>>> mean([D('0.5'), D('0.75'), D('0.625'), D('0.3')])
Decimal('0.5625')
```

Note: The mean is strongly affected by outliers and is not a
robust estimator for central location: the mean is not necessarily a typical example of the data points. For more robust, although less efficient, measures of central location, see `median()` and `mode()`. (In this case, “efficient” refers to statistical efficiency rather than computational efficiency.) The sample mean gives an unbiased estimate of the true population mean, which means that, taken on average over all the possible samples, mean(sample) converges on the true mean of the entire population. If `data` represents the entire population rather than a sample, then mean(data) is equivalent to calculating the true population mean μ.

```
statistics.median(data)
```

Return the median (middle value) of numeric data, using the common “mean of middle two” method. If `data` is empty, `StatisticsError` is raised.

The median is a robust measure of central location, and is less affected by the presence of outliers in your data. When the number of data points is odd, the middle data point is returned:

```
>>> median([1, 3, 5])
3
```

When the number of data points is even, the median is interpolated by taking the average of the two middle values:

```
>>> median([1, 3, 5, 7])
4.0
```

This is suited for when your data is discrete, and you don’t mind that the median may not be an actual data point.
See also: median_low(), median_high(), median_grouped()

statistics.median_low(data)
Return the low median of numeric data. If data is empty, StatisticsError is raised.

The low median is always a member of the data set. When the number of data points is odd, the middle value is returned. When it is even, the smaller of the two middle values is returned.

```python
>>> median_low([1, 3, 5])
3
>>> median_low([1, 3, 5, 7])
3
```

Use the low median when your data are discrete and you prefer the median to be an actual data point rather than interpolated.

statistics.median_high(data)
Return the high median of data. If data is empty, StatisticsError is raised.

The high median is always a member of the data set. When the number of data points is odd, the middle value is returned. When it is even, the larger of the two middle values is returned.

```python
>>> median_high([1, 3, 5])
3
>>> median_high([1, 3, 5, 7])
5
```

Use the high median when your data are discrete and you prefer
the median to be an actual data point rather than interpolated.

```
>>> median_grouped([52, 52, 53, 54])
52.5
```

In the following example, the data are rounded, so that each value represents the midpoint of data classes, e.g. 1 is the midpoint of the class 0.5-1.5, 2 is the midpoint of 1.5-2.5, 3 is the midpoint of 2.5-3.5, etc. With the data given, the middle value falls somewhere in the class 3.5-4.5, and interpolation is used to estimate it:

```
>>> median_grouped([1, 2, 2, 3, 4, 4, 4, 4, 4, 5])
3.7
```

Optional argument `interval` represents the class interval, and defaults to 1. Changing the class interval naturally will change the interpolation:

```
>>> median_grouped([1, 3, 3, 5, 7], interval=1)
3.25
>>> median_grouped([1, 3, 3, 5, 7], interval=2)
3.5
```

This function does not check whether the data points are at least `interval` apart.

**CPython implementation detail:** Under some circumstances, `median_grouped()` may coerce data points to floats. This
behaviour is likely to change in the future.

**See also:**
- Calculating the median.
- The SSMEDIAN function in the Gnome Gnumeric spreadsheet, including this discussion.

```python
>>> mode([1, 1, 2, 3, 3, 3, 3, 4])
3
```

The mode is unique in that it is the only statistic which also applies to nominal (non-numeric) data:

```python
>>> mode(['red', 'blue', 'blue', 'red', 'green', 'red'])
'red'
```

**statistics.pstdev(data, mu=None)**

Return the population standard deviation (the square root of the population variance). See pvariance() for arguments and other details.
statistics.pvariance(data, mu=None)

Return the population variance of data, a non-empty iterable of real-valued numbers. Variance, or second moment about the mean, is a measure of the variability (spread or dispersion) of data. A large variance indicates that the data is spread out; a small variance indicates it is clustered closely around the mean.

If the optional second argument mu is given, it should be the mean of data. If it is missing or None (the default), the mean is automatically calculated.

Use this function to calculate the variance from the entire population. To estimate the variance from a sample, the variance() function is usually a better choice.

Raises StatisticsError if data is empty.

Examples:

```python
generate code here
```

If you have already calculated the mean of your data, you can pass it as the optional second argument mu to avoid recalculation:
This function does not attempt to verify that you have passed the actual mean as $mu$. Using arbitrary values for $mu$ may lead to invalid or impossible results.

Decimals and Fractions are supported:

```python
>>> from decimal import Decimal as D
>>> pvariance([D("27.5"), D("30.25"), D("30.25"), Decimal('24.815')
```

```python
>>> from fractions import Fraction as F
>>> pvariance([F(1, 4), F(5, 4), F(1, 2)])
Fraction(13, 72)
```

**Note:** When called with the entire population, this gives the population variance $\sigma^2$. When called on a sample instead, this is the biased sample variance $s^2$, also known as variance with $N$ degrees of freedom.

If you somehow know the true population mean $\mu$, you may use this function to calculate the variance of a sample, giving the known population mean as the second argument. Provided the data points are representative (e.g. independent and identically distributed), the result will be an unbiased estimate of the population variance.

```
statistics.stdev(data, xbar=None)
```

Return the sample standard deviation (the square root of the sample variance). See `variance()` for arguments and other details.

```python
>>> stdev([1.5, 2.5, 2.5, 2.75, 3.25, 4.75])
1.0810874155219827
```
statistics.variance(data, xbar=None)

Return the sample variance of data, an iterable of at least two real-valued numbers. Variance, or second moment about the mean, is a measure of the variability (spread or dispersion) of data. A large variance indicates that the data is spread out; a small variance indicates it is clustered closely around the mean.

If the optional second argument xbar is given, it should be the mean of data. If it is missing or None (the default), the mean is automatically calculated.

Use this function when your data is a sample from a population. To calculate the variance from the entire population, see pvariance().

Raises StatisticsError if data has fewer than two values.

Examples:

```python
>>> data = [2.75, 1.75, 1.25, 0.25, 0.5, 1.25, 3.]
>>> variance(data)
1.3720238095238095
```

If you have already calculated the mean of your data, you can pass it as the optional second argument xbar to avoid recalculation:

```python
>>> m = mean(data)
>>> variance(data, m)
1.3720238095238095
```

This function does not attempt to verify that you have passed the actual mean as xbar. Using arbitrary values for xbar can lead to invalid or impossible results.
Decimal and Fraction values are supported:

```python
>>> from decimal import Decimal as D
>>> variance([D("27.5"), D("30.25"), D("30.25"), D('31.01875')]

>>> from fractions import Fraction as F
>>> variance([F(1, 6), F(1, 2), F(5, 3)])
Fraction(67, 108)
```

**Note:** This is the sample variance $s^2$ with Bessel's correction, also known as variance with N-1 degrees of freedom. Provided that the data points are representative (e.g. independent and identically distributed), the result should be an unbiased estimate of the true population variance.

If you somehow know the actual population mean $\mu$ you should pass it to the `pvariance()` function as the `mu` parameter to get the variance of a sample.
9.7.4. Exceptions

A single exception is defined:

```
exception statistics.StatisticsError
```

Subclass of `ValueError` for statistics-related exceptions.
10. Functional Programming Modules

The modules described in this chapter provide functions and classes that support a functional programming style, and general operations on callables.

The following modules are documented in this chapter:

- **10.1. itertools** — Functions creating iterators for efficient looping
  - 10.1.1. Itertool functions
  - 10.1.2. Itertools Recipes
- **10.2. functools** — Higher-order functions and operations on callable objects
  - 10.2.1. partial Objects
- **10.3. operator** — Standard operators as functions
  - 10.3.1. Mapping Operators to Functions
  - 10.3.2. Inplace Operators
10.1. **itertools** — Functions creating iterators for efficient looping

This module implements a number of iterator building blocks inspired by constructs from APL, Haskell, and SML. Each has been recast in a form suitable for Python.

The module standardizes a core set of fast, memory efficient tools that are useful by themselves or in combination. Together, they form an “iterator algebra” making it possible to construct specialized tools succinctly and efficiently in pure Python.

For instance, SML provides a tabulation tool: `tabulate(f)` which produces a sequence \( f(0), f(1), \ldots \). The same effect can be achieved in Python by combining `map()` and `count()` to form `map(f, count())`.

These tools and their built-in counterparts also work well with the high-speed functions in the `operator` module. For example, the multiplication operator can be mapped across two vectors to form an efficient dot-product: `sum(map(operator.mul, vector1, vector2))`.

**Infinite Iterators:**

<table>
<thead>
<tr>
<th>Iterator</th>
<th>Arguments</th>
<th>Results</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>count()</code></td>
<td>start, [step]</td>
<td>start, start+step, start+2*step, ...</td>
<td><code>count(10) --&gt; 10 11 12 13 14 ...</code></td>
</tr>
</tbody>
</table>
### cycle()

**p**

\[p_0, p_1, \ldots, p_{last}, p_0, p_1, \ldots\]

- **Example:**
  - `cycle('ABCD')` --> A B C D A B C D ...

### repeat()

**elem**, **[n]**

elem, elem, elem, \ldots endlessly or up to n times

- **Example:**
  - `repeat(10, 3)` --> 10 10 10

---

**Iterators terminating on the shortest input sequence:**

<table>
<thead>
<tr>
<th>Iterator</th>
<th>Arguments</th>
<th>Results</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>accumulate()</td>
<td>p , [func]</td>
<td>p0, p0+p1, p0+p1+p2, \ldots</td>
<td>accumulate([1, 2, 3, 4, 5]) 1 3 10</td>
</tr>
<tr>
<td>chain()</td>
<td>p, q, ...</td>
<td>p0, p1, ... plast, q0, q1, ...</td>
<td>chain('ABC', 'DEF')</td>
</tr>
<tr>
<td>chain.from_iterable()</td>
<td>iterable</td>
<td>p0, p1, ... plast, q0, q1, ...</td>
<td>chain.from_iterable(['ABC', 'DEF'])</td>
</tr>
<tr>
<td>compress()</td>
<td>data, selectors</td>
<td>(d[0] if s[0]), (d[1] if s[1]), ...</td>
<td>compress('ABCDEF', [1, 0, 1, 0, 1, 1])</td>
</tr>
<tr>
<td>dropwhile()</td>
<td>pred, seq</td>
<td>seq[n], seq[n+1], starting when pred fails</td>
<td>dropwhile(lambda range(10))</td>
</tr>
<tr>
<td>filterfalse()</td>
<td>pred, seq</td>
<td>elements of seq where pred(elem) is false</td>
<td>filterfalse([1, 2, 3, 4, 5, 0])</td>
</tr>
<tr>
<td>groupby()</td>
<td>iterable[, keyfunc]</td>
<td>sub-iterators grouped by value of keyfunc(v)</td>
<td>groupby('AAAABBBCCCD')</td>
</tr>
<tr>
<td>islice()</td>
<td>seq, [start[, stop [, step]]]</td>
<td>elements from seq[start:stop:step]</td>
<td>islice('ABCDEFG')</td>
</tr>
<tr>
<td>starmap()</td>
<td>func, seq</td>
<td>func(*seq[0]), func(*seq[1]), ...</td>
<td>starmap(pow, (10, 3))</td>
</tr>
</tbody>
</table>

---
<table>
<thead>
<tr>
<th>Function</th>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>takewhile()</td>
<td>pred, seq</td>
<td>pred fails</td>
</tr>
<tr>
<td>tee()</td>
<td>it, n</td>
<td>it1, it2, ... itn splits one iterator into n</td>
</tr>
<tr>
<td>zip_longest()</td>
<td>p, q, ...</td>
<td>(p[0], q[0]), (p[1], q[1]), ...</td>
</tr>
</tbody>
</table>

**Combinatoric generators:**

<table>
<thead>
<tr>
<th>Iterator</th>
<th>Arguments</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>product()</td>
<td>p, q, ... [repeat=1]</td>
<td>cartesian product, equivalent to a nested for loop</td>
</tr>
<tr>
<td>permutations()</td>
<td>p[r]</td>
<td>r-length tuples, all possible orderings, no repeated elements</td>
</tr>
<tr>
<td>combinations()</td>
<td>p, r</td>
<td>r-length tuples, in sorted order, no repeated elements</td>
</tr>
<tr>
<td>combinations_with_replacement()</td>
<td>p, r</td>
<td>r-length tuples, in sorted order, with repeated elements</td>
</tr>
<tr>
<td>Function</td>
<td>Result</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td><code>product('ABCD', repeat=2)</code></td>
<td>AA, AC, BA, BC, CA, CC, DA, DC</td>
<td></td>
</tr>
<tr>
<td><code>permutations('ABCD', 2)</code></td>
<td>AB, AD, BC, CA, CD, DB</td>
<td></td>
</tr>
<tr>
<td><code>combinations('ABCD', 2)</code></td>
<td>AB, AD, BD</td>
<td></td>
</tr>
<tr>
<td><code>combinations_with_replacement('ABCD', 2)</code></td>
<td>AA, AC, BB, BD, CD</td>
<td></td>
</tr>
</tbody>
</table>
10.1.1. Itertool functions

The following module functions all construct and return iterators. Some provide streams of infinite length, so they should only be accessed by functions or loops that truncate the stream.

**itertools.accumulate(iterable[, func])**

Make an iterator that returns accumulated sums, or accumulated results of other binary functions (specified via the optional `func` argument). If `func` is supplied, it should be a function of two arguments. Elements of the input `iterable` may be any type that can be accepted as arguments to `func`. (For example, with the default operation of addition, elements may be any addable type including `Decimal` or `Fraction`.) If the input iterable is empty, the output iterable will also be empty.

Equivalent to:

```python
def accumulate(iterable, func=operator.add):
    'Return running totals'
    # accumulate([1,2,3,4,5]) --> 1 3 6 10 15
    # accumulate([1,2,3,4,5], operator.mul) --> 1
    it = iter(iterable)
    try:
        total = next(it)
    except StopIteration:
        return
    yield total
    for element in it:
        total = func(total, element)
    yield total
```
There are a number of uses for the `func` argument. It can be set to `min()` for a running minimum, `max()` for a running maximum, or `operator.mul()` for a running product. Amortization tables can be built by accumulating interest and applying payments. First-order recurrence relations can be modeled by supplying the initial value in the iterable and using only the accumulated total in `func` argument:

```python
>>> data = [3, 4, 6, 2, 1, 9, 0, 7, 5, 8]
>>> list(accumulate(data, operator.mul))  # running product
[3, 12, 72, 144, 144, 0, 0, 0, 0]

>>> list(accumulate(data, max))          # running maximum
[3, 4, 6, 6, 9, 9, 9, 9, 9]

# Amortize a 5% loan of 1000 with 4 annual payments
>>> cashflows = [1000, -90, -90, -90, -90]
>>> list(accumulate(cashflows, lambda bal, pmt: bal))
[1000, 960.0, 918.0, 873.9000000000001, 827.5950000000001]

# Chaotic recurrence relation http://en.wikipedia.org/wiki/Logistic_map
>>> logistic_map = lambda x, _: r * x * (1 - x)
>>> r = 3.8
>>> x0 = 0.4
>>> inputs = repeat(x0, 36)  # only the initial value is used
>>> [format(x, '.2f') for x in accumulate(inputs, logistic_map)]
['0.40', '0.91', '0.30', '0.81', '0.60', '0.92', '0.88', '0.39', '0.90', '0.33', '0.84', '0.52', '0.93', '0.25', '0.71', '0.79', '0.63', '0.88', '0.83', '0.54', '0.95', '0.20', '0.60', '0.91', ...]
```

See `functools.reduce()` for a similar function that returns only the final accumulated value.

*New in version 3.2.*
*Changed in version 3.3:* Added the optional `func` parameter.

`itertools.chain(*iterables)`

Make an iterator that returns elements from the first iterable until it is exhausted, then proceeds to the next iterable, until all of the iterables are exhausted. Used for treating consecutive sequences as a single sequence. Equivalent to:

```python
def chain(*iterables):
    # chain('ABC', 'DEF') --> A B C D E F
    for it in iterables:
        for element in it:
            yield element
```

`classmethod chain.from_iterable(iterable)`

Alternate constructor for `chain()`. Gets chained inputs from a single iterable argument that is evaluated lazily. Roughly equivalent to:

```python
def from_iterable(iterables):
    # chain.from_iterable(['ABC', 'DEF']) --> A B
    for it in iterables:
        for element in it:
            yield element
```

`itertools.combinations(iterable, r)`

Return `r` length subsequences of elements from the input `iterable`.

Combinations are emitted in lexicographic sort order. So, if the input `iterable` is sorted, the combination tuples will be produced in sorted order.

Elements are treated as unique based on their position, not on their
value. So if the input elements are unique, there will be no repeat values in each combination.

Equivalent to:

```python
def combinations(iterable, r):
    # combinations('ABCD', 2) --> AB AC AD BC BD
    # combinations(range(4), 3) --> 012 013 023 1
    pool = tuple(iterable)
    n = len(pool)
    if r > n:
        return
    indices = list(range(r))
yield tuple(pool[i] for i in indices)
while True:
    for i in reversed(range(r)):
        if indices[i] != i + n - r:
            break
    else:
        return
    indices[i] += 1
for j in range(i+1, r):
    indices[j] = indices[j-1] + 1
yield tuple(pool[i] for i in indices)
```

The code for `combinations()` can be also expressed as a subsequence of `permutations()` after filtering entries where the elements are not in sorted order (according to their position in the input pool):

```python
def combinations(iterable, r):
    pool = tuple(iterable)
    n = len(pool)
    for indices in permutations(range(n), r):
        if sorted(indices) == list(indices):
            yield tuple(pool[i] for i in indices)
```
The number of items returned is \( n! / r! / (n-r)! \) when \( 0 \leq r \leq n \) or zero when \( r > n \).

**itertools.combinations_with_replacement(iterable, r)**

Return \( r \) length subsequences of elements from the input `iterable` allowing individual elements to be repeated more than once.

Combinations are emitted in lexicographic sort order. So, if the input `iterable` is sorted, the combination tuples will be produced in sorted order.

Elements are treated as unique based on their position, not on their value. So if the input elements are unique, the generated combinations will also be unique.

Equivalent to:

```python
def combinations_with_replacement(iterable, r):
    # combinations_with_replacement('ABC', 2) -->
    pool = tuple(iterable)
    n = len(pool)
    if not n and r:
        return
    indices = [0] * r
    yield tuple(pool[i] for i in indices)
    while True:
        for i in reversed(range(r)):
            if indices[i] != n - 1:
                break
        else:
            return
        indices[i:] = [indices[i] + 1] * (r - i)
    yield tuple(pool[i] for i in indices)
```
The code for `combinations_with_replacement()` can be also expressed as a subsequence of `product()` after filtering entries where the elements are not in sorted order (according to their position in the input pool):

```python
def combinations_with_replacement(iterable, r):
    pool = tuple(iterable)
    n = len(pool)
    for indices in product(range(n), repeat=r):
        if sorted(indices) == list(indices):
            yield tuple(pool[i] for i in indices)
```

The number of items returned is \((n+r-1)! / r! / (n-1)!\) when \(n > 0\).

*New in version 3.1.*

`itertools.compress(data, selectors)`

Make an iterator that filters elements from `data` returning only those that have a corresponding element in `selectors` that evaluates to True. Stops when either the `data` or `selectors` iterables has been exhausted. Equivalent to:

```python
def compress(data, selectors):
    # compress('ABCDEF', [1,0,1,0,1,1]) --> A C E
    return (d for d, s in zip(data, selectors) if
```

*New in version 3.1.*

`itertools.count(start=0, step=1)`

Make an iterator that returns evenly spaced values starting with
number \textit{start}. Often used as an argument to \texttt{map()} to generate consecutive data points. Also, used with \texttt{zip()} to add sequence numbers. Equivalent to:

```python
def count(start=0, step=1):
    # count(10) --> 10 11 12 13 14 ...
    # count(2.5, 0.5) --> 2.5 3.0 3.5 ...
    n = start
    while True:
        yield n
        n += step
```

When counting with floating point numbers, better accuracy can sometimes be achieved by substituting multiplicative code such as: \( (\text{start + step } \ast i \text{ for } i \text{ in count()}) \).

\textit{Changed in version 3.1}: Added \textit{step} argument and allowed non-integer arguments.

\texttt{itertools.cycle(iterable)}

Make an iterator returning elements from the iterable and saving a copy of each. When the iterable is exhausted, return elements from the saved copy. Repeats indefinitely. Equivalent to:

```python
def cycle(iterable):
    # cycle('ABCD') --> A B C D A B C D A B C D ...
    saved = []
    for element in iterable:
        yield element
        saved.append(element)
    while saved:
        for element in saved:
            yield element
```
Note, this member of the toolkit may require significant auxiliary storage (depending on the length of the iterable).

**itertools.dropwhile**(predicate, iterable)

Make an iterator that drops elements from the iterable as long as the predicate is true; afterwards, returns every element. Note, the iterator does not produce any output until the predicate first becomes false, so it may have a lengthy start-up time. Equivalent to:

```python
def dropwhile(predicate, iterable):
    # dropwhile(lambda x: x<5, [1,4,6,4,1]) --> 6
    iterable = iter(iterable)
    for x in iterable:
        if not predicate(x):
            yield x
        break
    for x in iterable:
        yield x
```

**itertools.filterfalse**(predicate, iterable)

Make an iterator that filters elements from iterable returning only those for which the predicate is False. If *predicate* is None, return the items that are false. Equivalent to:

```python
def filterfalse(predicate, iterable):
    # filterfalse(lambda x: x%2, range(10)) --> 0
    if predicate is None:
        predicate = bool
    for x in iterable:
        if not predicate(x):
            yield x
```
**itertools.groupby(iterable, key=None)**

Make an iterator that returns consecutive keys and groups from the *iterable*. The *key* is a function computing a key value for each element. If not specified or is None, *key* defaults to an identity function and returns the element unchanged. Generally, the iterable needs to already be sorted on the same key function.

The operation of `groupby()` is similar to the `uniq` filter in Unix. It generates a break or new group every time the value of the key function changes (which is why it is usually necessary to have sorted the data using the same key function). That behavior differs from SQL's GROUP BY which aggregates common elements regardless of their input order.

The returned group is itself an iterator that shares the underlying iterable with `groupby()`. Because the source is shared, when the `groupby()` object is advanced, the previous group is no longer visible. So, if that data is needed later, it should be stored as a list:

```python
groups = []
uniquekeys = []
data = sorted(data, key=keyfunc)
for k, g in groupby(data, keyfunc):
    groups.append(list(g))  # Store group iterator
    uniquekeys.append(k)
```

`groupby()` is equivalent to:

```python
class groupby:
    # [k for k, g in groupby('AAAABBBCCDAABBB')]  # [A, B, C, D, A, B]
    # [list(g) for k, g in groupby('AAAABBBCCD')]  # [[A, A, A], [B, B, B], [C, C], [D]]
    def __init__(self, iterable, key=None):
        if key is None:
```
key = lambda x: x
self.keyfunc = key
self.it = iter(iterable)
self.tgtkey = self.currkey = self.currval

def __iter__(self):
    return self
def __next__(self):
    while self.currkey == self.tgtkey:
        self.currvalue = next(self.it)  # E
        self.currkey = self.keyfunc(self.curr
self.tgtkey = self.currkey
return (self.currkey, self._grouper(self.

def _grouper(self, tgtkey):
    while self.currkey == tgtkey:
        yield self.currvalue
    try:
        self.currvalue = next(self.it)
    except StopIteration:
        return
    self.currkey = self.keyfunc(self.curr

itertools.islice(iterable, stop)
itertools.islice(iterable, start, stop[, step])

Make an iterator that returns selected elements from the iterable. If start is non-zero, then elements from the iterable are skipped until start is reached. Afterward, elements are returned consecutively unless step is set higher than one which results in items being skipped. If stop is None, then iteration continues until the iterator is exhausted, if at all; otherwise, it stops at the specified position. Unlike regular slicing, islice() does not support negative values for start, stop, or step. Can be used to extract related fields from data where the internal structure has been flattened (for example, a multi-line report may list a name field on every third line). Equivalent to:
def islice(iterable, *args):
    # islice('ABCDEFG', 2) --> A B
    # islice('ABCDEFG', 2, 4) --> C D
    # islice('ABCDEFG', 2, None) --> C D E F G
    # islice('ABCDEFG', 0, None, 2) --> A C E G
    s = slice(*args)
    it = iter(range(s.start or 0, s.stop or sys.maxsize))
    try:
        nexti = next(it)
    except StopIteration:
        return
    for i, element in enumerate(iterable):
        if i == nexti:
            yield element
        nexti = next(it)

If start is None, then iteration starts at zero. If step is None, then the step defaults to one.

`itertools.permutations(iterable, r=None)`

Return successive r length permutations of elements in the iterable.

If r is not specified or is None, then r defaults to the length of the iterable and all possible full-length permutations are generated.

Permutations are emitted in lexicographic sort order. So, if the input iterable is sorted, the permutation tuples will be produced in sorted order.

Elements are treated as unique based on their position, not on their value. So if the input elements are unique, there will be no repeat values in each permutation.
Equivalent to:

```python
def permutations(iterable, r=None):
    pool = tuple(iterable)
    n = len(pool)
    r = n if r is None else r
    if r > n:
        return
    indices = list(range(n))
    cycles = list(range(n, n-r, -1))
    yield tuple(pool[i] for i in indices[:r])
    while n:
        for i in reversed(range(r)):
            if cycles[i] == 0:
                indices[i:] = indices[i+1:] + indices[i]
                cycles[i] = n - i
            else:
                j = cycles[i]
                indices[i], indices[-j] = indices[-j], indices[i]
                yield tuple(pool[i] for i in indices)
        else:
            break
    return
```

The code for `permutations()` can be also expressed as a subsequence of `product()`, filtered to exclude entries with repeated elements (those from the same position in the input pool):

```python
def permutations(iterable, r=None):
    pool = tuple(iterable)
    n = len(pool)
    r = n if r is None else r
```
for indices in product(range(n), repeat=r):
    if len(set(indices)) == r:
        yield tuple(pool[i] for i in indices)

The number of items returned is \( n! / (n-r)! \) when \( 0 \leq r \leq n \) or zero when \( r > n \).

**itertools.product(*iterables, repeat=1)**

Cartesian product of input iterables.

Equivalent to nested for-loops in a generator expression. For example, `product(A, B)` returns the same as `((x, y) for x in A for y in B)`.

The nested loops cycle like an odometer with the rightmost element advancing on every iteration. This pattern creates a lexicographic ordering so that if the input's iterables are sorted, the product tuples are emitted in sorted order.

To compute the product of an iterable with itself, specify the number of repetitions with the optional `repeat` keyword argument. For example, `product(A, repeat=4)` means the same as `product(A, A, A, A).

This function is equivalent to the following code, except that the actual implementation does not build up intermediate results in memory:

```python
def product(*args, repeat=1):
    # product('ABCD', 'xy') --> Ax Ay Bx ByCx Cy
    # product(range(2), repeat=3) --> 000 001 010
    pools = [tuple(pool) for pool in args] * repeat
    result = [[]]
```
for pool in pools:
    result = [x+y] for x in result for y in pool
for prod in result:
    yield tuple(prod)

`itertools.repeat(object[, times])`

Make an iterator that returns `object` over and over again. Runs indefinitely unless the `times` argument is specified. Used as argument to `map()` for invariant parameters to the called function. Also used with `zip()` to create an invariant part of a tuple record. Equivalent to:

```python
def repeat(object, times=None):
    # repeat(10, 3) --> 10 10 10
    if times is None:
        while True:
            yield object
    else:
        for i in range(times):
            yield object
```

A common use for `repeat` is to supply a stream of constant values to `map` or `zip`:

```python
>>> list(map(pow, range(10), repeat(2)))
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

`itertools.starmap(function, iterable)`

Make an iterator that computes the function using arguments obtained from the iterable. Used instead of `map()` when argument parameters are already grouped in tuples from a single iterable (the data has been “pre-zipped”). The difference between `map()` and `starmap()` parallels the distinction between
function(a,b) and function(*c). Equivalent to:

```python
def starmap(function, iterable):
    # starmap(pow, [(2,5), (3,2), (10,3)]) --> 32
    for args in iterable:
        yield function(*args)
```

`itertools.takewhile(predicate, iterable)`

Make an iterator that returns elements from the iterable as long as the predicate is true. Equivalent to:

```python
def takewhile(predicate, iterable):
    # takewhile(lambda x: x<5, [1,4,6,4,1]) --> 1
    for x in iterable:
        if predicate(x):
            yield x
        else:
            break
```

`itertools.tee(iterable, n=2)`

Return $n$ independent iterators from a single iterable. Equivalent to:

```python
def tee(iterable, n=2):
    it = iter(iterable)
    deques = [collections.deque() for i in range(n)]
    def gen(mydeque):
        while True:
            if not mydeque:  # when the local deque is empty
                try:
                    newval = next(it)  # fetch a new value
                except StopIteration:
                    return
            for d in deques:
                d.append(newval)  # load it
Once `tee()` has made a split, the original *iterable* should not be used anywhere else; otherwise, the *iterable* could get advanced without the tee objects being informed.

This itertool may require significant auxiliary storage (depending on how much temporary data needs to be stored). In general, if one iterator uses most or all of the data before another iterator starts, it is faster to use `list()` instead of `tee()`.

**`itertools.zip_longest(*)`**

Make an iterator that aggregates elements from each of the iterables. If the iterables are of uneven length, missing values are filled-in with `fillvalue`. Iteration continues until the longest iterable is exhausted. Equivalent to:

```python
class ZipExhausted(Exception):
    pass

def zip_longest(*args, **kwds):
    # zip_longest('ABCD', 'xy', fillvalue='-') --
    fillvalue = kwds.get('fillvalue')
    counter = len(args) - 1
    def sentinel():
        nonlocal counter
        if not counter:
            raise ZipExhausted
        counter -= 1
        yield fillvalue
    fillers = repeat(fillvalue)
    iterators = [chain(it, sentinel(), fillers) for it in args]
    try:
        while True:
            item = zip(*iterators)
            yield tuple(i for i, it in zip(item, iterators) if not it)
```
while iterators:
    yield tuple(map(next, iterators))
except ZipExhausted:
    pass

If one of the iterables is potentially infinite, then the `zip_longest()` function should be wrapped with something that limits the number of calls (for example `islice()` or `takewhile()`). If not specified, `fillvalue` defaults to `None`. 
10.1.2. Itertools Recipes

This section shows recipes for creating an extended toolset using the existing itertools as building blocks.

The extended tools offer the same high performance as the underlying toolset. The superior memory performance is kept by processing elements one at a time rather than bringing the whole iterable into memory all at once. Code volume is kept small by linking the tools together in a functional style which helps eliminate temporary variables. High speed is retained by preferring “vectorized” building blocks over the use of for-loops and generators which incur interpreter overhead.

```python
def take(n, iterable):
    "Return first n items of the iterable as a list"
    return list(islice(iterable, n))

def tabulate(function, start=0):
    "Return function(0), function(1), ..."
    return map(function, count(start))

def tail(n, iterable):
    "Return an iterator over the last n items"
    # tail(3, 'ABCDEFG') --&gt; E F G
    return iter(collections.deque(iterable, maxlen=n))

def consume(iterator, n):
    "Advance the iterator n-steps ahead. If n is non"
    # Use functions that consume iterators at C speed
    if n is None:
        # feed the entire iterator into a zero-length
        collections.deque(iterator, maxlen=0)
    else:
```
# advance to the empty slice starting at position n
next(islice(iterator, n, n), None)

def nth(iterable, n, default=None):
    """Returns the nth item or a default value""
    return next(islice(iterable, n, None), default)

def quantify(iterable, pred=bool):
    """Count how many times the predicate is true""
    return sum(map(pred, iterable))

def padnone(iterable):
    """
    Returns the sequence elements and then returns None indefinitely.
    Useful for emulating the behavior of the built-in map() function.
    """
    return chain(iterable, repeat(None))

def ncycles(iterable, n):
    """Returns the sequence elements n times""
    return chain.from_iterable(repeat(tuple(iterable), n))

def dotproduct(vec1, vec2):
    return sum(map(operator.mul, vec1, vec2))

def flatten(listOfLists):
    """Flatten one level of nesting""
    return chain.from_iterable(listOfLists)

def repeatfunc(func, times=None, *args):
    """
    Repeat calls to func with specified arguments
    """
    if times is None:
        return starmap(func, repeat(args))
    return starmap(func, repeat(args, times))
from itertools import pairwise, tee, zip_longest

def pairwise(iterable):
    "s -> (s0,s1), (s1,s2), (s2, s3), ..."
    a, b = tee(iterable)
    next(b, None)
    return zip(a, b)

def grouper(iterable, n, fillvalue=None):
    "Collect data into fixed-length chunks or blocks"
    # grouper('ABCDEFG', 3, 'x') --> ABC DEF Gxx"
    args = [iter(iterable)] * n
    return zip_longest(*args, fillvalue=fillvalue)

def roundrobin(*iterables):
    "roundrobin('ABC', 'D', 'EF') --> A D E B F C"
    # Recipe credited to George Sakkis
    pending = len(iterables)
    nexts = cycle(iter(it).__next__ for it in iterables)
    while pending:
        try:
            for next in nexts:
                yield next()
        except StopIteration:
            pending -= 1
            nexts = cycle(islice(nexts, pending))

def partition(pred, iterable):
    'Use a predicate to partition entries into false entries and true entries'
    # partition(is_odd, range(10)) --> 0 2 4 6 8 &
    t1, t2 = tee(iterable)
    return filterfalse(pred, t1), filter(pred, t2)

def powerset(iterable):
    "powerset([1,2,3]) --> () (1,) (2,) (3,) (1,2) (1,3) (2,3) (1,2,3)"
    s = list(iterable)
    return chain.from_iterable(combinations(s, r) for r in range(len(s) + 1))
def unique_everseen(iterable, key=None):
    "List unique elements, preserving order. Remember all elements ever seen."
    seen = set()
    seen_add = seen.add
    if key is None:
        for element in filterfalse(seen.__contains__, iterable):
            seen_add(element)
            yield element
    else:
        for element in iterable:
            k = key(element)
            if k not in seen:
                seen_add(k)
                yield element

def unique_justseen(iterable, key=None):
    "List unique elements, preserving order. Remember only the element just seen."
    return map(next, map(itemgetter(1), groupby(iterable)))

def iter_except(func, exception, first=None):
    """Call a function repeatedly until an exception is raised.
    Converts a call-until-exception interface to an iterator.
    Like builtins.iter(func, sentinel) but uses an exception of a sentinel to end the loop.
   "
    Examples:
    iter_except(functools.partial(heappop, h), IndexError)
    iter_except(d.popitem, KeyError)
    iter_except(d.popleft, IndexError)
    iter_except(q.get_nowait, Queue.Empty)
    iter_except(s.pop, KeyError)
try:
    if first is not None:
        yield first() # For database
    while 1:
        yield func()
except exception:
    pass

def first_true(iterable, default=False, pred=None):
    """Returns the first true value in the iterable.

    If no true value is found, returns *default*

    If *pred* is not None, returns the first item for which pred(item) is true.
    ""
    # first_true([a,b,c], x) --> a or b or c or x
    # first_true([a,b], x, f) --> a if f(a) else b if f(b)
    return next(filter(pred, iterable), default)

def random_product(*args, repeat=1):
    "Random selection from itertools.product(*args, **kwds)"
    pools = [tuple(pool) for pool in args] * repeat
    return tuple(random.choice(pool) for pool in pools)

def random_permutation(iterable, r=None):
    "Random selection from itertools.permutations(iterable, r)"
    pool = tuple(iterable)
    r = len(pool) if r is None else r
    return tuple(random.sample(pool, r))

def random_combination(iterable, r):
    "Random selection from itertools.combinations(iterable, r)"
    pool = tuple(iterable)
    n = len(pool)
indices = sorted(random.sample(range(n), r))
return tuple(pool[i] for i in indices)

def random_combination_with_replacement(iterable, r):
    "Random selection from itertools.combinations_with_replacement(iterable, r)"
    pool = tuple(iterable)
n = len(pool)
indices = sorted(random.randint(0, n) for i in range(r))
return tuple(pool[i] for i in indices)

Note, many of the above recipes can be optimized by replacing global lookups with local variables defined as default values. For example, the `dotproduct` recipe can be written as:

def dotproduct(vec1, vec2, sum=sum, map=map, mul=operator.mul):
    return sum(map(mul, vec1, vec2))
10.2. **functools** — Higher-order functions and operations on callable objects

**Source code:** Lib/functools.py

The **functools** module is for higher-order functions: functions that act on or return other functions. In general, any callable object can be treated as a function for the purposes of this module.

The **functools** module defines the following functions:

**functools.cmp_to_key(func)**

Transform an old-style comparison function to a key function. Used with tools that accept key functions (such as `sorted()`, `min()`, `max()`, `heapq.nlargest()`, `heapq.nsmallest()`, `itertools.groupby()`). This function is primarily used as a transition tool for programs being converted from Python 2 which supported the use of comparison functions.

A comparison function is any callable that accept two arguments, compares them, and returns a negative number for less-than, zero for equality, or a positive number for greater-than. A key function is a callable that accepts one argument and returns another value to be used as the sort key.

Example:

```
sorted(iterable, key=cmp_to_key(locale.strcoll))
```
For sorting examples and a brief sorting tutorial, see Sorting HOW TO.

New in version 3.2.

@functools.lru_cache(maxsize=128, typed=False)
Decorator to wrap a function with a memoizing callable that saves up to the maxsize most recent calls. It can save time when an expensive or I/O bound function is periodically called with the same arguments.

Since a dictionary is used to cache results, the positional and keyword arguments to the function must be hashable.

If maxsize is set to None, the LRU feature is disabled and the cache can grow without bound. The LRU feature performs best when maxsize is a power-of-two.

If typed is set to True, function arguments of different types will be cached separately. For example, f(3) and f(3.0) will be treated as distinct calls with distinct results.

To help measure the effectiveness of the cache and tune the maxsize parameter, the wrapped function is instrumented with a cache_info() function that returns a named tuple showing hits, misses, maxsize and currsze. In a multi-threaded environment, the hits and misses are approximate.

The decorator also provides a cache_clear() function for clearing or invalidating the cache.

The original underlying function is accessible through the __wrapped__ attribute. This is useful for introspection, for
bypassing the cache, or for rewrapping the function with a different cache.

An **LRU (least recently used) cache** works best when the most recent calls are the best predictors of upcoming calls (for example, the most popular articles on a news server tend to change each day). The cache’s size limit assures that the cache does not grow without bound on long-running processes such as web servers.

Example of an LRU cache for static web content:

```python
@lru_cache(maxsize=32)
def get_pep(num):
    'Retrieve text of a Python Enhancement Proposal'
    resource = 'http://www.python.org/dev/peps/pep-
    try:
        with urllib.request.urlopen(resource) as s:
            return s.read()
    except urllib.error.HTTPError:
        return 'Not Found'

>>> for n in 8, 290, 308, 320, 8, 218, 320, 279, ...
...    pep = get_pep(n)
...    print(n, len(pep))

>>> get_pep.cache_info()
CacheInfo(hits=3, misses=8, maxsize=32, currsize=8)
```

Example of efficiently computing Fibonacci numbers using a cache to implement a **dynamic programming** technique:

```python
@lru_cache(maxsize=None)
def fib(n):
    if n < 2:
        return n
```
```python
return fib(n-1) + fib(n-2)
```

```python
>>> [fib(n) for n in range(16)]
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610]
```

```python
>>> fib.cache_info()
CacheInfo(hits=28, misses=16, maxsize=None, currs
```

New in version 3.2.

Changed in version 3.3: Added the typed option.

@functools.total_ordering

Given a class defining one or more rich comparison ordering methods, this class decorator supplies the rest. This simplifies the effort involved in specifying all of the possible rich comparison operations:

The class must define one of `__lt__()`, `__le__()`, `__gt__()`, or `__ge__()`. In addition, the class should supply an `__eq__()` method.

For example:

```python
@total_ordering
class Student:
    def _is_valid_operand(self, other):
        return (hasattr(other, "lastname") and
                hasattr(other, "firstname"))
    def __eq__(self, other):
        if not self._is_valid_operand(other):
            return NotImplemented
        return ((self.lastname.lower(), self.firstname.
```

```python
def is_valid_operand(self, other):
```
if not self._is_valid_operand(other):
    return NotImplemented
return ((self.lastname.lower(), self.firstname(
(other.lastname.lower(), other.firstname

Note: While this decorator makes it easy to create well behaved totally ordered types, it does come at the cost of slower execution and more complex stack traces for the derived comparison methods. If performance benchmarking indicates this is a bottleneck for a given application, implementing all six rich comparison methods instead is likely to provide an easy speed boost.

New in version 3.2.

Changed in version 3.4: Returning NotImplemented from the underlying comparison function for unrecognised types is now supported.

functools.partial(func, *args, **keywords)

Return a new partial object which when called will behave like func called with the positional arguments args and keyword arguments keywords. If more arguments are supplied to the call, they are appended to args. If additional keyword arguments are supplied, they extend and override keywords. Roughly equivalent to:

def partial(func, *args, **keywords):
    def newfunc(*fargs, **fkeywords):
        newkeywords = keywords.copy()
        newkeywords.update(fkeywords)
        return func(*(args + fargs), **newkeyword
    newfunc.func = func
The `partial()` is used for partial function application which “freezes” some portion of a function’s arguments and/or keywords resulting in a new object with a simplified signature. For example, `partial()` can be used to create a callable that behaves like the `int()` function where the `base` argument defaults to two:

```python
decl = partial(int, base=2)
decl('10010')
```

```python
from functools import partial
dec1 = partial(int, base=2)
dec1('10010')
```

```python
class functools.partialmethod(func, *args, **keywords):
    Return a new partialmethod descriptor which behaves like partial except that it is designed to be used as a method definition rather than being directly callable.

    func must be a descriptor or a callable (objects which are both, like normal functions, are handled as descriptors).

    When func is a descriptor (such as a normal Python function, classmethod(), staticmethod(), abstractmethod() or another instance of partialmethod), calls to __get__ are delegated to the underlying descriptor, and an appropriate partial object returned as the result.

    When func is a non-descriptor callable, an appropriate bound method is created dynamically. This behaves like a normal Python
function when used as a method: the \textit{self} argument will be inserted as the first positional argument, even before the \textit{args} and \textit{keywords} supplied to the \texttt{partialmethod} constructor.

Example:

```python
>>> class Cell(object):
...     def __init__(self):
...         self._alive = False
...     @property
...     def alive(self):
...         return self._alive
...     def set_state(self, state):
...         self._alive = bool(state)
...     set_alive = partialmethod(set_state, True)
...     set_dead = partialmethod(set_state, False)
... >>> c = Cell()
>>> c.alive
False
>>> c.set_alive()
>>> c.alive
True
```

\textit{New in version 3.4.}

\texttt{functools.reduce(function, iterable[, initializer])}

Apply \textit{function} of two arguments cumulatively to the items of \textit{sequence}, from left to right, so as to reduce the sequence to a single value. For example, \texttt{reduce(lambda x, y: x+y, [1, 2, 3, 4, 5])} calculates (((((1+2)+3)+4)+5). The left argument, \(x\), is the accumulated value and the right argument, \(y\), is the update value from the \textit{sequence}. If the optional \textit{initializer} is present, it is placed before the items of the sequence in the
calculation, and serves as a default when the sequence is empty. If
\textit{initializer} is not given and \textit{sequence} contains only one item, the
first item is returned.

Roughly equivalent to:

```python
def reduce(function, iterable, initializer=None):
    it = iter(iterable)
    if initializer is None:
        value = next(it)
    else:
        value = initializer
    for element in it:
        value = function(value, element)
    return value
```

\texttt{@functools.singledispatch}(\texttt{default})

Transforms a function into a \textit{single-dispatch generic function}.

To define a generic function, decorate it with the
\texttt{@singledispatch} decorator. Note that the dispatch happens on
the type of the first argument, create your function accordingly:

```python
>>> from functools import singledispatch
>>> @singledispatch
... def fun(arg, verbose=False):
...     if verbose:
...         print("Let me just say,", end=" ")
...     print(arg)
```

To add overloaded implementations to the function, use the
\texttt{register()} attribute of the generic function. It is a decorator,
taking a type parameter and decorating a function implementing
the operation for that type:
To enable registering lambdas and pre-existing functions, the register() attribute can be used in a functional form:

```python
>>> @fun.register(int)
... def _(arg, verbose=False):
...     if verbose:
...         print("Strength in numbers, eh?", end"
...         print(arg)
... >>> @fun.register(list)
... def _(arg, verbose=False):
...     if verbose:
...         print("Enumerate this:")
...     for i, elem in enumerate(arg):
...         print(i, elem)
```

The register() attribute returns the undecorated function which enables decorator stacking, pickling, as well as creating unit tests for each variant independently:

```python
>>> def nothing(arg, verbose=False):
...     print("Nothing.")
... >>> fun.register(type(None), nothing)

>>> @fun.register(float)
... @fun.register(Decimal)
... def fun_num(arg, verbose=False):
...     if verbose:
...         print("Half of your number:", end"
...         print(arg / 2)
... >>> fun_num is fun
False
```
When called, the generic function dispatches on the type of the first argument:

```python
>>> fun("Hello, world.")
Hello, world.
>>> fun("test.", verbose=True)
Let me just say, test.
>>> fun(42, verbose=True)
Strength in numbers, eh? 42
>>> fun(['spam', 'spam', 'eggs', 'spam'], verbose=True)
Enumerate this:
0 spam
1 spam
2 eggs
3 spam
>>> fun(None)
Nothing.
>>> fun(1.23)
0.615
```

Where there is no registered implementation for a specific type, its method resolution order is used to find a more generic implementation. The original function decorated with `@singledispatch` is registered for the base object type, which means it is used if no better implementation is found.

To check which implementation will the generic function choose for a given type, use the `dispatch()` attribute:

```python
>>> fun.dispatch(float)
<function fun_num at 0x1035a2840>
>>> fun.dispatch(dict)  # note: default implementation
<function fun at 0x103fe0000>
```
To access all registered implementations, use the read-only registry attribute:

```python
>>> fun.registry.keys()
dict_keys([<class 'NoneType'>, <class 'int'>, <class 'decimal.Decimal'>, <class 'list'>, <class 'float'>])
```

```python
>>> fun.registry[float]
<function fun_num at 0x1035a2840>
```

```python
>>> fun.registry[object]
<function fun at 0x103fe0000>
```

_New in version 3.4._

`functools.update_wrapper(wrapper, wrapped, assigned=WRAPPER_ASSIGNMENTS, updated=WRAPPER_UPDATES)`

Update a `wrapper` function to look like the `wrapped` function. The optional arguments are tuples to specify which attributes of the original function are assigned directly to the matching attributes on the wrapper function and which attributes of the wrapper function are updated with the corresponding attributes from the original function. The default values for these arguments are the module level constants `WRAPPER_ASSIGNMENTS` (which assigns to the wrapper function's `__name__`, `__module__`, `__annotations__` and `__doc__`, the documentation string) and `WRAPPER_UPDATES` (which updates the wrapper function's `__dict__`, i.e. the instance dictionary).

To allow access to the original function for introspection and other purposes (e.g. bypassing a caching decorator such as `lru_cache()`), this function automatically adds a `__wrapped__` attribute to the wrapper that refers to the function being wrapped.
The main intended use for this function is in `decorator` functions which wrap the decorated function and return the wrapper. If the wrapper function is not updated, the metadata of the returned function will reflect the wrapper definition rather than the original function definition, which is typically less than helpful.

`update_wrapper()` may be used with callables other than functions. Any attributes named in `assigned` or `updated` that are missing from the object being wrapped are ignored (i.e. this function will not attempt to set them on the wrapper function). `AttributeError` is still raised if the wrapper function itself is missing any attributes named in `updated`.

*New in version 3.2:* Automatic addition of the `__wrapped__` attribute.

*New in version 3.2:* Copying of the `__annotations__` attribute by default.

*Changed in version 3.2:* Missing attributes no longer trigger an `AttributeError`.

*Changed in version 3.4:* The `__wrapped__` attribute now always refers to the wrapped function, even if that function defined a `__wrapped__` attribute. (see issue 17482)

```python
@functools.wraps(wrapped,
                 assigned=WRAPPER_ASSIGNMENTS,
                 updated=WRAPPER_UPDATES)
```

This is a convenience function for invoking `update_wrapper()` as a function decorator when defining a wrapper function. It is equivalent to

```
partial(update_wrapper, wrapped=wrapped, assigned=assigned, updated=WRAPPER_UPDATES)
```
For example:

```python
>>> from functools import wraps
>>> def my_decorator(f):
...     @wraps(f)
...     def wrapper(*args, **kwds):
...         print('Calling decorated function')
...         return f(*args, **kwds)
...     return wrapper
...     
>>> @my_decorator
... def example():
...     """Docstring""
...     print('Called example function')
...     
>>> example()
Calling decorated function
Called example function
>>> example.__name__
'example'
>>> example.__doc__
'Docstring'
```

Without the use of this decorator factory, the name of the example function would have been 'wrapper', and the docstring of the original example() would have been lost.
10.2.1. **partial** Objects

**partial** objects are callable objects created by `partial()`. They have three read-only attributes:

**partial.func**
A callable object or function. Calls to the **partial** object will be forwarded to `func` with new arguments and keywords.

**partial.args**
The leftmost positional arguments that will be prepended to the positional arguments provided to a **partial** object call.

**partial.keywords**
The keyword arguments that will be supplied when the **partial** object is called.

**partial** objects are like function objects in that they are callable, weak referencable, and can have attributes. There are some important differences. For instance, the __name__ and __doc__ attributes are not created automatically. Also, **partial** objects defined in classes behave like static methods and do not transform into bound methods during instance attribute look-up.
10.3. operator — Standard operators as functions

Source code: Lib/operator.py

The operator module exports a set of efficient functions corresponding to the intrinsic operators of Python. For example, `operator.add(x, y)` is equivalent to the expression `x+y`. The function names are those used for special class methods; variants without leading and trailing `__` are also provided for convenience.

The functions fall into categories that perform object comparisons, logical operations, mathematical operations and sequence operations.

The object comparison functions are useful for all objects, and are named after the rich comparison operators they support:

```python
operator.lt(a, b)  
operator.le(a, b)  
operator.eq(a, b)  
operator.ne(a, b)  
operator.ge(a, b)  
operator.gt(a, b)  
operator.__lt__(a, b)  
operator.__le__(a, b)  
operator.__eq__(a, b)  
operator.__ne__(a, b)  
operator.__ge__(a, b)  
operator.__gt__(a, b)
```
Perform “rich comparisons” between $a$ and $b$. Specifically, $\text{lt}(a, b)$ is equivalent to $a < b$, $\text{le}(a, b)$ is equivalent to $a \leq b$, $\text{eq}(a, b)$ is equivalent to $a == b$, $\text{ne}(a, b)$ is equivalent to $a \neq b$, $\text{gt}(a, b)$ is equivalent to $a > b$ and $\text{ge}(a, b)$ is equivalent to $a \geq b$. Note that these functions can return any value, which may or may not be interpretable as a Boolean value. See Comparisons for more information about rich comparisons.

The logical operations are also generally applicable to all objects, and support truth tests, identity tests, and boolean operations:

```
operator.not_(obj)
```

Return the outcome of not $obj$. (Note that there is no __not__() method for object instances; only the interpreter core defines this operation. The result is affected by the __bool__() and __len__() methods.)

```
operator.truth(obj)
```

Return True if $obj$ is true, and False otherwise. This is equivalent to using the bool constructor.

```
operator.is_(a, b)
```

Return $a$ is $b$. Tests object identity.

```
operator.is_not(a, b)
```

Return $a$ is not $b$. Tests object identity.

The mathematical and bitwise operations are the most numerous:

```
operator.abs(obj)
```

```
operator.__abs__(obj)
```
Return the absolute value of *obj*.

```python
operator.add(a, b)
operator.__add__(a, b)
    Return *a + b*, for *a* and *b* numbers.

operator.and_(a, b)
operator.__and__(a, b)
    Return the bitwise and of *a* and *b*.

operator.floordiv(a, b)
operator.__floordiv__(a, b)
    Return *a // b*.

operator.index(a)
operator.__index__(a)
    Return *a* converted to an integer. Equivalent to *a.__index__()*.  

operator.inv(obj)
operator.invert(obj)
operator.__inv__(obj)
operator.__invert__(obj)
    Return the bitwise inverse of the number *obj*. This is equivalent to ~obj.

operator.lshift(a, b)
operator.__lshift__(a, b)
    Return *a* shifted left by *b*.

operator.mod(a, b)
operator.__mod__(a, b)
    Return *a % b*.
operator.mul(a, b)
operator.__mul__(a, b)
    Return a * b, for a and b numbers.

evaluator.matmul(a, b)
evaluator.__matmul__(a, b)
    Return a @ b.

New in version 3.5.
evaluator.neg(obj)
evaluator.__neg__(obj)
    Return obj negated (-obj).

evaluator.or_(a, b)
evaluator.__or__(a, b)
    Return the bitwise or of a and b.

evaluator.pos(obj)
evaluator.__pos__(obj)
    Return obj positive (+obj).

evaluator.pow(a, b)
evaluator.__pow__(a, b)
    Return a ** b, for a and b numbers.

evaluator.rshift(a, b)
evaluator.__rshift__(a, b)
    Return a shifted right by b.

evaluator.sub(a, b)
evaluator.__sub__(a, b)
Return `a - b`.

```python
operator.truediv(a, b)
operator.__truediv__(a, b)
```

Return `a / b` where 2/3 is .66 rather than 0. This is also known as “true” division.

```python
operator.xor(a, b)
operator.__xor__(a, b)
```

Return the bitwise exclusive or of `a` and `b`.

Operations which work with sequences (some of them with mappings too) include:

```python
operator.concat(a, b)
operator.__concat__(a, b)
```

Return `a + b` for `a` and `b` sequences.

```python
operator.contains(a, b)
operator.__contains__(a, b)
```

Return the outcome of the test `b` in `a`. Note the reversed operands.

```python
operator.countOf(a, b)
```

Return the number of occurrences of `b` in `a`.

```python
operator.delitem(a, b)
operator.__delitem__(a, b)
```

Remove the value of `a` at index `b`.

```python
operator.GetItem(a, b)
operator.__getitem__(a, b)
```
Return the value of \(a\) at index \(b\).

\[
\text{operator}.\text{indexOf}(a, b)
\]

Return the index of the first of occurrence of \(b\) in \(a\).

\[
\text{operator}.\text{setItem}(a, b, c)
\]

\[
\text{operator}.\text{__setItem__}(a, b, c)
\]

Set the value of \(a\) at index \(b\) to \(c\).

\[
\text{operator}.\text{length\_hint}(\text{obj}, \text{default}=0)
\]

Return an estimated length for the object \(o\). First try to return its actual length, then an estimate using \text{object}.\text{__length\_hint__}(), and finally return the default value.

*New in version 3.4.*

The \text{operator} module also defines tools for generalized attribute and item lookups. These are useful for making fast field extractors as arguments for \text{map()}, \text{sorted()}, \text{itertools.groupby()}, or other functions that expect a function argument.

\[
\text{operator}.\text{attrgetter}(\text{attr})
\]

\[
\text{operator}.\text{attrgetter}(*\text{attrs})
\]

Return a callable object that fetches \text{attr} from its operand. If more than one attribute is requested, returns a tuple of attributes. The attribute names can also contain dots. For example:

- After \(f = \text{attrgetter('name')}\), the call \(f(b)\) returns \(b.name\).
- After \(f = \text{attrgetter('name', 'date')}\), the call \(f(b)\) returns \((b.name, b.date)\).
- After \(f = \text{attrgetter('name.first', 'name.last')}\),
the call f(b) returns (b.name.first, b.name.last).

Equivalent to:

```python
def attrgetter(*items):
    if any(not isinstance(item, str) for item in items):
        raise TypeError('attribute name must be a string')
    if len(items) == 1:
        attr = items[0]
        def g(obj):
            return resolve_attr(obj, attr)
    else:
        def g(obj):
            return tuple(resolve_attr(obj, attr) for attr in items)
        return g

def resolve_attr(obj, attr):
    for name in attr.split('.'):  # Split attribute name by dots
        obj = getattr(obj, name)
    return obj
```

operator.itemgetter(item)
operator.itemgetter(*items)

Return a callable object that fetches item from its operand using the operand's __getitem__() method. If multiple items are specified, returns a tuple of lookup values. For example:

- After `f = itemgetter(2)`, the call `f(r)` returns `r[2]`.
- After `g = itemgetter(2, 5, 3)`, the call `g(r)` returns `(r[2], r[5], r[3])`.

Equivalent to:

```python
def itemgetter(*items):
    if len(items) == 1:
        return items[0]
```

```python
g = items[0]
def g(obj):
    return obj[item]
else:
    def g(obj):
        return tuple(obj[item] for item in it)
return g
```

The items can be any type accepted by the operand's `__getitem__()` method. Dictionaries accept any hashable value. Lists, tuples, and strings accept an index or a slice:

```bash
>>> itemgetter(1)('ABCDEFG')
'B'
>>> itemgetter(1,3,5)('ABCDEFG')
('B', 'D', 'F')
>>> itemgetter(slice(2,None))('ABCDEFG')
'CDEFG'
```

Example of using `itemgetter()` to retrieve specific fields from a tuple record:

```bash
>>> inventory = [('apple', 3), ('banana', 2), ('pear', 5), ('orange', 1)]
>>> getcount = itemgetter(1)
>>> list(map(getcount, inventory))
[3, 2, 5, 1]
>>> sorted(inventory, key=getcount)
[('orange', 1), ('banana', 2), ('apple', 3), ('pear', 5)]
```

operator. `methodcaller(name[, args...])`

Return a callable object that calls the method `name` on its operand. If additional arguments and/or keyword arguments are given, they will be given to the method as well. For example:
• After \( f = \text{methodcaller('name')} \), the call \( f(b) \) returns \( b.name() \).
• After \( f = \text{methodcaller('name', 'foo', bar=1)} \), the call \( f(b) \) returns \( b.name('foo', bar=1) \).

Equivalent to:

```python
def methodcaller(name, *args, **kwargs):
    def caller(obj):
        return getattr(obj, name)(*args, **kwargs)
    return caller
```
10.3.1. Mapping Operators to Functions

This table shows how abstract operations correspond to operator symbols in the Python syntax and the functions in the `operator` module.

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<th>Syntax</th>
<th>Function</th>
</tr>
</thead>
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<td>add(a, b)</td>
</tr>
<tr>
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</tr>
<tr>
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</tr>
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<tr>
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</tr>
<tr>
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<tr>
<td>Bitwise Or</td>
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<td>b</td>
</tr>
<tr>
<td>Exponentiation</td>
<td>a ** b</td>
<td>pow(a, b)</td>
</tr>
<tr>
<td>Identity</td>
<td>a is b</td>
<td>is_(a, b)</td>
</tr>
<tr>
<td>Identity</td>
<td>a is not b</td>
<td>is_not(a, b)</td>
</tr>
<tr>
<td>Indexed Assignment</td>
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<td>setitem(obj, k, v)</td>
</tr>
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<td>Indexed Deletion</td>
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<td>getitem(obj, k)</td>
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</tbody>
</table>
| Operation                  | Symbol  | Function  
<table>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Shift</td>
<td>$a &lt;&lt; b$</td>
<td>lshift(a, b)</td>
</tr>
<tr>
<td>Modulo</td>
<td>$a % b$</td>
<td>mod(a, b)</td>
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<tr>
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<td>$a * b$</td>
<td>mul(a, b)</td>
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<td>$a @ b$</td>
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<td>$+ a$</td>
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<td>$a &gt;&gt; b$</td>
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</tr>
<tr>
<td>Slice Assignment</td>
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<td>setitem(seq, slice(i, j), values)</td>
</tr>
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</tr>
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<td>seq[i:j]</td>
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<tr>
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<td>truth(obj)</td>
</tr>
<tr>
<td>Ordering</td>
<td>$a &lt; b$</td>
<td>lt(a, b)</td>
</tr>
<tr>
<td>Ordering</td>
<td>$a &lt;= b$</td>
<td>le(a, b)</td>
</tr>
<tr>
<td>Equality</td>
<td>$a == b$</td>
<td>eq(a, b)</td>
</tr>
<tr>
<td>Difference</td>
<td>$a != b$</td>
<td>ne(a, b)</td>
</tr>
<tr>
<td>Ordering</td>
<td>$a &gt;= b$</td>
<td>ge(a, b)</td>
</tr>
<tr>
<td>Ordering</td>
<td>$a &gt; b$</td>
<td>gt(a, b)</td>
</tr>
</tbody>
</table>
10.3.2. Inplace Operators

Many operations have an “in-place” version. Listed below are functions providing a more primitive access to in-place operators than the usual syntax does; for example, the statement \( x += y \) is equivalent to \( x = \text{operator.iadd}(x, y) \). Another way to put it is to say that \( z = \text{operator.iadd}(x, y) \) is equivalent to the compound statement \( z = x; z += y \).

In those examples, note that when an in-place method is called, the computation and assignment are performed in two separate steps. The in-place functions listed below only do the first step, calling the in-place method. The second step, assignment, is not handled.

For immutable targets such as strings, numbers, and tuples, the updated value is computed, but not assigned back to the input variable:

```python
>>> a = 'hello'
>>> iadd(a, ' world')
'hello world'
>>> a
'hello'
```

For mutable targets such as lists and dictionaries, the inplace method will perform the update, so no subsequent assignment is necessary:

```python
>>> s = ['h', 'e', 'l', 'l', 'o']
>>> iadd(s, [' ', 'w', 'o', 'r', 'l', 'd'])
['h', 'e', 'l', 'l', 'o', ' ', 'w', 'o', 'r', 'l', 'd']
>>> s
['h', 'e', 'l', 'l', 'o', ' ', 'w', 'o', 'r', 'l', 'd']
```
operator.\texttt{iadd}(a, b)
operator.__\texttt{iadd__}(a, b)
\hspace{1em}a = iadd(a, b) is equivalent to a += b.

operator.\texttt{iand}(a, b)
operator.__\texttt{iand__}(a, b)
\hspace{1em}a = iand(a, b) is equivalent to a &= b.

operator.\texttt{iconcat}(a, b)
operator.__\texttt{iconcat__}(a, b)
\hspace{1em}a = iconcat(a, b) is equivalent to a += b for a and b sequences.

operator.\texttt{ifloordiv}(a, b)
operator.__\texttt{ifloordiv__}(a, b)
\hspace{1em}a = ifloordiv(a, b) is equivalent to a //= b.

operator.\texttt{ilshift}(a, b)
operator.__\texttt{ilshift__}(a, b)
\hspace{1em}a = ilshift(a, b) is equivalent to a <<= b.

operator.\texttt{imod}(a, b)
operator.__\texttt{imod__}(a, b)
\hspace{1em}a = imod(a, b) is equivalent to a %= b.

operator.\texttt{imul}(a, b)
operator.__\texttt{imul__}(a, b)
\hspace{1em}a = imul(a, b) is equivalent to a *= b.

operator.\texttt{imatmul}(a, b)
operator.__\texttt{imatmul__}(a, b)
\hspace{1em}a = imatmul(a, b) is equivalent to a @= b.
New in version 3.5.

operator.\texttt{.ivor}(a, b)
operator.\texttt{.__ivor__}(a, b)
    \(a = \texttt{.ivor}(a, b)\) is equivalent to \(a \mid= b\).

operator.\texttt{.ipow}(a, b)
operator.\texttt{.__ipow__}(a, b)
    \(a = \texttt{.ipow}(a, b)\) is equivalent to \(a **= b\).

operator.\texttt{.irshift}(a, b)
operator.\texttt{.__irshift__}(a, b)
    \(a = \texttt{.irshift}(a, b)\) is equivalent to \(a >>= b\).

operator.\texttt{.isub}(a, b)
operator.\texttt{.__isub__}(a, b)
    \(a = \texttt{.isub}(a, b)\) is equivalent to \(a -= b\).

operator.\texttt{.itruediv}(a, b)
operator.\texttt{.__itruediv__}(a, b)
    \(a = \texttt{.itruediv}(a, b)\) is equivalent to \(a /= b\).

operator.\texttt{.ixor}(a, b)
operator.\texttt{.__ixor__}(a, b)
    \(a = \texttt{.ixor}(a, b)\) is equivalent to \(a ^= b\).
11. File and Directory Access

The modules described in this chapter deal with disk files and directories. For example, there are modules for reading the properties of files, manipulating paths in a portable way, and creating temporary files. The full list of modules in this chapter is:

- **11.1. pathlib — Object-oriented filesystem paths**
  - 11.1.1. Basic use
  - 11.1.2. Pure paths
    - 11.1.2.1. General properties
    - 11.1.2.2. Operators
    - 11.1.2.3. Accessing individual parts
    - 11.1.2.4. Methods and properties
  - 11.1.3. Concrete paths
    - 11.1.3.1. Methods
- **11.2. os.path — Common pathname manipulations**
- **11.3. fileinput — Iterate over lines from multiple input streams**
- **11.4. stat — Interpreting stat() results**
- **11.5. filecmp — File and Directory Comparisons**
  - 11.5.1. The dircmp class
- **11.6. tempfile — Generate temporary files and directories**
  - 11.6.1. Examples
  - 11.6.2. Deprecated functions and variables
- **11.7. glob — Unix style pathname pattern expansion**
- **11.8. fnmatch — Unix filename pattern matching**
- **11.9. linecache — Random access to text lines**
- **11.10. shutil — High-level file operations**
  - 11.10.1. Directory and files operations
    - 11.10.1.1. copytree example
    - 11.10.1.2. rmtree example
  - 11.10.2. Archiving operations
- 11.10.2.1. Archiving example
  - 11.10.3. Querying the size of the output terminal
- 11.11. `macpath` — Mac OS 9 path manipulation functions

**See also:**

**Module `os`**
Operating system interfaces, including functions to work with files at a lower level than Python `file objects`.

**Module `io`**
Python’s built-in I/O library, including both abstract classes and some concrete classes such as file I/O.

**Built-in function `open()`**
The standard way to open files for reading and writing with Python.
11. File and Directory Access
11.1. **pathlib** — Object-oriented filesystem paths

*New in version 3.4.*

This module offers classes representing filesystem paths with semantics appropriate for different operating systems. Path classes are divided between pure paths, which provide purely computational operations without I/O, and concrete paths, which inherit from pure paths but also provide I/O operations.

If you’ve never used this module before or just aren’t sure which class
is right for your task, **Path** is most likely what you need. It instantiates a *concrete path* for the platform the code is running on.

Pure paths are useful in some special cases; for example:

1. If you want to manipulate Windows paths on a Unix machine (or vice versa). You cannot instantiate a **WindowsPath** when running on Unix, but you can instantiate **PureWindowsPath**.

2. You want to make sure that your code only manipulates paths without actually accessing the OS. In this case, instantiating one of the pure classes may be useful since those simply don’t have any OS-accessing operations.

**Note:** This module has been included in the standard library on a *provisional basis*. Backwards incompatible changes (up to and including removal of the package) may occur if deemed necessary by the core developers.

**See also:** [PEP 428](https://www.python.org/dev/peps/pep-0428/): The pathlib module – object-oriented filesystem paths.

**See also:** For low-level path manipulation on strings, you can also use the `os.path` module.
11.1.1. Basic use

Importing the main class:

```python
>>> from pathlib import Path
```

Listing subdirectories:

```python
>>> p = Path('.
>>> [x for x in p.iterdir() if x.is_dir()]
[PosixPath('.hg'), PosixPath('docs'), PosixPath('dist'),
PosixPath('__pycache__'), PosixPath('build')]
```

Listing Python source files in this directory tree:

```python
>>> list(p.glob('**/*.py'))
[PosixPath('test_pathlib.py'), PosixPath('setup.py'),
PosixPath('pathlib.py'), PosixPath('docs/conf.py'),
PosixPath('build/lib/pathlib.py')]
```

Navigating inside a directory tree:

```python
>>> p = Path('/etc')
>>> q = p / 'init.d' / 'reboot'
>>> q
PosixPath('/etc/init.d/reboot')
>>> q.resolve()
PosixPath('/etc/rc.d/init.d/halt')
```

Querying path properties:

```python
>>> q.exists()
True
```
Opening a file:

```python
>>> with q.open() as f: f.readline()
... '#!/bin/bash
'
```
11.1.2. Pure paths

Pure path objects provide path-handling operations which don't actually access a filesystem. There are three ways to access these classes, which we also call *flavours*:

```python
from pathlib import PurePath

class pathlib.PurePath(*pathsegments):
    A generic class that represents the system's path flavour (instantiating it creates either a PurePosixPath or a PureWindowsPath):

    >>> PurePath('setup.py')  # Running on a Unix
    PurePosixPath('setup.py')

    Each element of *pathsegments* can be either a string representing a path segment, or another path object:

    >>> PurePath('foo', 'some/path', 'bar')
    PurePosixPath('foo/some/path/bar')
    >>> PurePath(Path('foo'), Path('bar'))
    PurePosixPath('foo/bar')

    When *pathsegments* is empty, the current directory is assumed:

    >>> PurePath()
    PurePosixPath('..')

    When several absolute paths are given, the last is taken as an anchor (mimicking `os.path.join()`'s behaviour):

    >>> PurePath('/etc', '/usr', 'lib64')
    PurePosixPath('/usr/lib64')
```
However, in a Windows path, changing the local root doesn’t discard the previous drive setting:

```python
>>> PureWindowsPath('c:/Program Files', 'c:/Program Files')
PureWindowsPath('c:/Program Files')
```

Spurious slashes and single dots are collapsed, but double dots ('..') are not, since this would change the meaning of a path in the face of symbolic links:

```python
>>> PurePath('foo//bar')
PurePosixPath('foo/bar')
>>> PurePath('foo../bar')
PurePosixPath('foo/..bar')
```

(a naïve approach would make
PurePosixPath('foo/..bar') equivalent to
PurePosixPath('bar'), which is wrong if foo is a symbolic link to another directory)

```python
class pathlib.PurePosixPath(*pathsegments)
A subclass of PurePath, this path flavour represents non-Windows filesystem paths:
```

```python
>>> PurePosixPath('/etc')
PurePosixPath('/etc')
```

`pathsegments` is specified similarly to `PurePath`. 
class pathlib.PureWindowsPath(*pathsegments)

A subclass of PurePath, this path flavour represents Windows filesystem paths:

```python
>>> PureWindowsPath('c:/Program Files/')
PureWindowsPath('c:/Program Files')
```

`pathsegments` is specified similarly to PurePath.

Regardless of the system you're running on, you can instantiate all of these classes, since they don't provide any operation that does system calls.

11.1.2.1. General properties

Paths are immutable and hashable. Paths of a same flavour are comparable and orderable. These properties respect the flavour's case-folding semantics:

```python
>>> PurePosixPath('foo') == PurePosixPath('FOO')
False
>>> PureWindowsPath('foo') == PureWindowsPath('FOO')
True
>>> PureWindowsPath('FOO') in { PureWindowsPath('foo') }
True
>>> PureWindowsPath('C:') < PureWindowsPath('d:')
True
```

Paths of a different flavour compare unequal and cannot be ordered:

```python
>>> PureWindowsPath('foo') == PurePosixPath('foo')
False
>>> PureWindowsPath('foo') < PurePosixPath('foo')
```
11.1.2.2. Operators

The slash operator helps create child paths, similarly to `os.path.join()`:

```python
>>> p = PurePath('/etc')
>>> p
PurePosixPath('/etc')
>>> p / 'init.d' / 'apache2'
PurePosixPath('/etc/init.d/apache2')
>>> q = PurePath('bin')
>>> '/usr' / q
PurePosixPath('/usr/bin')
```

The string representation of a path is the raw filesystem path itself (in native form, e.g. with backslashes under Windows), which you can pass to any function taking a file path as a string:

```python
>>> p = PurePath('/etc')
>>> str(p)
'/etc'
>>> p = PureWindowsPath('c:/Program Files')
>>> str(p)
'c:\\Program Files'
```

Similarly, calling `bytes` on a path gives the raw filesystem path as a bytes object, as encoded by `os.fsencode()`:

```python
>>> bytes(p)
b'/etc'
```
11.1.2.3. Accessing individual parts

To access the individual “parts” (components) of a path, use the following property:

**PurePath**. **parts**

A tuple giving access to the path's various components:

```python
>>> p = PurePath('/usr/bin/python3')
>>> p.parts
('/', 'usr', 'bin', 'python3')

>>> p = PureWindowsPath('c:/Program Files/PSF')
>>> p.parts
('c:\', 'Program Files', 'PSF')
```

(note how the drive and local root are regrouped in a single part)

11.1.2.4. Methods and properties

Pure paths provide the following methods and properties:

**PurePath**. **drive**

A string representing the drive letter or name, if any:

```python
>>> PureWindowsPath('c:/Program Files/').drive
'c:'
>>> PureWindowsPath('/Program Files/').drive
''
```
UNC shares are also considered drives:

```python
>>> PureWindowsPath('//host/share/foo.txt').drive
'\\\host\share'
```

**PurePath. root**

A string representing the (local or global) root, if any:

```python
>>> PureWindowsPath('c:/Program Files/').root
'\'
>>> PureWindowsPath('c:Program Files/').root
'c:('
>>> PurePosixPath('/etc').root
'/'
```

UNC shares always have a root:

```python
>>> PureWindowsPath('//host/share').root
'\'
```

**PurePath. anchor**

The concatenation of the drive and root:

```python
>>> PureWindowsPath('c:/Program Files/').anchor
'c:\'
>>> PureWindowsPath('c:Program Files/').anchor
'c:('
>>> PurePosixPath('/etc').anchor
'/'
>>> PureWindowsPath('//host/share').anchor
'\\\host\share\'
```
**PurePath**. `parents`

An immutable sequence providing access to the logical ancestors of the path:

```python
>>> p = PureWindowsPath('c:/foo/bar/setup.py')
>>> p.parents[0]
PureWindowsPath('c:/foo/bar')
>>> p.parents[1]
PureWindowsPath('c:/foo')
>>> p.parents[2]
PureWindowsPath('c:/')
```

**PurePath**. `parent`

The logical parent of the path:

```python
>>> p = PurePosixPath('/a/b/c/d')
>>> p.parent
PurePosixPath('/a/b/c')
```

You cannot go past an anchor, or empty path:

```python
>>> p = PurePosixPath('/')
>>> p.parent
PurePosixPath('/')
>>> p = PurePosixPath('.')
>>> p.parent
PurePosixPath('.')
```

**Note:** This is a purely lexical operation, hence the following behaviour:

```python
>>> p = PurePosixPath('foo/..')
>>> p.parent
PurePosixPath('foo')
```
If you want to walk an arbitrary filesystem path upwards, it is recommended to first call `Path.resolve()` so as to resolve symlinks and eliminate ".." components.

**PurePath.name**

A string representing the final path component, excluding the drive and root, if any:

```python
>>> PurePosixPath('my/library/setup.py').name
'setup.py'
```

UNC drive names are not considered:

```python
>>> PureWindowsPath('//some/share/setup.py').name
'setup.py'
>>> PureWindowsPath('//some/share').name
''
```

**PurePath.suffix**

The file extension of the final component, if any:

```python
>>> PurePosixPath('my/library/setup.py').suffix
'.py'
>>> PurePosixPath('my/library.tar.gz').suffix
'.gz'
>>> PurePosixPath('my/library').suffix
''
```

**PurePath.suffixes**

A list of the path's file extensions:

```python
>>> PurePosixPath('my/library.tar.gar').suffixes
['.tar', '.gar']
```
```python
>>> PurePosixPath('my/library.tar.gz').suffixes
['.tar', '.gz']
>>> PurePosixPath('my/library').suffixes
[]
```

**PurePath.stem**

The final path component, without its suffix:

```python
>>> PurePosixPath('my/library.tar.gz').stem
'library.tar'
>>> PurePosixPath('my/library.tar').stem
'library'
>>> PurePosixPath('my/library').stem
'library'
```

**PurePath.as_posix()**

Return a string representation of the path with forward slashes (/):

```python
>>> p = PureWindowsPath('c:\windows')
>>> str(p)
'c:\windows'
>>> p.as_posix()
'c:/windows'
```

**PurePath.as_uri()**

Represent the path as a file URI. `ValueError` is raised if the path isn't absolute.

```python
>>> p = PurePosixPath('/etc/passwd')
>>> p.as_uri()
'file:///etc/passwd'
>>> p = PureWindowsPath('c:/Windows')
>>> p.as_uri()
'file:///c:/Windows'
```
PurePath.\texttt{is\_absolute()}

Return whether the path is absolute or not. A path is considered absolute if it has both a root and (if the flavour allows) a drive:

```python
>>> PurePosixPath('/a/b').is_absolute()
True
>>> PurePosixPath('a/b').is_absolute()
False
>>> PureWindowsPath('c:/a/b').is_absolute()
True
>>> PureWindowsPath('/a/b').is_absolute()
False
>>> PureWindowsPath('c:').is_absolute()
False
>>> PureWindowsPath('//some/share').is_absolute()
True
```

PurePath.\texttt{is\_reserved()}

With \texttt{PureWindowsPath}, return \texttt{True} if the path is considered reserved under Windows, \texttt{False} otherwise. With \texttt{PurePosixPath}, \texttt{False} is always returned.

```python
>>> PureWindowsPath('nul').is_reserved()
True
>>> PurePosixPath('nul').is_reserved()
False
```

File system calls on reserved paths can fail mysteriously or have unintended effects.

PurePath.\texttt{joinpath(*)other}

Calling this method is equivalent to combining the path with each of
the other arguments in turn:

```python
>>> PurePosixPath('/etc').joinpath('passwd')
PurePosixPath('/etc/passwd')
>>> PurePosixPath('/etc').joinpath(PurePosixPath('/etc/passwd'))
PurePosixPath('/etc/init.d/apache2')
>>> PureWindowsPath('c:').joinpath('/Program Files')
PureWindowsPath('c:/Program Files')
```

`PurePath.match(pattern)`

Match this path against the provided glob-style pattern. Return True if matching is successful, False otherwise.

If `pattern` is relative, the path can be either relative or absolute, and matching is done from the right:

```python
>>> PurePath('a/b.py').match('*.py')
True
>>> PurePath('/a/b/c.py').match('b/*.py')
True
>>> PurePath('/a/b/c.py').match('a/*.py')
False
```

If `pattern` is absolute, the path must be absolute, and the whole path must match:

```python
>>> PurePath('/a.py').match('/*.*py')
True
>>> PurePath('a/b.py').match('/*.*py')
False
```

As with other methods, case-sensitivity is observed:
>>> PureWindowsPath('b.py').match('*.PY')
True
PurePath.relative_to(*other)
Compute a version of this path relative to the path represented by
other. If it’s impossible, ValueError is raised:
>>> p = PurePosixPath('/etc/passwd')
>>> p.relative_to('/')
PurePosixPath('etc/passwd')
>>> p.relative_to('/etc')
PurePosixPath('passwd')
>>> p.relative_to('/usr')
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
File "pathlib.py", line 694, in relative_to
.format(str(self), str(formatted)))
ValueError: '/etc/passwd' does not start with '/usr'
PurePath.with_name(name)
Return a new path with the name changed. If the original path
doesn’t have a name, ValueError is raised:
>>> p = PureWindowsPath('c:/Downloads/pathlib.tar.gz'
>>> p.with_name('setup.py')
PureWindowsPath('c:/Downloads/setup.py')
>>> p = PureWindowsPath('c:/')
>>> p.with_name('setup.py')
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
File "/home/antoine/cpython/default/Lib/pathlib.py"
raise ValueError("%r has an empty name" % (self
ValueError: PureWindowsPath('c:/') has an empty name


PurePath\.with_suffix(suffix)

Return a new path with the suffix changed. If the original path doesn't have a suffix, the new suffix is appended instead:

```python
>>> p = PureWindowsPath('c:/Downloads/pathlib.tar.gz')
>>> p.with_suffix('.bz2')
PureWindowsPath('c:/Downloads/pathlib.tar.bz2')
>>> p = PureWindowsPath('README')
>>> p.with_suffix('.txt')
PureWindowsPath('README.txt')
```
11.1.3. Concrete paths

Concrete paths are subclasses of the pure path classes. In addition to operations provided by the latter, they also provide methods to do system calls on path objects. There are three ways to instantiate concrete paths:

\textit{class pathlib.Path(*pathsegments)}

A subclass of PurePath, this class represents concrete paths of the system’s path flavour (instantiating it creates either a PosixPath or a WindowsPath):

\begin{verbatim}
>>> Path('setup.py')
PosixPath('setup.py')
\end{verbatim}

\textit{pathsegments} is specified similarly to PurePath.

\textit{class pathlib.PosixPath(*pathsegments)}

A subclass of Path and PurePosixPath, this class represents concrete non-Windows filesystem paths:

\begin{verbatim}
>>> PosixPath('/etc')
PosixPath('/etc')
\end{verbatim}

\textit{pathsegments} is specified similarly to PurePath.

\textit{class pathlib.WindowsPath(*pathsegments)}

A subclass of Path and PureWindowsPath, this class represents concrete Windows filesystem paths:

\begin{verbatim}
>>> WindowsPath('c:/Program Files/')
WindowsPath('c:/Program Files')
\end{verbatim}
*pathsegments* is specified similarly to *PurePath*.

You can only instantiate the class flavour that corresponds to your system (allowing system calls on non-compatible path flavours could lead to bugs or failures in your application):

```python
>>> import os
>>> os.name 'posix'
>>> Path('setup.py')
PosixPath('setup.py')
>>> PosixPath('setup.py')
PosixPath('setup.py')
>>> WindowsPath('setup.py')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "pathlib.py", line 798, in __new__
    % (cls.__name__,))
NotImplementedError: cannot instantiate 'WindowsPath'
```

### 11.1.3.1. Methods

Concrete paths provide the following methods in addition to pure paths methods. Many of these methods can raise an *OSError* if a system call fails (for example because the path doesn’t exist):

*classmethod* `Path.cwd()`

Return a new path object representing the current directory (as returned by `os.getcwd()`):

```python
>>> Path.cwd()
PosixPath('/home/antoine/pathlib')
```
**classmethod** `Path.home()`

Return a new path object representing the user’s home directory (as returned by `os.path.expanduser()` with ~ construct):

```python
>>> Path.home()
PosixPath('/home/antoine')
```

*New in version 3.5.*

`Path.stat()`

Return information about this path (similarly to `os.stat()`). The result is looked up at each call to this method.

```python
>>> p = Path('setup.py')
>>> p.stat().st_size
956
>>> p.stat().st_mtime
1327883547.852554
```

`Path.chmod(mode)`

Change the file mode and permissions, like `os.chmod()`:

```python
>>> p = Path('setup.py')
>>> p.stat().st_mode
33277
>>> p.chmod(0o444)
>>> p.stat().st_mode
33060
```

`Path.exists()`

Whether the path points to an existing file or directory:

```python
>>> Path('.').exists()
True
```
Path('setup.py').exists()
True
Path('/etc').exists()
True
Path('nonexistentfile').exists()
False

**Note:** If the path points to a symlink, `exists()` returns whether the symlink *points to* an existing file or directory.

Path.**expanduser**()
Return a new path with expanded ~ and ~user constructs, as returned by `os.path.expanduser()`:

```python
>>> p = PosixPath('~/films/Monty Python')
>>> p.expanduser()
PosixPath('/home/eric/films/Monty Python')
```

*New in version 3.5.*

Path.**glob**(pattern)
Glob the given *pattern* in the directory represented by this path, yielding all matching files (of any kind):

```python
>>> sorted(Path('.').glob('*.py'))
[PosixPath('pathlib.py'), PosixPath('setup.py'),
>>> sorted(Path('.').glob('*/*.py'))
[PosixPath('docs/conf.py')]
```

The "**" pattern means "this directory and all subdirectories, recursively". In other words, it enables recursive globbing:

```python
>>> sorted(Path('.').glob('**/*.py'))
```
[PosixPath('build/lib/pathlib.py'),
  PosixPath('docs/conf.py'),
  PosixPath('pathlib.py'),
  PosixPath('setup.py'),
  PosixPath('test_pathlib.py')]

**Note:** Using the “**” pattern in large directory trees may consume an inordinate amount of time.

**Path.group()**
Return the name of the group owning the file. **KeyError** is raised if the file’s gid isn’t found in the system database.

**Path.is_dir()**
Return True if the path points to a directory (or a symbolic link pointing to a directory), False if it points to another kind of file.

False is also returned if the path doesn’t exist or is a broken symlink; other errors (such as permission errors) are propagated.

**Path.is_file()**
Return True if the path points to a regular file (or a symbolic link pointing to a regular file), False if it points to another kind of file.

False is also returned if the path doesn’t exist or is a broken symlink; other errors (such as permission errors) are propagated.

**Path.is_symlink()**
Return True if the path points to a symbolic link, False otherwise.

False is also returned if the path doesn’t exist; other errors (such as permission errors) are propagated.
Path.is_socket()
Return True if the path points to a Unix socket (or a symbolic link pointing to a Unix socket), False if it points to another kind of file.

False is also returned if the path doesn’t exist or is a broken symlink; other errors (such as permission errors) are propagated.

Path.is_fifo()
Return True if the path points to a FIFO (or a symbolic link pointing to a FIFO), False if it points to another kind of file.

False is also returned if the path doesn’t exist or is a broken symlink; other errors (such as permission errors) are propagated.

Path.is_block_device()
Return True if the path points to a block device (or a symbolic link pointing to a block device), False if it points to another kind of file.

False is also returned if the path doesn’t exist or is a broken symlink; other errors (such as permission errors) are propagated.

Path.is_char_device()
Return True if the path points to a character device (or a symbolic link pointing to a character device), False if it points to another kind of file.

False is also returned if the path doesn’t exist or is a broken symlink; other errors (such as permission errors) are propagated.

Path.iterdir()
When the path points to a directory, yield path objects of the directory contents:
>>> p = Path('docs')
>>> for child in p.iterdir(): child
...
PosixPath('docs/conf.py')
PosixPath('docs/_templates')
PosixPath('docs/make.bat')
PosixPath('docs/index.rst')
PosixPath('docs/_build')
PosixPath('docs/_static')
PosixPath('docs/Makefile')

Path.

Path.

Path.

Path.

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Path.
the target directory already exists.

If exist_ok is true, FileExistsError exceptions will be ignored (same behavior as the POSIX mkdir -p command), but only if the last path component is not an existing non-directory file.

*Changed in version 3.5:* The exist_ok parameter was added.

Path.open(*mode=''r'', buffering=-1, encoding=None, errors=None, newline=None*)

Open the file pointed to by the path, like the built-in open() function does:

```python
>>> p = Path('setup.py')
>>> with p.open() as f:
...    f.readline()  
...    f.readline()
'#!/usr/bin/env python3
```

Path.owner()

Return the name of the user owning the file. KeyError is raised if the file's uid isn't found in the system database.

Path.read_bytes()

Return the binary contents of the pointed-to file as a bytes object:

```python
>>> p = Path('my_binary_file')
>>> p.write_bytes(b'Binary file contents')
20
>>> p.read_bytes()
b'Binary file contents'
```

*New in version 3.5.*
Path.read_text(encoding=None, errors=None)

Return the decoded contents of the pointed-to file as a string:

```python
>>> p = Path('my_text_file')
>>> p.write_text('Text file contents')
18
>>> p.read_text()
'Text file contents'
```

The optional parameters have the same meaning as in `open()`.

*New in version 3.5.*

Path.rename(target)

Rename this file or directory to the given target. target can be either a string or another path object:

```python
>>> p = Path('foo')
>>> p.open('w').write('some text')
9
>>> target = Path('bar')
>>> p.rename(target)
>>> target.open().read()
'some text'
```

Path.replace(target)

Rename this file or directory to the given target. If target points to an existing file or directory, it will be unconditionally replaced.

Path.resolve()

Make the path absolute, resolving any symlinks. A new path object is returned:

```python
>>> p = Path()
```
".." components are also eliminated (this is the only method to do so):

```python
>>> p = Path('docs/../setup.py')
>>> p.resolve()
PosixPath('/home/antoine/pathlib/setup.py')
```

If the path doesn't exist, `FileNotFoundError` is raised. If an infinite loop is encountered along the resolution path, `RuntimeError` is raised.

**Path.rglob(pattern)**

This is like calling `glob()` with "**" added in front of the given `pattern`:

```python
>>> sorted(Path().rglob("*.py"))
[PosixPath('build/lib/pathlib.py'),
 PosixPath('docs/conf.py'),
 PosixPath('pathlib.py'),
 PosixPath('setup.py'),
 PosixPath('test_pathlib.py')]
```

**Path.rmdir()**

Remove this directory. The directory must be empty.

**Path.samefile(other_path)**

Return whether this path points to the same file as `other_path`, which can be either a Path object, or a string. The semantics are similar to `os.path.samefile()` and `os.path.samestat()`.
An **OSError** can be raised if either file cannot be accessed for some reason.

```python
>>> p = Path('spam')
>>> q = Path('eggs')
>>> p.samefile(q)
False
>>> p.samefile('spam')
True
```

*New in version 3.5.*

**Path.symlink_to**(target, target_is_directory=False)

Make this path a symbolic link to target. Under Windows, **target_is_directory** must be true (default False) if the link’s target is a directory. Under POSIX, **target_is_directory**'s value is ignored.

```python
>>> p = Path('mylink')
>>> p.symlink_to('setup.py')
>>> p.resolve()
PosixPath('/home/antoine/pathlib/setup.py')
>>> p.stat().st_size
956
>>> p.lstat().st_size
8
```

**Note:** The order of arguments (link, target) is the reverse of **os.symlink()**'s.

**Path.touch**(mode=0o777, exist_ok=True)

Create a file at this given path. If **mode** is given, it is combined with the process’ umask value to determine the file mode and access flags. If the file already exists, the function succeeds if **exist_ok** is
true (and its modification time is updated to the current time), otherwise `FileExistsError` is raised.

Path.**unlink**()

Remove this file or symbolic link. If the path points to a directory, use `Path.rmdir()` instead.

Path.**write_bytes**(data)

Open the file pointed to in bytes mode, write `data` to it, and close the file:

```python
>>> p = Path('my_binary_file')
>>> p.write_bytes(b'Binary file contents')
20
>>> p.read_bytes()
b'Binary file contents'
```

An existing file of the same name is overwritten.

*New in version 3.5.*

Path.**write_text**(data, encoding=None, errors=None)

Open the file pointed to in text mode, write `data` to it, and close the file:

```python
>>> p = Path('my_text_file')
>>> p.write_text('Text file contents')
18
>>> p.read_text()
'Text file contents'
```

*New in version 3.5.*
11.2. os.path — Common pathname manipulations

This module implements some useful functions on pathnames. To read or write files see open(), and for accessing the filesystem see the os module. The path parameters can be passed as either strings, or bytes. Applications are encouraged to represent file names as (Unicode) character strings. Unfortunately, some file names may not be representable as strings on Unix, so applications that need to support arbitrary file names on Unix should use bytes objects to represent path names. Vice versa, using bytes objects cannot represent all file names on Windows (in the standard mbcs encoding), hence Windows applications should use string objects to access all files.

Unlike a unix shell, Python does not do any automatic path expansions. Functions such as expanduser() and expandvars() can be invoked explicitly when an application desires shell-like path expansion. (See also the glob module.)

See also: The pathlib module offers high-level path objects.

Note: All of these functions accept either only bytes or only string objects as their parameters. The result is an object of the same type, if a path or file name is returned.

Note: Since different operating systems have different path name conventions, there are several versions of this module in the standard library. The os.path module is always the path module suitable for the operating system Python is running on, and therefore
usable for local paths. However, you can also import and use the individual modules if you want to manipulate a path that is always in one of the different formats. They all have the same interface:

- **posixpath** for UNIX-style paths
- **ntpath** for Windows paths
- **macpath** for old-style MacOS paths

**os.path.abspath(path)**

Return a normalized absolutized version of the pathname `path`. On most platforms, this is equivalent to calling the function `normpath()` as follows: `normpath(join(os.getcwd(), path))`.

**os.path.basename(path)**

Return the base name of pathname `path`. This is the second element of the pair returned by passing `path` to the function `split()`. Note that the result of this function is different from the Unix `basename` program; where `basename` for `/foo/bar/' returns 'bar', the `basename()` function returns an empty string ('').

**os.path.commonpath(paths)**

Return the longest common sub-path of each pathname in the sequence `paths`. Raise `ValueError` if `paths` contains both absolute and relative pathnames, or if `paths` is empty. Unlike `commonprefix()`, this returns a valid path.

Availability: Unix, Windows

*New in version 3.5.*
os.path.commonprefix(list)

Return the longest path prefix (taken character-by-character) that is a prefix of all paths in list. If list is empty, return the empty string ('').

Note: This function may return invalid paths because it works a character at a time. To obtain a valid path, see commonpath().

```python
>>> os.path.commonprefix(['/usr/lib', '/usr/local/lib', '/usr/l'])
'/usr'
```

os.path.dirname(path)

Return the directory name of pathname path. This is the first element of the pair returned by passing path to the function split().

os.path.exists(path)

Return True if path refers to an existing path or an open file descriptor. Returns False for broken symbolic links. On some platforms, this function may return False if permission is not granted to execute os.stat() on the requested file, even if the path physically exists.

Changed in version 3.3: path can now be an integer: True is returned if it is an open file descriptor, False otherwise.

os.path.lexists(path)

Return True if path refers to an existing path. Returns True for
broken symbolic links. Equivalent to \texttt{exists()} on platforms lacking \texttt{os.lstat()}.

\texttt{os.path.expanduser(path)}

On Unix and Windows, return the argument with an initial component of \texttt{~} or \texttt{~user} replaced by that \texttt{user}'s home directory.

On Unix, an initial \texttt{~} is replaced by the environment variable \texttt{HOME} if it is set; otherwise the current user’s home directory is looked up in the password directory through the built-in module \texttt{pwd}. An initial \texttt{~user} is looked up directly in the password directory.

On Windows, \texttt{HOME} and \texttt{USERPROFILE} will be used if set, otherwise a combination of \texttt{HOMEPATH} and \texttt{HOMEDRIVE} will be used. An initial \texttt{~user} is handled by stripping the last directory component from the created user path derived above.

If the expansion fails or if the path does not begin with a tilde, the path is returned unchanged.

\texttt{os.path.expandvars(path)}

Return the argument with environment variables expanded. Substrings of the form \texttt{$name} or \texttt{{name}} are replaced by the value of environment variable \texttt{name}. Malformed variable names and references to non-existing variables are left unchanged.

On Windows, \texttt{%name%} expansions are supported in addition to \texttt{$name} and \texttt{{name}}.

\texttt{os.path.getatime(path)}

Return the time of last access of \texttt{path}. The return value is a number giving the number of seconds since the epoch (see the
time module). Raise OSError if the file does not exist or is inaccessible.

If os.stat_float_times() returns True, the result is a floating point number.

os.path.getmtime(path)
Return the time of last modification of path. The return value is a number giving the number of seconds since the epoch (see the time module). Raise OSError if the file does not exist or is inaccessible.

If os.stat_float_times() returns True, the result is a floating point number.

os.path.getctime(path)
Return the system's ctime which, on some systems (like Unix) is the time of the last metadata change, and, on others (like Windows), is the creation time for path. The return value is a number giving the number of seconds since the epoch (see the time module). Raise OSError if the file does not exist or is inaccessible.

os.path.getsize(path)
Return the size, in bytes, of path. Raise OSError if the file does not exist or is inaccessible.

os.path.isabs(path)
Return True if path is an absolute pathname. On Unix, that means it begins with a slash, on Windows that it begins with a (back)slash after chopping off a potential drive letter.

os.path.isfile(path)
Return True if `path` is an existing regular file. This follows symbolic links, so both `islink()` and `isfile()` can be true for the same path.

`os.path.isdir(path)`
Return True if `path` is an existing directory. This follows symbolic links, so both `islink()` and `isdir()` can be true for the same path.

`os.path.islink(path)`
Return True if `path` refers to a directory entry that is a symbolic link. Always False if symbolic links are not supported by the python runtime.

`os.path.ismount(path)`
Return True if pathname `path` is a mount point: a point in a file system where a different file system has been mounted. On POSIX, the function checks whether `path`'s parent, `path/..`, is on a different device than `path`, or whether `path/..` and `path` point to the same i-node on the same device — this should detect mount points for all Unix and POSIX variants. On Windows, a drive letter root and a share UNC are always mount points, and for any other path `GetVolumePathName` is called to see if it is different from the input path.

*New in version 3.4:* Support for detecting non-root mount points on Windows.

`os.path.join(path, *paths)`
Join one or more path components intelligently. The return value is the concatenation of `path` and any members of `*paths` with exactly one directory separator (`os.sep`) following each non-empty part
except the last, meaning that the result will only end in a separator if the last part is empty. If a component is an absolute path, all previous components are thrown away and joining continues from the absolute path component.

On Windows, the drive letter is not reset when an absolute path component (e.g., r'\foo') is encountered. If a component contains a drive letter, all previous components are thrown away and the drive letter is reset. Note that since there is a current directory for each drive, os.path.join("c:","foo") represents a path relative to the current directory on drive C: (c:foo), not c:\foo.

**os.path.normcase(path)**

Normalize the case of a pathname. On Unix and Mac OS X, this returns the path unchanged; on case-insensitive filesystems, it converts the path to lowercase. On Windows, it also converts forward slashes to backward slashes. Raise a TypeError if the type of path is not str or bytes.

**os.path.normpath(path)**

Normalize a pathname by collapsing redundant separators and up-level references so that A//B, A/B/, A/.B and A/foo/../B all become A/B. This string manipulation may change the meaning of a path that contains symbolic links. On Windows, it converts forward slashes to backward slashes. To normalize case, use normcase().

**os.path.realpath(path)**

Return the canonical path of the specified filename, eliminating any symbolic links encountered in the path (if they are supported by the operating system).
os.path.relpatherp\texttt{(path, start=\texttt{os.getcwd})}}

Return a relative filepath to \texttt{path} either from the current directory or from an optional \texttt{start} directory. This is a path computation: the filesystem is not accessed to confirm the existence or nature of \texttt{path} or \texttt{start}.

\texttt{start} defaults to \texttt{os.getcwd}.

Availability: Unix, Windows.

os.path.samefile\texttt{(path1, path2)}

Return True if both pathname arguments refer to the same file or directory. This is determined by the device number and i-node number and raises an exception if an \texttt{os.stat()} call on either pathname fails.

Availability: Unix, Windows.

\textit{Changed in version 3.2}: Added Windows support.

\textit{Changed in version 3.4}: Windows now uses the same implementation as all other platforms.

os.path.sameopenfile\texttt{(fp1, fp2)}

Return True if the file descriptors \texttt{fp1} and \texttt{fp2} refer to the same file.

Availability: Unix, Windows.

\textit{Changed in version 3.2}: Added Windows support.

os.path.samestat\texttt{(stat1, stat2)}

Return True if the stat tuples \texttt{stat1} and \texttt{stat2} refer to the same file. These structures may have been returned by \texttt{os.fstat()}, 
os.lstat(), or os.stat(). This function implements the underlying comparison used by samefile() and sameopenfile().

Availability: Unix, Windows.

*Changed in version 3.4:* Added Windows support.

**os.path.split(path)**

Split the pathname path into a pair, (head, tail) where tail is the last pathname component and head is everything leading up to that. The tail part will never contain a slash; if path ends in a slash, tail will be empty. If there is no slash in path, head will be empty. If path is empty, both head and tail are empty. Trailing slashes are stripped from head unless it is the root (one or more slashes only). In all cases, join(head, tail) returns a path to the same location as path (but the strings may differ). Also see the functions dirname() and basename().

**os.path.splitdrive(path)**

Split the pathname path into a pair (drive, tail) where drive is either a mount point or the empty string. On systems which do not use drive specifications, drive will always be the empty string. In all cases, drive + tail will be the same as path.

On Windows, splits a pathname into drive/UNC sharepoint and relative path.

If the path contains a drive letter, drive will contain everything up to and including the colon. e.g. splitdrive("c:/dir") returns ("c:", "/dir")

If the path contains a UNC path, drive will contain the host name
and share, up to but not including the fourth separator. E.g.
splitdrive("//host/computer/dir") returns
("//host/computer", "/dir")

```
os.path.splitext(path)
```

Split the pathname `path` into a pair `(root, ext)` such that `root + ext == path`, and `ext` is empty or begins with a period and contains at most one period. Leading periods on the basename are ignored; `splitext('.cshrc')` returns `('.cshrc', '')`.

```
os.path.splitunc(path)
```

*Deprecated since version 3.1:* Use `splitdrive` instead.

Split the pathname `path` into a pair `(unc, rest)` so that `unc` is the UNC mount point (such as `r'\\host\\mount'`), if present, and `rest` the rest of the path (such as `r'\\path\\file.ext'`). For paths containing drive letters, `unc` will always be the empty string.

Availability: Windows.

```
os.path.supports_unicode_filenames
```

True if arbitrary Unicode strings can be used as file names (within limitations imposed by the file system).
11.3. **fileinput** — Iterate over lines from multiple input streams

**Source code:** Lib/fileinput.py

This module implements a helper class and functions to quickly write a loop over standard input or a list of files. If you just want to read or write one file see `open()`.

The typical use is:

```python
import fileinput
for line in fileinput.input():
    process(line)
```

This iterates over the lines of all files listed in `sys.argv[1:]`, defaulting to `sys.stdin` if the list is empty. If a filename is `'-'`, it is also replaced by `sys.stdin`. To specify an alternative list of filenames, pass it as the first argument to `input()`. A single file name is also allowed.

All files are opened in text mode by default, but you can override this by specifying the `mode` parameter in the call to `input()` or `FileInput`. If an I/O error occurs during opening or reading a file, `OSError` is raised.

*Changed in version 3.3:* `IOError` used to be raised; it is now an alias of `OSError`.

If `sys.stdin` is used more than once, the second and further use will
return no lines, except perhaps for interactive use, or if it has been explicitly reset (e.g. using `sys.stdin.seek(0)`).

Empty files are opened and immediately closed; the only time their presence in the list of filenames is noticeable at all is when the last file opened is empty.

Lines are returned with any newlines intact, which means that the last line in a file may not have one.

You can control how files are opened by providing an opening hook via the `openhook` parameter to `fileinput.input()` or `FileInput()`. The hook must be a function that takes two arguments, `filename` and `mode`, and returns an accordingly opened file-like object. Two useful hooks are already provided by this module.

The following function is the primary interface of this module:

```python
fileinput.input(files=None, inplace=False, backup='', bufsize=0, mode='r', openhook=None)
```

Create an instance of the `FileInput` class. The instance will be used as global state for the functions of this module, and is also returned to use during iteration. The parameters to this function will be passed along to the constructor of the `FileInput` class.

The `FileInput` instance can be used as a context manager in the `with` statement. In this example, `input` is closed after the `with` statement is exited, even if an exception occurs:

```python
with fileinput.input(files=('spam.txt', 'eggs.txt')) as f:
    for line in f:
        process(line)
```
Changed in version 3.2: Can be used as a context manager.

The following functions use the global state created by `fileinput.input()`; if there is no active state, `RuntimeError` is raised.

`fileinput.filename()`  
Return the name of the file currently being read. Before the first line has been read, returns None.

`fileinput.fileno()`  
Return the integer “file descriptor” for the current file. When no file is opened (before the first line and between files), returns -1.

`fileinput.lineno()`  
Return the cumulative line number of the line that has just been read. Before the first line has been read, returns 0. After the last line of the last file has been read, returns the line number of that line.

`fileinput.filelineno()`  
Return the line number in the current file. Before the first line has been read, returns 0. After the last line of the last file has been read, returns the line number of that line within the file.

`fileinput.isfirstline()`  
Returns true if the line just read is the first line of its file, otherwise returns false.

`fileinput.isstdin()`  
Returns true if the last line was read from `sys.stdin`, otherwise returns false.
fileinput.nextfile()

Close the current file so that the next iteration will read the first line from the next file (if any); lines not read from the file will not count towards the cumulative line count. The filename is not changed until after the first line of the next file has been read. Before the first line has been read, this function has no effect; it cannot be used to skip the first file. After the last line of the last file has been read, this function has no effect.

fileinput.close()

Close the sequence.

The class which implements the sequence behavior provided by the module is available for subclassing as well:

class fileinput.FileInput(files=None, inplace=False, backup='', bufsize=0, mode='r', openhook=None)

Class FileInput is the implementation; its methods filename(), fileno(), lineno(), filelineno(), isfirstline(), isstdin(), nextfile() and close() correspond to the functions of the same name in the module. In addition it has a readline() method which returns the next input line, and a __getitem__() method which implements the sequence behavior. The sequence must be accessed in strictly sequential order; random access and readline() cannot be mixed.

With mode you can specify which file mode will be passed to open(). It must be one of 'r', 'rU', 'U' and 'rb'.

The openhook, when given, must be a function that takes two arguments, filename and mode, and returns an accordingly opened
file-like object. You cannot use `inplace` and `openhook` together.

A `FileInput` instance can be used as a context manager in the `with` statement. In this example, `input` is closed after the `with` statement is exited, even if an exception occurs:

```python
with FileInput(files=('spam.txt', 'eggs.txt')) as process(input)
```

*Changed in version 3.2:* Can be used as a context manager.

*Deprecated since version 3.4:* The 'rU' and 'U' modes.

**Optional in-place filtering:** if the keyword argument `inplace=True` is passed to `fileinput.input()` or to the `FileInput` constructor, the file is moved to a backup file and standard output is directed to the input file (if a file of the same name as the backup file already exists, it will be replaced silently). This makes it possible to write a filter that rewrites its input file in place. If the `backup` parameter is given (typically as `backup='.<some extension>'`), it specifies the extension for the backup file, and the backup file remains around; by default, the extension is '.bak' and it is deleted when the output file is closed. In-place filtering is disabled when standard input is read.

The two following opening hooks are provided by this module:

```
fileinput.hook_compressed(filename, mode)
```

Transparently opens files compressed with gzip and bzip2 (recognized by the extensions '.gz' and '.bz2') using the `gzip` and `bz2` modules. If the filename extension is not '.gz' or '.bz2', the file is opened normally (ie, using `open()` without any decompression).
Usage example:
```
fi = fileinput.FileInput(openhook=fileinput.hook_compressed)
```

`fileinput.hook_encoded(encoding)`

Returns a hook which opens each file with `codecs.open()`, using the given `encoding` to read the file.

Usage example:
```
fi = fileinput.FileInput(openhook=fileinput.hook_encoded("iso-8859-1"))
```
11.4. **stat — Interpreting stat() results**

**Source code:** Modules/_stat.c
Lib/stat.py

The `stat` module defines constants and functions for interpreting the results of `os.stat()`, `os.fstat()` and `os.lstat()` (if they exist). For complete details about the `stat()`, `fstat()` and `lstat()` calls, consult the documentation for your system.

*Changed in version 3.4:* The `stat` module is backed by a C implementation.

The `stat` module defines the following functions to test for specific file types:

- **`stat.S_ISDIR(mode)`**
  - Return non-zero if the mode is from a directory.

- **`stat.S_ISCHR(mode)`**
  - Return non-zero if the mode is from a character special device file.

- **`stat.S_ISBLK(mode)`**
  - Return non-zero if the mode is from a block special device file.

- **`stat.S_ISREG(mode)`**
  - Return non-zero if the mode is from a regular file.

- **`stat.S_ISFIFO(mode)`**
Return non-zero if the mode is from a FIFO (named pipe).

\texttt{stat.S_ISLNK(mode)}

Return non-zero if the mode is from a symbolic link.

\texttt{stat.S_ISSOCK(mode)}

Return non-zero if the mode is from a socket.

\texttt{stat.S_ISDOOR(mode)}

Return non-zero if the mode is from a door.

\textit{New in version 3.4.}

\texttt{stat.S_ISPORT(mode)}

Return non-zero if the mode is from an event port.

\textit{New in version 3.4.}

\texttt{stat.S_ISWHT(mode)}

Return non-zero if the mode is from a whiteout.

\textit{New in version 3.4.}

Two additional functions are defined for more general manipulation of the file’s mode:

\texttt{stat.S_IMODE(mode)}

Return the portion of the file’s mode that can be set by \texttt{os.chmod()}—that is, the file’s permission bits, plus the sticky bit, set-group-id, and set-user-id bits (on systems that support them).

\texttt{stat.S_IFMT(mode)}

Return the portion of the file’s mode that describes the file type (used by the \texttt{S_IS*()} functions above).
Normally, you would use the `os.path.is*()` functions for testing the type of a file; the functions here are useful when you are doing multiple tests of the same file and wish to avoid the overhead of the `stat()` system call for each test. These are also useful when checking for information about a file that isn't handled by `os.path`, like the tests for block and character devices.

Example:

```python
import os, sys
from stat import *

def walktree(top, callback):
    '''recursively descend the directory tree rooted at top,
calling the callback function for each regular file.'''
    for f in os.listdir(top):
        pathname = os.path.join(top, f)
        mode = os.stat(pathname).st_mode
        if S_ISDIR(mode):
            # It's a directory, recurse into it
            walktree(pathname, callback)
        elif S_ISREG(mode):
            # It's a file, call the callback function
            callback(pathname)
        else:
            # Unknown file type, print a message
            print('Skipping %s' % pathname)

def visitfile(file):
    print('visiting', file)

if __name__ == '__main__':
    walktree(sys.argv[1], visitfile)
```
An additional utility function is provided to convert a file’s mode in a human readable string:

```
stat.filemode(mode)
```

Convert a file’s mode to a string of the form ‘-rwxrwxrwx’.

*New in version 3.3.*

*Changed in version 3.4:* The function supports `S_IFDOOR`, `S_IFPORT` and `S_IFWHT`.

All the variables below are simply symbolic indexes into the 10-tuple returned by `os.stat()`, `os.fstat()` or `os.lstat()`.

```
stat.ST_MODE
Inode protection mode.

stat.ST_INO
Inode number.

stat.ST_DEV
Device inode resides on.

stat.ST_NLINK
Number of links to the inode.

stat.ST_UID
User id of the owner.

stat.ST_GID
Group id of the owner.

stat.ST_SIZE
Size in bytes of a plain file; amount of data waiting on some special
The interpretation of “file size” changes according to the file type. For plain files this is the size of the file in bytes. For FIFOs and sockets under most flavors of Unix (including Linux in particular), the “size” is the number of bytes waiting to be read at the time of the call to `os.stat()`, `os.fstat()`, or `os.lstat()`; this can sometimes be useful, especially for polling one of these special files after a non-blocking open. The meaning of the size field for other character and block devices varies more, depending on the implementation of the underlying system call.

The variables below define the flags used in the `ST_MODE` field.

Use of the functions above is more portable than use of the first set of flags:

- `stat.S_IFSOCK`: Socket.
- `stat.S_IFLNK`:
Symbolic link.

`stat.S_IFREG`
Regular file.

`stat.S_IFBLK`
Block device.

`stat.S_IFDIR`
Directory.

`stat.S_IFCHR`
Character device.

`stat.S_IFIFO`
FIFO.

`stat.S_IFDOOR`
Door.

*New in version 3.4.*

`stat.S_IFPORT`
Event port.

*New in version 3.4.*

`stat.S_IFWHT`
Whiteout.

*New in version 3.4.*

**Note:** `S_IFDOOR`, `S_IFPORT` or `S_IFWHT` are defined as 0 when the platform does not have support for the file types.
The following flags can also be used in the `mode` argument of `os.chmod()`:

```c
stat.S_ISUID
  Set UID bit.

stat.S_ISGID
  Set-group-ID bit. This bit has several special uses. For a directory it indicates that BSD semantics is to be used for that directory: files created there inherit their group ID from the directory, not from the effective group ID of the creating process, and directories created there will also get the `S_ISGID` bit set. For a file that does not have the group execution bit (`S_IXGRP`) set, the set-group-ID bit indicates mandatory file/record locking (see also `S_ENFMT`).

stat.S_ISVTX
  Sticky bit. When this bit is set on a directory it means that a file in that directory can be renamed or deleted only by the owner of the file, by the owner of the directory, or by a privileged process.

stat.S_IRWXU
  Mask for file owner permissions.

stat.S_IRUSR
  Owner has read permission.

stat.S_IWUSR
  Owner has write permission.

stat.S_IXUSR
  Owner has execute permission.

stat.S_IRWXG
```
Mask for group permissions.

stat.\texttt{S\_IRGRP}
Group has read permission.

stat.\texttt{S\_IWGRP}
Group has write permission.

stat.\texttt{S\_IXGRP}
Group has execute permission.

stat.\texttt{S\_IRWXO}
Mask for permissions for others (not in group).

stat.\texttt{S\_IROTH}
Others have read permission.

stat.\texttt{S\_IWOTH}
Others have write permission.

stat.\texttt{S\_IXOTH}
Others have execute permission.

stat.\texttt{S\_ENFMT}
System V file locking enforcement. This flag is shared with \texttt{S\_ISGID}: file/record locking is enforced on files that do not have the group execution bit (\texttt{S\_IXGRP}) set.

stat.\texttt{S\_IREAD}
Unix V7 synonym for \texttt{S\_IRUSR}.

stat.\texttt{S\_IWRITE}
Unix V7 synonym for \texttt{S\_IWUSR}. 
The following flags can be used in the `flags` argument of `os.chflags()`:

- **stat.S_IEXEC**
  Unix V7 synonym for `S_IXUSR`.

- **stat.UF_NODUMP**
  Do not dump the file.

- **stat.UF_IMMUTABLE**
  The file may not be changed.

- **stat.UF_APPEND**
  The file may only be appended to.

- **stat.UF_OPAQUE**
  The directory is opaque when viewed through a union stack.

- **stat.UF_NOUNLINK**
  The file may not be renamed or deleted.

- **stat.UF_COMPRESSED**
  The file is stored compressed (Mac OS X 10.6+).

- **stat.UF_HIDDEN**
  The file should not be displayed in a GUI (Mac OS X 10.5+).

- **stat.SF_ARCHIVED**
  The file may be archived.

- **stat.SF_IMMUTABLE**
  The file may not be changed.

- **stat.SF_APPEND**
The file may only be appended to.

stat.\texttt{SF\_NOUNLINK}

The file may not be renamed or deleted.

stat.\texttt{SF\_SNAPSHOT}

The file is a snapshot file.

See the *BSD or Mac OS systems man page \texttt{chflags(2)} for more information.

On Windows, the following file attribute constants are available for use when testing bits in the \texttt{st\_file\_attributes} member returned by \texttt{os.stat()}. See the Windows API documentation for more detail on the meaning of these constants.

stat.\texttt{FILE\_ATTRIBUTE\_ARCHIVE}
stat.\texttt{FILE\_ATTRIBUTE\_COMPRESSED}
stat.\texttt{FILE\_ATTRIBUTE\_DEVICE}
stat.\texttt{FILE\_ATTRIBUTE\_DIRECTORY}
stat.\texttt{FILE\_ATTRIBUTE\_ENCRYPTED}
stat.\texttt{FILE\_ATTRIBUTE\_HIDDEN}
stat.\texttt{FILE\_ATTRIBUTE\_INTEGRITY\_STREAM}
stat.\texttt{FILE\_ATTRIBUTE\_NORMAL}
stat.\texttt{FILE\_ATTRIBUTE\_NOT\_CONTENT\_INDEXED}
stat.\texttt{FILE\_ATTRIBUTE\_NO\_SCRUB\_DATA}
stat.\texttt{FILE\_ATTRIBUTE\_OFFLINE}
stat.\texttt{FILE\_ATTRIBUTE\_READONLY}
stat.\texttt{FILE\_ATTRIBUTE\_REPARSE\_POINT}
stat.\texttt{FILE\_ATTRIBUTE\_SPARSE\_FILE}
stat.\texttt{FILE\_ATTRIBUTE\_SYSTEM}
stat.\texttt{FILE\_ATTRIBUTE\_TEMPORARY}
stat.\texttt{FILE\_ATTRIBUTE\_VIRTUAL}
New in version 3.5.
11.5. `filecmp` — File and Directory Comparisons

**Source code:** `Lib/filecmp.py`

The `filecmp` module defines functions to compare files and directories, with various optional time/correctness trade-offs. For comparing files, see also the `difflib` module.

The `filecmp` module defines the following functions:

**`filecmp.cmp(f1, f2, shallow=True)`**

Compare the files named `f1` and `f2`, returning `True` if they seem equal, `False` otherwise.

If `shallow` is true, files with identical `os.stat()` signatures are taken to be equal. Otherwise, the contents of the files are compared.

Note that no external programs are called from this function, giving it portability and efficiency.

This function uses a cache for past comparisons and the results, with cache entries invalidated if the `os.stat()` information for the file changes. The entire cache may be cleared using `clear_cache()`.

**`filecmp.cmpfiles(dir1, dir2, common, shallow=True)`**

Compare the files in the two directories `dir1` and `dir2` whose names are given by `common`. 
Returns three lists of file names: `match`, `mismatch`, `errors`. `match` contains the list of files that match, `mismatch` contains the names of those that don't, and `errors` lists the names of files which could not be compared. Files are listed in `errors` if they don't exist in one of the directories, the user lacks permission to read them or if the comparison could not be done for some other reason.

The `shallow` parameter has the same meaning and default value as for `filecmp.cmp()`.

For example, `cmpfiles('a', 'b', ['c', 'd/e'])` will compare `a/c` with `b/c` and `a/d/e` with `b/d/e`. 'c' and 'd/e' will each be in one of the three returned lists.

`filecmp.clear_cache()`

Clear the filecmp cache. This may be useful if a file is compared so quickly after it is modified that it is within the mtime resolution of the underlying filesystem.

*New in version 3.4.*
11.5.1. The `dircmp` class

```python
class filecmp.dircmp(a, b, ignore=None, hide=None)
```

Construct a new directory comparison object, to compare the
directories `a` and `b`. `ignore` is a list of names to ignore, and defaults
to `filecmp.DEFAULT_IGNORES`. `hide` is a list of names to hide, and defaults to `[os.curdir, os.pardir]`.

The `dircmp` class compares files by doing `shallow` comparisons
as described for `filecmp.cmp()`.

The `dircmp` class provides the following methods:

- **report()**
  
  Print (to `sys.stdout`) a comparison between `a` and `b`.

- **report_partial_closure()**
  
  Print a comparison between `a` and `b` and common immediate
  subdirectories.

- **report_full_closure()**
  
  Print a comparison between `a` and `b` and common subdirectories (recursively).

The `dircmp` class offers a number of interesting attributes that
may be used to get various bits of information about the directory
trees being compared.

Note that via `__getattr__()` hooks, all attributes are computed
lazily, so there is no speed penalty if only those attributes which are
lightweight to compute are used.
left
  The directory \textit{a}.

right
  The directory \textit{b}.

left\_list
  Files and subdirectories in \textit{a}, filtered by \textit{hide} and \textit{ignore}.

right\_list
  Files and subdirectories in \textit{b}, filtered by \textit{hide} and \textit{ignore}.

common
  Files and subdirectories in both \textit{a} and \textit{b}.

left\_only
  Files and subdirectories only in \textit{a}.

right\_only
  Files and subdirectories only in \textit{b}.

common\_dirs
  Subdirectories in both \textit{a} and \textit{b}.

common\_files
  Files in both \textit{a} and \textit{b}.

common\_funny
  Names in both \textit{a} and \textit{b}, such that the type differs between the directories, or names for which \texttt{os.stat()} reports an error.

same\_files
  Files which are identical in both \textit{a} and \textit{b}, using the class's file comparison operator.
**diff_files**

Files which are in both a and b, whose contents differ according to the class's file comparison operator.

**funny_files**

Files which are in both a and b, but could not be compared.

**subdirs**

A dictionary mapping names in common_dirs to dircmp objects.

`filecmp.DEFAULT_IGNORES`

*New in version 3.4.*

List of directories ignored by `dircmp` by default.

Here is a simplified example of using the `subdirs` attribute to search recursively through two directories to show common different files:

```python
>>> from filecmp import dircmp
>>> def print_diff_files(dcmp):
...     for name in dcmp.diff_files:
...         print("diff_file %s found in %s and %s" %
...               (name, dcmp.left, dcmp.right))
...     for sub_dcmp in dcmp.subdirs.values():
...         print_diff_files(sub_dcmp)
...
>>> dcmp = dircmp('dir1', 'dir2')
>>> print_diff_files(dcmp)
```
11.6. **tempfile** — Generate temporary files and directories

**Source code:** Lib/tempfile.py

This module creates temporary files and directories. It works on all supported platforms. `TemporaryFile`, `NamedTemporaryFile`, `TemporaryDirectory`, and `SpooledTemporaryFile` are high-level interfaces which provide automatic cleanup and can be used as context managers. `mkstemp()` and `mkdtemp()` are lower-level functions which require manual cleanup.

All the user-callable functions and constructors take additional arguments which allow direct control over the location and name of temporary files and directories. Files names used by this module include a string of random characters which allows those files to be securely created in shared temporary directories. To maintain backward compatibility, the argument order is somewhat odd; it is recommended to use keyword arguments for clarity.

The module defines the following user-callable items:

```python
import tempfile

# Return a file-like object that can be used as a temporary storage area.
# The file is created securely, using the same rules as mkstemp(). It will be destroyed as soon as it is closed (including
# an implicit close when the object is garbage collected). Under Unix, the directory entry for the file is either not created at all or is
# removed immediately after the file is created. Other platforms do
```

```python
tempfile.TemporaryFile(mode='w+b', buffering=None, encoding=None, newline=None, suffix=None, prefix=None, dir=None)
```
not support this; your code should not rely on a temporary file
created using this function having or not having a visible name in
the file system.

The resulting object can be used as a context manager (see
Examples). On completion of the context or destruction of the file
object the temporary file will be removed from the filesystem.

The *mode* parameter defaults to 'w+b' so that the file created can
be read and written without being closed. Binary mode is used so
that it behaves consistently on all platforms without regard for the
data that is stored. *buffering*, *encoding* and *newline* are interpreted
as for *open()*.

The *dir*, *prefix* and *suffix* parameters have the same meaning and
defaults as with *mkstemp()*.

The returned object is a true file object on POSIX platforms. On
other platforms, it is a file-like object whose *file* attribute is the
underlying true file object.

The *os.O_TMPFILE* flag is used if it is available and works (Linux-
specific, requires Linux kernel 3.11 or later).

*Changed in version 3.5*: The *os.O_TMPFILE* flag is now used if
available.

```
NamedTemporaryFile(mode='w+b', buffering=None, encoding=None, newline=None, suffix=None, prefix=None, dir=None, delete=True)
```

This function operates exactly as *TemporaryFile()* does, except
that the file is guaranteed to have a visible name in the file system
(on Unix, the directory entry is not unlinked). That name can be
retrieved from the name attribute of the file object. Whether the name can be used to open the file a second time, while the named temporary file is still open, varies across platforms (it can be so used on Unix; it cannot on Windows NT or later). If delete is true (the default), the file is deleted as soon as it is closed. The returned object is always a file-like object whose file attribute is the underlying true file object. This file-like object can be used in a with statement, just like a normal file.

tempfile.SpooledTemporaryFile(max_size=0, mode='w+b', buffering=None, encoding=None, newline=None, suffix=None, prefix=None, dir=None)

This function operates exactly as TemporaryFile() does, except that data is spooled in memory until the file size exceeds max_size, or until the file's fileno() method is called, at which point the contents are written to disk and operation proceeds as with TemporaryFile().

The resulting file has one additional method, rollover(), which causes the file to roll over to an on-disk file regardless of its size.

The returned object is a file-like object whose _file attribute is either an io.BytesIO or io.StringIO object (depending on whether binary or text mode was specified) or a true file object, depending on whether rollover() has been called. This file-like object can be used in a with statement, just like a normal file.

*Changed in version 3.3:* the truncate method now accepts a size argument.

tempfile.TemporaryDirectory(suffix=None, prefix=None, dir=None)
This function securely creates a temporary directory using the same rules as `mkdtemp()`. The resulting object can be used as a context manager (see Examples). On completion of the context or destruction of the temporary directory object the newly created temporary directory and all its contents are removed from the filesystem.

The directory name can be retrieved from the name attribute of the returned object. When the returned object is used as a context manager, the name will be assigned to the target of the as clause in the with statement, if there is one.

The directory can be explicitly cleaned up by calling the cleanup() method.

New in version 3.2.

```
tempfile.mkstemp(suffix=None, prefix=None, dir=None, text=False)
```

Creates a temporary file in the most secure manner possible. There are no race conditions in the file's creation, assuming that the platform properly implements the `os.O_EXCL` flag for `os.open()`. The file is readable and writable only by the creating user ID. If the platform uses permission bits to indicate whether a file is executable, the file is executable by no one. The file descriptor is not inherited by child processes.

Unlike `TemporaryFile()`, the user of `mkstemp()` is responsible for deleting the temporary file when done with it.

If `suffix` is not None, the file name will end with that suffix, otherwise there will be no suffix. `mkstemp()` does not put a dot between the file name and the suffix; if you need one, put it at the
beginning of suffix.

If prefix is not None, the file name will begin with that prefix; otherwise, a default prefix is used. The default is the return value of gettempdir() or gettempprefix(), as appropriate.

If dir is not None, the file will be created in that directory; otherwise, a default directory is used. The default directory is chosen from a platform-dependent list, but the user of the application can control the directory location by setting the TMPDIR, TEMP or TMP environment variables. There is thus no guarantee that the generated filename will have any nice properties, such as not requiring quoting when passed to external commands via os.popen().

If any of suffix, prefix, and dir are not None, they must be the same type. If they are bytes, the returned name will be bytes instead of str. If you want to force a bytes return value with otherwise default behavior, pass suffix=b''.

If text is specified, it indicates whether to open the file in binary mode (the default) or text mode. On some platforms, this makes no difference.

mkstemp() returns a tuple containing an OS-level handle to an open file (as would be returned by os.open()) and the absolute path name of that file, in that order.

*Changed in version 3.5:* suffix, prefix, and dir may now be supplied in bytes in order to obtain a bytes return value. Prior to this, only str was allowed. suffix and prefix now accept and default to None to cause an appropriate default value to be used.
tempfile.mkdtemp(suffix=\texttt{None}, prefix=\texttt{None}, dir=\texttt{None})

Creates a temporary directory in the most secure manner possible. There are no race conditions in the directory’s creation. The directory is readable, writable, and searchable only by the creating user ID.

The user of \texttt{mkdtemp()} is responsible for deleting the temporary directory and its contents when done with it.

The \textit{prefix}, \textit{suffix}, and \textit{dir} arguments are the same as for \texttt{mkstemp()}. \texttt{mkdtemp()} returns the absolute pathname of the new directory.

\textit{Changed in version 3.5: suffix, prefix, and dir may now be supplied in bytes in order to obtain a bytes return value. Prior to this, only str was allowed. suffix and prefix now accept and default to None to cause an appropriate default value to be used.}

tempfile.gettempdir()

Return the name of the directory used for temporary files. This defines the default value for the \textit{dir} argument to all functions in this module.

Python searches a standard list of directories to find one which the calling user can create files in. The list is:

1. The directory named by the \texttt{TMPDIR} environment variable.
2. The directory named by the \texttt{TEMP} environment variable.
3. The directory named by the \texttt{TMP} environment variable.
4. A platform-specific location:
   \begin{itemize}
   \item On Windows, the directories \texttt{C:}\textbackslash TEMP, \texttt{C:}\textbackslash TMP, \texttt{\TEMP}, and \texttt{\TMP}, in that order.
   \end{itemize}
- On all other platforms, the directories /tmp, /var/tmp, and /usr/tmp, in that order.

5. As a last resort, the current working directory.

The result of this search is cached, see the description of `tempdir` below.

```python
tempfile.gettempdirb()
```

Same as `gettempdir()` but the return value is in bytes.

*New in version 3.5.*

```python
tempfile.gettempprefix()
```

Return the filename prefix used to create temporary files. This does not contain the directory component.

```python
tempfile.gettempprefixb()
```

Same as `gettempprefix()` but the return value is in bytes.

*New in version 3.5.*

The module uses a global variable to store the name of the directory used for temporary files returned by `gettempdir()`. It can be set directly to override the selection process, but this is discouraged. All functions in this module take a `dir` argument which can be used to specify the directory and this is the recommend approach.

```python
tempfile.tempdir
```

When set to a value other than `None`, this variable defines the default value for the `dir` argument to all the functions defined in this module.

If `tempdir` is unset or `None` at any call to any of the above functions except `gettempprefix()` it is initialized following the
algorithm described in `gettempdir()`.
11.6.1. Examples

Here are some examples of typical usage of the `tempfile` module:

```python
>>> import tempfile

# create a temporary file and write some data to it
>>> fp = tempfile.TemporaryFile()
>>> fp.write(b'Hello world!')
# read data from file
>>> fp.seek(0)
>>> fp.read()
b'Hello world!'
# close the file, it will be removed
>>> fp.close()

# create a temporary file using a context manager
>>> with tempfile.TemporaryFile() as fp:
...    fp.write(b'Hello world!')
...    fp.seek(0)
...    fp.read()
b'Hello world!'

# file is now closed and removed

# create a temporary directory using the context manager
>>> with tempfile.TemporaryDirectory() as tmpdirname:
...    print('created temporary directory', tmpdirname)

# directory and contents have been removed
```
11.6.2. Deprecated functions and variables

A historical way to create temporary files was to first generate a file name with the `mktemp()` function and then create a file using this name. Unfortunately this is not secure, because a different process may create a file with this name in the time between the call to `mktemp()` and the subsequent attempt to create the file by the first process. The solution is to combine the two steps and create the file immediately. This approach is used by `mkstemp()` and the other functions described above.

```python
tempfile.mktemp(suffix='', prefix='tmp', dir=None)
```

*Deprecated since version 2.3:* Use `mkstemp()` instead.

Return an absolute pathname of a file that did not exist at the time the call is made. The `prefix`, `suffix`, and `dir` arguments are similar to those of `mkstemp()`, except that bytes file names, `suffix=None` and `prefix=None` are not supported.

**Warning:** Use of this function may introduce a security hole in your program. By the time you get around to doing anything with the file name it returns, someone else may have beaten you to the punch. `mktemp()` usage can be replaced easily with `NamedTemporaryFile()`, passing it the `delete=False` parameter:

```python
>>> f = NamedTemporaryFile(delete=False)
>>> f.name
'/tmp/tmptjuijtt'
>>> f.write(b"Hello World!\n")
13
>>> f.close()
```
>>> os.unlink(f.name)
>>> os.path.exists(f.name)
False
11.7. `glob` — Unix style pathname pattern expansion

Source code: Lib/glob.py

The `glob` module finds all the pathnames matching a specified pattern according to the rules used by the Unix shell, although results are returned in arbitrary order. No tilde expansion is done, but *, ?, and character ranges expressed with [] will be correctly matched. This is done by using the `os.listdir()` and `fnmatch.fnmatch()` functions in concert, and not by actually invoking a subshell. Note that unlike `fnmatch.fnmatch()`, `glob` treats filenames beginning with a dot (.) as special cases. (For tilde and shell variable expansion, use `os.path.expanduser()` and `os.path.expandvars()`.)

For a literal match, wrap the meta-characters in brackets. For example, '[]' matches the character '?'.

See also: The `pathlib` module offers high-level path objects.

glob.glob(pathname, *, recursive=False)

Return a possibly-empty list of path names that match `pathname`, which must be a string containing a path specification. `pathname` can be either absolute (like `/usr/src/Python-1.5/Makefile`) or relative (like `../../Tools/*//*.gif`), and can contain shell-style wildcards. Broken symlinks are included in the results (as in the shell).

If `recursive` is true, the pattern "**" will match any files and zero or
more directories and subdirectories. If the pattern is followed by an os.sep, only directories and subdirectories match.

**Note:** Using the "***" pattern in large directory trees may consume an inordinate amount of time.

*Changed in version 3.5:* Support for recursive globs using "***".

**glob**. **iglob**(pathname, recursive=False)

Return an iterator which yields the same values as **glob**() without actually storing them all simultaneously.

**glob**. **escape**(pathname)

Escape all special characters (',', '*' and '['). This is useful if you want to match an arbitrary literal string that may have special characters in it. Special characters in drive/UNC sharepoints are not escaped, e.g. on Windows escape('///?/c:/Quo vadis?.txt') returns '///?/c:/Quo vadis[?].txt'.

*New in version 3.4.*

For example, consider a directory containing the following files: 1.gif, 2.txt, card.gif and a subdirectory sub which contains only the file 3.txt. **glob**() will produce the following results. Notice how any leading components of the path are preserved.

```python
>>> import glob
glob.glob('./[0-9].*')
['./1.gif', './2.txt']
glob.glob('*.gif')
['1.gif', 'card.gif']
glob.glob('??.gif')
['1.gif']
```
If the directory contains files starting with . they won’t be matched by default. For example, consider a directory containing card.gif and .card.gif:

```python
>>> import glob
>>> glob.glob('*.gif')
['card.gif']
>>> glob.glob('.c*')
['.card.gif']
```

See also:

Module `fnmatch`

Shell-style filename (not path) expansion
11.8. **fnmatch** — Unix filename pattern matching

**Source code:** Lib/fnmatch.py

This module provides support for Unix shell-style wildcards, which are *not* the same as regular expressions (which are documented in the `re` module). The special characters used in shell-style wildcards are:

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>matches everything</td>
</tr>
<tr>
<td>?</td>
<td>matches any single character</td>
</tr>
<tr>
<td>[seq]</td>
<td>matches any character in <code>seq</code></td>
</tr>
<tr>
<td>![seq]</td>
<td>matches any character not in <code>seq</code></td>
</tr>
</tbody>
</table>

For a literal match, wrap the meta-characters in brackets. For example, `'[?]'` matches the character `'?'.`

Note that the filename separator (`'/'` on Unix) is *not* special to this module. See module `glob` for pathname expansion (`glob` uses `fnmatch()` to match pathname segments). Similarly, filenames starting with a period are not special for this module, and are matched by the `*` and `?` patterns.

```python
def fnmatch(filename, pattern)
    Test whether the `filename` string matches the `pattern` string, returning `True` or `False`. If the operating system is case-```
insensitive, then both parameters will be normalized to all lower- or upper-case before the comparison is performed. `fnmatchcase()` can be used to perform a case-sensitive comparison, regardless of whether that's standard for the operating system.

This example will print all file names in the current directory with the extension `.txt`:

```python
import fnmatch
import os

for file in os.listdir('.'):  
    if fnmatch.fnmatch(file, '*.txt'): 
        print(file)
```

`fnmatch.fnmatchcase(filename, pattern)`
Test whether `filename` matches `pattern`, returning `True` or `False`; the comparison is case-sensitive.

`fnmatch.filter(names, pattern)`
Return the subset of the list of `names` that match `pattern`. It is the same as `[n for n in names if fnmatch(n, pattern)]`, but implemented more efficiently.

`fnmatch.translate(pattern)`
Return the shell-style `pattern` converted to a regular expression.

Example:

```python
>>> import fnmatch, re
>>> regex = fnmatch.translate('*.txt')
>>> regex
'.*\.txt\Z(?ms)'
```
>>> reobj = re.compile(regex)
>>> reobj.match('foobar.txt')
<_sre.SRE_Match object; span=(0, 10), match='foobar.txt'>

See also:

**Module glob**

Unix shell-style path expansion.
Python » 3.5.1 Documentation » The Python Standard Library » 11. File and Directory Access »
11.9. linecache — Random access to text lines

Source code: Lib/linecache.py

The linecache module allows one to get any line from a Python source file, while attempting to optimize internally, using a cache, the common case where many lines are read from a single file. This is used by the traceback module to retrieve source lines for inclusion in the formatted traceback.

The tokenize.open() function is used to open files. This function uses tokenize.detect_encoding() to get the encoding of the file; in the absence of an encoding token, the file encoding defaults to UTF-8.

The linecache module defines the following functions:

linecache.getline(filename, lineno, module_globals=None)

Get line lineno from file named filename. This function will never raise an exception — it will return '' on errors (the terminating newline character will be included for lines that are found).

If a file named filename is not found, the function will look for it in the module search path, sys.path, after first checking for a PEP 302 __loader__ in module_globals, in case the module was imported from a zipfile or other non-filesystem import source.

linecache.clearcache()

Clear the cache. Use this function if you no longer need lines from
files previously read using `getline()`.

```python
linecache.checkcache(filename=None)
```

Check the cache for validity. Use this function if files in the cache may have changed on disk, and you require the updated version. If `filename` is omitted, it will check all the entries in the cache.

```python
linecache.lazycache(filename, module_globals)
```

Capture enough detail about a non-file-based module to permit getting its lines later via `getline()` even if `module_globals` is None in the later call. This avoids doing I/O until a line is actually needed, without having to carry the module globals around indefinitely.

*New in version 3.5.*

Example:

```python
>>> import linecache

>>> linecache.getline(linecache.__file__, 8)
'import sys\n'
```
11.10. **shutil** — High-level file operations

**Source code:** Lib/shutil.py

The **shutil** module offers a number of high-level operations on files and collections of files. In particular, functions are provided which support file copying and removal. For operations on individual files, see also the **os** module.

**Warning:** Even the higher-level file copying functions (**shutil.copy()**, **shutil.copy2()**) cannot copy all file metadata.

On POSIX platforms, this means that file owner and group are lost as well as ACLs. On Mac OS, the resource fork and other metadata are not used. This means that resources will be lost and file type and creator codes will not be correct. On Windows, file owners, ACLs and alternate data streams are not copied.
11.10.1. Directory and files operations

`shutil.copyfileobj(fsrc, fdst[, length])`

Copy the contents of the file-like object `fsrc` to the file-like object `fdst`. The integer `length`, if given, is the buffer size. In particular, a negative `length` value means to copy the data without looping over the source data in chunks; by default the data is read in chunks to avoid uncontrolled memory consumption. Note that if the current file position of the `fsrc` object is not 0, only the contents from the current file position to the end of the file will be copied.

`shutil.copyfile(src, dst, *, follow_symlinks=True)`

Copy the contents (no metadata) of the file named `src` to a file named `dst` and return `dst`. `src` and `dst` are path names given as strings. `dst` must be the complete target file name; look at `shutil.copy()` for a copy that accepts a target directory path. If `src` and `dst` specify the same file, `SameFileError` is raised.

The destination location must be writable; otherwise, an `OSError` exception will be raised. If `dst` already exists, it will be replaced. Special files such as character or block devices and pipes cannot be copied with this function.

If `follow_symlinks` is false and `src` is a symbolic link, a new symbolic link will be created instead of copying the file `src` points to.

*Changed in version 3.3:* `IOError` used to be raised instead of `OSError`. Added `follow_symlinks` argument. Now returns `dst`.

*Changed in version 3.4:* Raise `SameFileError` instead of `Error`. 
Since the former is a subclass of the latter, this change is backward compatible.

**exception** `shutil.SameFileError`

This exception is raised if source and destination in `copyfile()` are the same file.

*New in version 3.4.*

`shutil.copymode(src, dst, *, follow_symlinks=True)`

Copy the permission bits from `src` to `dst`. The file contents, owner, and group are unaffected. `src` and `dst` are path names given as strings. If `follow_symlinks` is false, and both `src` and `dst` are symbolic links, `copymode()` will attempt to modify the mode of `dst` itself (rather than the file it points to). This functionality is not available on every platform; please see `copystat()` for more information. If `copymode()` cannot modify symbolic links on the local platform, and it is asked to do so, it will do nothing and return.

*Changed in version 3.3: Added `follow_symlinks` argument.*

`shutil.copystat(src, dst, *, follow_symlinks=True)`

Copy the permission bits, last access time, last modification time, and flags from `src` to `dst`. On Linux, `copystat()` also copies the “extended attributes” where possible. The file contents, owner, and group are unaffected. `src` and `dst` are path names given as strings.

If `follow_symlinks` is false, and `src` and `dst` both refer to symbolic links, `copystat()` will operate on the symbolic links themselves rather than the files the symbolic links refer to—reading the information from the `src` symbolic link, and writing the information to the `dst` symbolic link.
**Note:** Not all platforms provide the ability to examine and modify symbolic links. Python itself can tell you what functionality is locally available.

- If `os.chmod` in `os.supports_follow_symlinks` is True, `copystat()` can modify the permission bits of a symbolic link.
- If `os.utime` in `os.supports_follow_symlinks` is True, `copystat()` can modify the last access and modification times of a symbolic link.
- If `os.chflags` in `os.supports_follow_symlinks` is True, `copystat()` can modify the flags of a symbolic link. (os.chflags is not available on all platforms.)

On platforms where some or all of this functionality is unavailable, when asked to modify a symbolic link, `copystat()` will copy everything it can. `copystat()` never returns failure.

Please see `os.supports_follow_symlinks` for more information.

*Changed in version 3.3:* Added `follow_symlinks` argument and support for Linux extended attributes.

```python
shutil.copy(src, dst, *, follow_symlinks=True)
```

Copies the file `src` to the file or directory `dst`. `src` and `dst` should be strings. If `dst` specifies a directory, the file will be copied into `dst` using the base filename from `src`. Returns the path to the newly created file.

If `follow_symlinks` is false, and `src` is a symbolic link, `dst` will be created as a symbolic link. If `follow_symlinks` is true and `src` is a symbolic link, `dst` will be a copy of the file `src` refers to.

`copy()` copies the file data and the file's permission mode (see
os.chmod()). Other metadata, like the file’s creation and modification times, is not preserved. To preserve all file metadata from the original, use copy2() instead.

*Changed in version 3.3:* Added *follow_symlinks* argument. Now returns path to the newly created file.

```python
shutil.copy2(src, dst, *, follow_symlinks=True)
```

Identical to copy() except that copy2() also attempts to preserve all file metadata.

When *follow_symlinks* is false, and *src* is a symbolic link, copy2() attempts to copy all metadata from the *src* symbolic link to the newly-created *dst* symbolic link. However, this functionality is not available on all platforms. On platforms where some or all of this functionality is unavailable, copy2() will preserve all the metadata it can; copy2() never returns failure.

copy2() uses copystat() to copy the file metadata. Please see copystat() for more information about platform support for modifying symbolic link metadata.

*Changed in version 3.3:* Added *follow_symlinks* argument, try to copy extended file system attributes too (currently Linux only). Now returns path to the newly created file.

```python
shutil.ignore_patterns(*patterns)
```

This factory function creates a function that can be used as a callable for copytree()‘s ignore argument, ignoring files and directories that match one of the glob-style patterns provided. See the example below.

```python
shutil.copytree(src, dst, symlinks=False, ignore=None,
```
Recursively copy an entire directory tree rooted at src, returning the destination directory. The destination directory, named by dst, must not already exist; it will be created as well as missing parent directories. Permissions and times of directories are copied with copystat(), individual files are copied using shutil.copy2().

If symlinks is true, symbolic links in the source tree are represented as symbolic links in the new tree and the metadata of the original links will be copied as far as the platform allows; if false or omitted, the contents and metadata of the linked files are copied to the new tree.

When symlinks is false, if the file pointed by the symlink doesn’t exist, an exception will be added in the list of errors raised in an Error exception at the end of the copy process. You can set the optional ignore_dangling_symlinks flag to true if you want to silence this exception. Notice that this option has no effect on platforms that don’t support os.symlink().

If ignore is given, it must be a callable that will receive as its arguments the directory being visited by copytree(), and a list of its contents, as returned by os.listdir(). Since copytree() is called recursively, the ignore callable will be called once for each directory that is copied. The callable must return a sequence of directory and file names relative to the current directory (i.e. a subset of the items in its second argument); these names will then be ignored in the copy process. ignore_patterns() can be used to create such a callable that ignores names based on glob-style patterns.

If exception(s) occur, an Error is raised with a list of reasons.
If `copy_function` is given, it must be a callable that will be used to copy each file. It will be called with the source path and the destination path as arguments. By default, `shutil.copy2()` is used, but any function that supports the same signature (like `shutil.copy()`) can be used.

*Changed in version 3.3:* Copy metadata when `symlinks` is false. Now returns `dst`.

*Changed in version 3.2:* Added the `copy_function` argument to be able to provide a custom copy function. Added the `ignore_dangling_symlinks` argument to silent dangling symlinks errors when `symlinks` is false.

```
shutil.rmtree(path, ignore_errors=False, onerror=None)
```

Delete an entire directory tree; `path` must point to a directory (but not a symbolic link to a directory). If `ignore_errors` is true, errors resulting from failed removals will be ignored; if false or omitted, such errors are handled by calling a handler specified by `onerror` or, if that is omitted, they raise an exception.

---

**Note:** On platforms that support the necessary fd-based functions a symlink attack resistant version of `rmtree()` is used by default. On other platforms, the `rmtree()` implementation is susceptible to a symlink attack: given proper timing and circumstances, attackers can manipulate symlinks on the filesystem to delete files they wouldn’t be able to access otherwise. Applications can use the `rmtree.avoids_symlink_attacks` function attribute to determine which case applies.

If `onerror` is provided, it must be a callable that accepts three
parameters: *function*, *path*, and *excinfo*.

The first parameter, *function*, is the function which raised the exception; it depends on the platform and implementation. The second parameter, *path*, will be the path name passed to *function*. The third parameter, *excinfo*, will be the exception information returned by *sys.exc_info()*.

Exceptions raised by *onerror* will not be caught.

*Changed in version 3.3:* Added a symlink attack resistant version that is used automatically if platform supports fd-based functions.

**rmtree**. *avoids_symlink_attacks*

Indicates whether the current platform and implementation provides a symlink attack resistant version of *rmtree()*. Currently this is only true for platforms supporting fd-based directory access functions.

*New in version 3.3.*

**shutil**. *move*(src, dst, copy_function=copy2)

Recursively move a file or directory (src) to another location (dst) and return the destination.

If the destination is an existing directory, then src is moved inside that directory. If the destination already exists but is not a directory, it may be overwritten depending on *os.rename()* semantics.

If the destination is on the current filesystem, then *os.rename()* is used. Otherwise, *src* is copied to *dst* using *copy_function* and then removed. In case of symlinks, a new symlink pointing to the target of *src* will be created in or as *dst* and *src* will be removed.
If \textit{copy\_function} is given, it must be a callable that takes two arguments \textit{src} and \textit{dst}, and will be used to copy \textit{src} to \textit{dest} if \texttt{os.rename()} cannot be used. If the source is a directory, \texttt{copytree()} is called, passing it the \textit{copy\_function}. The default \textit{copy\_function} is \texttt{copy2()}. Using \texttt{copy()} as the \textit{copy\_function} allows the move to succeed when it is not possible to also copy the metadata, at the expense of not copying any of the metadata.

\textit{Changed in version 3.3:} Added explicit symlink handling for foreign filesystems, thus adapting it to the behavior of GNU's \texttt{mv}. Now returns \textit{dst}.

\textit{Changed in version 3.5:} Added the \textit{copy\_function} keyword argument.

\texttt{shutil.disk\_usage(path)}

Return disk usage statistics about the given path as a \texttt{named tuple} with the attributes \texttt{total}, \texttt{used} and \texttt{free}, which are the amount of total, used and free space, in bytes.

\textit{New in version 3.3.}

Availability: Unix, Windows.

\texttt{shutil.chown(path, user=None, group=None)}

Change owner \texttt{user} and/or \texttt{group} of the given \texttt{path}.

\texttt{user} can be a system user name or a uid; the same applies to \texttt{group}. At least one argument is required.

See also \texttt{os.chown()}, the underlying function.

Availability: Unix.
New in version 3.3.

```
shutil.which(cmd, mode=os.F_OK | os.X_OK, path=None)
```

Return the path to an executable which would be run if the given `cmd` was called. If no `cmd` would be called, return None.

`mode` is a permission mask passed a to `os.access()`, by default determining if the file exists and executable.

When no `path` is specified, the results of `os.environ()` are used, returning either the “PATH” value or a fallback of `os.defpath`.

On Windows, the current directory is always prepended to the `path` whether or not you use the default or provide your own, which is the behavior the command shell uses when finding executables. Additionally, when finding the `cmd` in the `path`, the `PATHEXT` environment variable is checked. For example, if you call `shutil.which("python")`, `which()` will search `PATHEXT` to know that it should look for `python.exe` within the `path` directories. For example, on Windows:

```
>>> shutil.which("python")
'C:\Python33\python.EXE'
```

New in version 3.3.

```
exception shutil.Error
```

This exception collects exceptions that are raised during a multi-file operation. For `copytree()`, the exception argument is a list of 3-tuples (`srcname`, `dstname`, `exception`).

11.10.1.1. copytree example
This example is the implementation of the `copytree()` function, described above, with the docstring omitted. It demonstrates many of the other functions provided by this module.

```python
def copytree(src, dst, symlinks=False):
    names = os.listdir(src)
    os.makedirs(dst)
    errors = []
    for name in names:
        srcname = os.path.join(src, name)
        dstname = os.path.join(dst, name)
        try:
            if symlinks and os.path.islink(srcname):
                linkto = os.readlink(srcname)
                os.symlink(linkto, dstname)
            elif os.path.isdir(srcname):
                copytree(srcname, dstname, symlinks)
            else:
                copy2(srcname, dstname)
                # XXX What about devices, sockets etc.?
        except OSError as why:
            errors.append((srcname, dstname, str(why))
            # catch the Error from the recursive copytree so that we can
            # continue with other files
        except Error as err:
            errors.extend(err.args[0])
        try:
            copystat(src, dst)
        except OSError as why:
            # can't copy file access times on Windows
            if why.winerror is None:
                errors.extend((src, dst, str(why)))
        if errors:
            raise Error(errors)
```
Another example that uses the `ignore_patterns()` helper:

```python
from shutil import copytree, ignore_patterns

# Copytree with ignore_patterns

# This will copy everything except .pyc files and files or directories
# whose name starts with tmp.
```

Another example that uses the `ignore` argument to add a logging call:

```python
from shutil import copytree
import logging

# Logpath function to add logging

def _logpath(path, names):
    logging.info('Working in %s' % path)
    return []  # nothing will be ignored

# Copytree with _logpath

# 11.10.1.2. rmtree example

This example shows how to remove a directory tree on Windows
where some of the files have their read-only bit set. It uses the
onerror callback to clear the readonly bit and reattempt the remove. Any
subsequent failure will propagate.

```python
import os, stat
import shutil

# Remove readonly function

def remove_readonly(func, path, _):
    "Clear the readonly bit and reattempt the remove"
    os.chmod(path, stat.S_IWRITE)
    func(path)
```
shutil.rmtree(directory, onerror=remove_readonly)
11.10.2. Archiving operations

New in version 3.2.

High-level utilities to create and read compressed and archived files are also provided. They rely on the zipfile and tarfile modules.

```
shutil.make_archive(base_name, format[, root_dir[, base_dir[, verbose[, dry_run[, owner[, group[, logger]]]]]]])
```

Create an archive file (such as zip or tar) and return its name.

- **base_name** is the name of the file to create, including the path, minus any format-specific extension. **format** is the archive format: one of “zip”, “tar”, “bztar” (if the bz2 module is available), “xztar” (if the lzma module is available) or “gztar”.

- **root_dir** is a directory that will be the root directory of the archive; for example, we typically chdir into **root_dir** before creating the archive.

- **base_dir** is the directory where we start archiving from; i.e. **base_dir** will be the common prefix of all files and directories in the archive.

**root_dir** and **base_dir** both default to the current directory.

If **dry_run** is true, no archive is created, but the operations that would be executed are logged to **logger**.

**owner** and **group** are used when creating a tar archive. By default, uses the current owner and group.

**logger** must be an object compatible with PEP 282, usually an
instance of `logging.Logger`.

The `verbose` argument is unused and deprecated.

*Changed in version 3.5:* Added support for the `xztar` format.

**shutil.get_archive_formats()**

Return a list of supported formats for archiving. Each element of the returned sequence is a tuple `(name, description)`.

By default `shutil` provides these formats:

- `gztar`: gzip’ed tar-file
- `bztar`: bzip2’ed tar-file (if the `bz2` module is available.)
- `xztar`: xz’ed tar-file (if the `lzma` module is available.)
- `tar`: uncompressed tar file
- `zip`: ZIP file

You can register new formats or provide your own archiver for any existing formats, by using `register_archive_format()`.

**shutil.register_archive_format(name, function[, extra_args[, description]])**

Register an archiver for the format `name`.

`function` is the callable that will be used to unpack archives. The callable will receive the `base_name` of the file to create, followed by the `base_dir` (which defaults to `os.curdir`) to start archiving from. Further arguments are passed as keyword arguments: `owner`, `group`, `dry_run` and `logger` (as passed in `make_archive()`).

If given, `extra_args` is a sequence of `(name, value)` pairs that will be used as extra keywords arguments when the archiver callable is used.
description is used by get_archive_formats() which returns the list of archivers. Defaults to an empty string.

shutil.unregister_archive_format(name)
Remove the archive format name from the list of supported formats.

shutil.unpack_archive(filename[, extract_dir[, format]])
Unpack an archive. filename is the full path of the archive.

extract_dir is the name of the target directory where the archive is unpacked. If not provided, the current working directory is used.

format is the archive format: one of “zip”, “tar”, or “gztar”. Or any other format registered with register_unpack_format(). If not provided, unpack_archive() will use the archive file name extension and see if an unpacker was registered for that extension. In case none is found, a ValueError is raised.

shutil.register_unpack_format(name, extensions, function[, extra_args[, description]])
Registers an unpack format. name is the name of the format and extensions is a list of extensions corresponding to the format, like .zip for Zip files.

function is the callable that will be used to unpack archives. The callable will receive the path of the archive, followed by the directory the archive must be extracted to.

When provided, extra_args is a sequence of (name, value) tuples that will be passed as keywords arguments to the callable.

description can be provided to describe the format, and will be
returned by the `get_unpack_formats()` function.

```python
shutil.unregister_unpack_format(name)
```

Unregister an unpack format. `name` is the name of the format.

```python
shutil.get_unpack_formats()
```

Return a list of all registered formats for unpacking. Each element of the returned sequence is a tuple `(name, extensions, description)`.

By default `shutil` provides these formats:

- `gztar`: gzip’ed tar-file
- `bztar`: bzip2’ed tar-file (if the `bz2` module is available.)
- `xztar`: xz’ed tar-file (if the `lzma` module is available.)
- `tar`: uncompressed tar file
- `zip`: ZIP file

You can register new formats or provide your own unpacker for any existing formats, by using `register_unpack_format()`.

### 11.10.2.1. Archiving example

In this example, we create a gzip’ed tar-file archive containing all files found in the `.ssh` directory of the user:

```python
>>> from shutil import make_archive
>>> import os
>>> archive_name = os.path.expanduser(os.path.join('~', 'myarchive.tar.gz'))
>>> root_dir = os.path.expanduser(os.path.join('~', 'myarchive.tar.gz'))
>>> make_archive(archive_name, 'gztar', root_dir)
'/Users/tarek/myarchive.tar.gz'
```
The resulting archive contains:

$ tar -tzvf /Users/tarek/myarchive.tar.gz

- drwx------ tarek/staff 0 2010-02-01 16:23:40 .
- -rw-r--r-- tarek/staff 609 2008-06-09 13:26:54 ./authorized_keys
- -rwxr-xr-x tarek/staff 65 2008-06-09 13:26:54 ./config
- -rwx------ tarek/staff 668 2008-06-09 13:26:54 ./id_dsa
- -rwxr-xr-x tarek/staff 609 2008-06-09 13:26:54 ./id_dsa.pub
- -rw------- tarek/staff 1675 2008-06-09 13:26:54 ./id_rsa
- -rw-r--r-- tarek/staff 397 2008-06-09 13:26:54 ./id_rsa.pub
- -rw-r--r-- tarek/staff 37192 2010-02-06 18:23:10 ./known_hosts
11.10.3. Querying the size of the output terminal

New in version 3.3.

`shutil.get_terminal_size(fallback=(columns, lines))`

Get the size of the terminal window.

For each of the two dimensions, the environment variable, `COLUMNS` and `LINES` respectively, is checked. If the variable is defined and the value is a positive integer, it is used.

When `COLUMNS` or `LINES` is not defined, which is the common case, the terminal connected to `sys.__stdout__` is queried by invoking `os.get_terminal_size()`.

If the terminal size cannot be successfully queried, either because the system doesn’t support querying, or because we are not connected to a terminal, the value given in `fallback` parameter is used. `fallback` defaults to `(80, 24)` which is the default size used by many terminal emulators.

The value returned is a named tuple of type `os.terminal_size`.

See also: The Single UNIX Specification, Version 2, Other Environment Variables.
11.11. `macpath` — Mac OS 9 path manipulation functions

This module is the Mac OS 9 (and earlier) implementation of the `os.path` module. It can be used to manipulate old-style Macintosh pathnames on Mac OS X (or any other platform).

The following functions are available in this module: `normcase()`, `normpath()`, `isabs()`, `join()`, `split()`, `isdir()`, `isfile()`, `walk()`, `exists()`. For other functions available in `os.path` dummy counterparts are available.
12. Data Persistence

The modules described in this chapter support storing Python data in a persistent form on disk. The `pickle` and `marshal` modules can turn many Python data types into a stream of bytes and then recreate the objects from the bytes. The various DBM-related modules support a family of hash-based file formats that store a mapping of strings to other strings.

The list of modules described in this chapter is:

- **12.1. pickle — Python object serialization**
  - 12.1.1. Relationship to other Python modules
    - 12.1.1.1. Comparison with `marshal`
    - 12.1.1.2. Comparison with `json`
  - 12.1.2. Data stream format
  - 12.1.3. Module Interface
  - 12.1.4. What can be pickled and unpickled?
  - 12.1.5. Pickling Class Instances
    - 12.1.5.1. Persistence of External Objects
    - 12.1.5.2. Dispatch Tables
    - 12.1.5.3. Handling Stateful Objects
  - 12.1.6. RestrictingGlobals
  - 12.1.7. Performance
  - 12.1.8. Examples
- **12.2. copyreg — Register pickle support functions**
  - 12.2.1. Example
- **12.3. shelve — Python object persistence**
  - 12.3.1. Restrictions
  - 12.3.2. Example
- **12.4. marshal — Internal Python object serialization**
- **12.5. dbm — Interfaces to Unix “databases”**
12.5.1. `dbm.gnu` — GNU's reinterpretation of `dbm`
12.5.2. `dbm.ndbm` — Interface based on `ndbm`
12.5.3. `dbm.dumb` — Portable DBM implementation

- **12.6. `sqlite3` — DB-API 2.0 interface for SQLite databases**
  - 12.6.1. Module functions and constants
  - 12.6.2. Connection Objects
  - 12.6.3. Cursor Objects
  - 12.6.4. Row Objects
  - 12.6.5. SQLite and Python types
    - 12.6.5.1. Introduction
    - 12.6.5.2. Using adapters to store additional Python types in SQLite databases
      - 12.6.5.2.1. Letting your object adapt itself
      - 12.6.5.2.2. Registering an adapter callable
    - 12.6.5.3. Converting SQLite values to custom Python types
    - 12.6.5.4. Default adapters and converters
  - 12.6.6. Controlling Transactions
  - 12.6.7. Using `sqlite3` efficiently
    - 12.6.7.1. Using shortcut methods
    - 12.6.7.2. Accessing columns by name instead of by index
    - 12.6.7.3. Using the connection as a context manager
  - 12.6.8. Common issues
    - 12.6.8.1. Multithreading
12.1. pickle — Python object serialization

The pickle module implements binary protocols for serializing and de-serializing a Python object structure. “Pickling” is the process whereby a Python object hierarchy is converted into a byte stream, and “unpickling” is the inverse operation, whereby a byte stream (from a binary file or bytes-like object) is converted back into an object hierarchy. Pickling (and unpickling) is alternatively known as “serialization”, “marshalling,” [1] or “flattening”; however, to avoid confusion, the terms used here are “pickling” and “unpickling”.

**Warning:** The pickle module is not secure against erroneous or maliciously constructed data. Never unpickle data received from an untrusted or unauthenticated source.
12.1.1. Relationship to other Python modules

12.1.1.1. Comparison with marshal

Python has a more primitive serialization module called marshal, but in general pickle should always be the preferred way to serialize Python objects. marshal exists primarily to support Python’s .pyc files.

The pickle module differs from marshal in several significant ways:

- The pickle module keeps track of the objects it has already serialized, so that later references to the same object won’t be serialized again. marshal doesn’t do this.

This has implications both for recursive objects and object sharing. Recursive objects are objects that contain references to themselves. These are not handled by marshal, and in fact, attempting to marshal recursive objects will crash your Python interpreter. Object sharing happens when there are multiple references to the same object in different places in the object hierarchy being serialized. pickle stores such objects only once, and ensures that all other references point to the master copy. Shared objects remain shared, which can be very important for mutable objects.

- marshal cannot be used to serialize user-defined classes and their instances. pickle can save and restore class instances transparently, however the class definition must be importable and live in the same module as when the object was stored.
The **marshal** serialization format is not guaranteed to be portable across Python versions. Because its primary job in life is to support `.pyc` files, the Python implementers reserve the right to change the serialization format in non-backwards compatible ways should the need arise. The **pickle** serialization format is guaranteed to be backwards compatible across Python releases.

### 12.1.1.2. Comparison with json

There are fundamental differences between the pickle protocols and **JSON (JavaScript Object Notation)**:

- **JSON** is a text serialization format (it outputs unicode text, although most of the time it is then encoded to `utf-8`), while pickle is a binary serialization format;
- **JSON** is human-readable, while pickle is not;
- **JSON** is interoperable and widely used outside of the Python ecosystem, while pickle is Python-specific;
- **JSON**, by default, can only represent a subset of the Python built-in types, and no custom classes; pickle can represent an extremely large number of Python types (many of them automatically, by clever usage of Python’s introspection facilities; complex cases can be tackled by implementing **specific object APIs**).

**See also:** The **json** module: a standard library module allowing JSON serialization and deserialization.
12.1.2. Data stream format

The data format used by pickle is Python-specific. This has the advantage that there are no restrictions imposed by external standards such as JSON or XDR (which can’t represent pointer sharing); however it means that non-Python programs may not be able to reconstruct pickled Python objects.

By default, the pickle data format uses a relatively compact binary representation. If you need optimal size characteristics, you can efficiently compress pickled data.

The module pickletools contains tools for analyzing data streams generated by pickle. pickletools source code has extensive comments about opcodes used by pickle protocols.

There are currently 5 different protocols which can be used for pickling. The higher the protocol used, the more recent the version of Python needed to read the pickle produced.

- Protocol version 0 is the original “human-readable” protocol and is backwards compatible with earlier versions of Python.
- Protocol version 1 is an old binary format which is also compatible with earlier versions of Python.
- Protocol version 2 was introduced in Python 2.3. It provides much more efficient pickling of new-style classes. Refer to PEP 307 for information about improvements brought by protocol 2.
- Protocol version 3 was added in Python 3.0. It has explicit support for bytes objects and cannot be unpickled by Python 2.x. This is the default protocol, and the recommended protocol when compatibility with other Python 3 versions is required.
- Protocol version 4 was added in Python 3.4. It adds support for very large objects, pickling more kinds of objects, and some data
format optimizations. Refer to PEP 3154 for information about improvements brought by protocol 4.

**Note:** Serialization is a more primitive notion than persistence; although *pickle* reads and writes file objects, it does not handle the issue of naming persistent objects, nor the (even more complicated) issue of concurrent access to persistent objects. The *pickle* module can transform a complex object into a byte stream and it can transform the byte stream into an object with the same internal structure. Perhaps the most obvious thing to do with these byte streams is to write them onto a file, but it is also conceivable to send them across a network or store them in a database. The *shelve* module provides a simple interface to pickle and unpickle objects on DBM-style database files.
12.1.3. Module Interface

To serialize an object hierarchy, you simply call the `dumps()` function. Similarly, to de-serialize a data stream, you call the `loads()` function. However, if you want more control over serialization and deserialization, you can create a `Pickler` or an `Unpickler` object, respectively.

The `pickle` module provides the following constants:

- **pickle.HIGHEST_PROTOCOL**
  
  An integer, the highest protocol version available. This value can be passed as a protocol value to functions `dump()` and `dumps()` as well as the `Pickler` constructor.

- **pickle.DEFAULT_PROTOCOL**
  
  An integer, the default protocol version used for pickling. May be less than `HIGHEST_PROTOCOL`. Currently the default protocol is 3, a new protocol designed for Python 3.

The `pickle` module provides the following functions to make the pickling process more convenient:

- **pickle.dump(obj, file, protocol=None, *, fix_imports=True)**
  
  Write a pickled representation of `obj` to the open file object `file`. This is equivalent to `Pickler(file, protocol).dump(obj)`.

  The optional `protocol` argument, an integer, tells the pickler to use the given protocol; supported protocols are 0 to `HIGHEST_PROTOCOL`. If not specified, the default is `DEFAULT_PROTOCOL`. If a negative number is specified,
**HIGHEST_PROTOCOL** is selected.

The *file* argument must have a write() method that accepts a single bytes argument. It can thus be an on-disk file opened for binary writing, an *io.BytesIO* instance, or any other custom object that meets this interface.

If *fix_imports* is true and *protocol* is less than 3, pickle will try to map the new Python 3 names to the old module names used in Python 2, so that the pickle data stream is readable with Python 2.

```python
pickle.dumps(obj, protocol=None, *, fix_imports=True)
```

Return the pickled representation of the object as a bytes object, instead of writing it to a file.

Arguments *protocol* and *fix_imports* have the same meaning as in dump().

```python
pickle.load(file, *, fix_imports=True, encoding="ASCII", errors="strict")
```

Read a pickled object representation from the open file object *file* and return the reconstituted object hierarchy specified therein. This is equivalent to Unpickler(file).load().

The protocol version of the pickle is detected automatically, so no protocol argument is needed. Bytes past the pickled object's representation are ignored.

The argument *file* must have two methods, a read() method that takes an integer argument, and a readline() method that requires no arguments. Both methods should return bytes. Thus *file* can be an on-disk file opened for binary reading, an *io.BytesIO* object, or any other custom object that meets this interface.
Optional keyword arguments are `fix_imports`, `encoding` and `errors`, which are used to control compatibility support for pickle stream generated by Python 2. If `fix_imports` is true, pickle will try to map the old Python 2 names to the new names used in Python 3. The `encoding` and `errors` tell pickle how to decode 8-bit string instances pickled by Python 2; these default to ‘ASCII’ and ‘strict’, respectively. The `encoding` can be ‘bytes’ to read these 8-bit string instances as bytes objects.

```python
pickle.loads(bytes_object, *, fix_imports=True, encoding="ASCII", errors="strict")
```

Read a pickled object hierarchy from a bytes object and return the reconstituted object hierarchy specified therein.

The protocol version of the pickle is detected automatically, so no protocol argument is needed. Bytes past the pickled object’s representation are ignored.

Optional keyword arguments are `fix_imports`, `encoding` and `errors`, which are used to control compatibility support for pickle stream generated by Python 2. If `fix_imports` is true, pickle will try to map the old Python 2 names to the new names used in Python 3. The `encoding` and `errors` tell pickle how to decode 8-bit string instances pickled by Python 2; these default to ‘ASCII’ and ‘strict’, respectively. The `encoding` can be ‘bytes’ to read these 8-bit string instances as bytes objects.

The `pickle` module defines three exceptions:

```python
exception pickle.PickleError
```

Common base class for the other pickling exceptions. It inherits `Exception`.
 exception pickle.**PicklingError**

Error raised when an unpicklable object is encountered by **Pickler**. It inherits **PickleError**.

Refer to What can be pickled and unpickled? to learn what kinds of objects can be pickled.

 exception pickle.**UnpicklingError**

Error raised when there is a problem unpickling an object, such as a data corruption or a security violation. It inherits **PickleError**.

Note that other exceptions may also be raised during unpickling, including (but not necessarily limited to) AttributeError, EOFError, ImportError, and IndexError.

The **pickle** module exports two classes, **Pickler** and **Unpickler**:

**class pickle.**Pickler**(file, protocol=None, *, fix_imports=True)**

This takes a binary file for writing a pickle data stream.

The optional **protocol** argument, an integer, tells the pickler to use the given protocol; supported protocols are 0 to **HIGHEST_PROTOCOL**. If not specified, the default is **DEFAULT_PROTOCOL**. If a negative number is specified, **HIGHEST_PROTOCOL** is selected.

The **file** argument must have a write() method that accepts a single bytes argument. It can thus be an on-disk file opened for binary writing, an **io.BytesIO** instance, or any other custom object that meets this interface.

If **fix_imports** is true and **protocol** is less than 3, pickle will try to map the new Python 3 names to the old module names used in
Python 2, so that the pickle data stream is readable with Python 2.

**dump**(obj)

Write a pickled representation of obj to the open file object given in the constructor.

**persistent_id**(obj)

Do nothing by default. This exists so a subclass can override it.

If persistent_id() returns None, obj is pickled as usual. Any other value causes Pickler to emit the returned value as a persistent ID for obj. The meaning of this persistent ID should be defined by Unpickler.persistent_load(). Note that the value returned by persistent_id() cannot itself have a persistent ID.

See Persistence of External Objects for details and examples of uses.

**dispatch_table**

A pickler object’s dispatch table is a registry of reduction functions of the kind which can be declared using copyreg.pickle(). It is a mapping whose keys are classes and whose values are reduction functions. A reduction function takes a single argument of the associated class and should conform to the same interface as a __reduce__() method.

By default, a pickler object will not have a dispatch_table attribute, and it will instead use the global dispatch table managed by the copyreg module. However, to customize the pickling for a specific pickler object one can set the dispatch_table attribute to a dict-like object. Alternatively, if
a subclass of Pickler has a dispatch_table attribute then this will be used as the default dispatch table for instances of that class.

See Dispatch Tables for usage examples.

*New in version 3.3.*

**fast**

Deprecated. Enable fast mode if set to a true value. The fast mode disables the usage of memo, therefore speeding the pickling process by not generating superfluous PUT opcodes. It should not be used with self-referential objects, doing otherwise will cause Pickler to recurse infinitely.

Use pickletools.optimize() if you need more compact pickles.

```python
class pickle.Unpickler(file, *, fix_imports=True, encoding="ASCII", errors="strict")
```

This takes a binary file for reading a pickle data stream.

The protocol version of the pickle is detected automatically, so no protocol argument is needed.

The argument file must have two methods, a read() method that takes an integer argument, and a readline() method that requires no arguments. Both methods should return bytes. Thus file can be an on-disk file object opened for binary reading, an io.BytesIO object, or any other custom object that meets this interface.

Optional keyword arguments are fix_imports, encoding and errors, which are used to control compatibility support for pickle stream
generated by Python 2. If `fix_imports` is true, pickle will try to map
the old Python 2 names to the new names used in Python 3. The
`encoding` and `errors` tell pickle how to decode 8-bit string instances
pickled by Python 2; these default to ‘ASCII’ and ‘strict’,
respectively. The `encoding` can be ‘bytes’ to read these ß8-bit
string instances as bytes objects.

**load()**

Read a pickled object representation from the open file object
given in the constructor, and return the reconstituted object
hierarchy specified therein. Bytes past the pickled object's
representation are ignored.

**persistent_load(pid)**

Raise an `UnpicklingError` by default.

If defined, `persistent_load()` should return the object
specified by the persistent ID `pid`. If an invalid persistent ID is
encountered, an `UnpicklingError` should be raised.

See Persistence of External Objects for details and examples of
uses.

**find_class(module, name)**

Import `module` if necessary and return the object called `name`
from it, where the `module` and `name` arguments are `str`
objects. Note, unlike its name suggests, `find_class()` is also
used for finding functions.

Subclasses may override this to gain control over what type of
objects and how they can be loaded, potentially reducing
security risks. Refer to Restricting Globals for details.
12.1.4. What can be pickled and unpickled?

The following types can be pickled:

- None, True, and False
- integers, floating point numbers, complex numbers
- strings, bytes, bytearrays
- tuples, lists, sets, and dictionaries containing only picklable objects
- functions defined at the top level of a module (using `def`, not `lambda`)
- built-in functions defined at the top level of a module
- classes that are defined at the top level of a module
- instances of such classes whose `__dict__` or the result of calling `__getstate__()` is picklable (see section Pickling Class Instances for details).

Attempts to pickle unpicklable objects will raise the `PicklingError` exception; when this happens, an unspecified number of bytes may have already been written to the underlying file. Trying to pickle a highly recursive data structure may exceed the maximum recursion depth, a `RecursionError` will be raised in this case. You can carefully raise this limit with `sys.setrecursionlimit()`.

Note that functions (built-in and user-defined) are pickled by “fully qualified” name reference, not by value. [2] This means that only the function name is pickled, along with the name of the module the function is defined in. Neither the function’s code, nor any of its function attributes are pickled. Thus the defining module must be importable in the unpickling environment, and the module must contain the named object, otherwise an exception will be raised. [3]
Similarly, classes are pickled by named reference, so the same restrictions in the unpickling environment apply. Note that none of the class’s code or data is pickled, so in the following example the class attribute `attr` is not restored in the unpickling environment:

```python
class Foo:
    attr = 'A class attribute'

picklestring = pickle.dumps(Foo)
```

These restrictions are why picklable functions and classes must be defined in the top level of a module.

Similarly, when class instances are pickled, their class’s code and data are not pickled along with them. Only the instance data are pickled. This is done on purpose, so you can fix bugs in a class or add methods to the class and still load objects that were created with an earlier version of the class. If you plan to have long-lived objects that will see many versions of a class, it may be worthwhile to put a version number in the objects so that suitable conversions can be made by the class’s `__setstate__()` method.
12.1.5. Pickling Class Instances

In this section, we describe the general mechanisms available to you to define, customize, and control how class instances are pickled and unpickled.

In most cases, no additional code is needed to make instances picklable. By default, pickle will retrieve the class and the attributes of an instance via introspection. When a class instance is unpickled, its \_\_init\_() method is usually *not* invoked. The default behaviour first creates an uninitialized instance and then restores the saved attributes. The following code shows an implementation of this behaviour:

```python
def save(obj):
    return (obj._class_, obj._dict_)

def load(cls, attributes):
    obj = cls._new_(cls)
    obj._dict_.update(attributes)
    return obj
```

Classes can alter the default behaviour by providing one or several special methods:

*object.\_\_getnewargs\_ex\_()*

In protocols 4 and newer, classes that implements the \_\_getnewargs\_ex\_() method can dictate the values passed to the \_\_new\_() method upon unpickling. The method must return a pair (args, kwargs) where args is a tuple of positional arguments and kwargs a dictionary of named arguments for constructing the object. Those will be passed to the \_\_new\_()
method upon unpickling.

You should implement this method if the __new__() method of your class requires keyword-only arguments. Otherwise, it is recommended for compatibility to implement __getnewargs__().

object.__getnewargs__()  
This method serves a similar purpose as __getnewargs_ex__() but for protocols 2 and newer. It must return a tuple of arguments args which will be passed to the __new__() method upon unpickling.

In protocols 4 and newer, __getnewargs__() will not be called if __getnewargs_ex__() is defined.

object.__getstate__()  
Classes can further influence how their instances are pickled; if the class defines the method __getstate__(), it is called and the returned object is pickled as the contents for the instance, instead of the contents of the instance’s dictionary. If the __getstate__() method is absent, the instance’s __dict__ is pickled as usual.

object.__setstate__(state)  
Upon unpickling, if the class defines __setstate__(), it is called with the unpickled state. In that case, there is no requirement for the state object to be a dictionary. Otherwise, the pickled state must be a dictionary and its items are assigned to the new instance’s dictionary.

Note: If __getstate__() returns a false value, the __setstate__() method will not be called upon unpickling.
Refer to the section **Handling Stateful Objects** for more information about how to use the methods **__getstate__()** and **__setstate__()**.

**Note:** At unpickling time, some methods like **__getattr__()**, **__getattribute__()**, or **__setattr__()** may be called upon the instance. In case those methods rely on some internal invariant being true, the type should implement **__getnewargs__()** or **__getnewargs_ex__()** to establish such an invariant; otherwise, neither **__new__()** nor **__init__()** will be called.

As we shall see, pickle does not use directly the methods described above. In fact, these methods are part of the copy protocol which implements the **__reduce__()** special method. The copy protocol provides a unified interface for retrieving the data necessary for pickling and copying objects. [4]

Although powerful, implementing **__reduce__()** directly in your classes is error prone. For this reason, class designers should use the high-level interface (i.e., **__getnewargs_ex__()**, **__getstate__()** and **__setstate__()**) whenever possible. We will show, however, cases where using **__reduce__()** is the only option or leads to more efficient pickling or both.

**object.__reduce__()**

The interface is currently defined as follows. The **__reduce__()** method takes no argument and shall return either a string or preferably a tuple (the returned object is often referred to as the "reduce value").

If a string is returned, the string should be interpreted as the name
of a global variable. It should be the object's local name relative to its module; the pickle module searches the module namespace to determine the object's module. This behaviour is typically useful for singletons.

When a tuple is returned, it must be between two and five items long. Optional items can either be omitted, or None can be provided as their value. The semantics of each item are in order:

- A callable object that will be called to create the initial version of the object.
- A tuple of arguments for the callable object. An empty tuple must be given if the callable does not accept any argument.
- Optionally, the object's state, which will be passed to the object's `__setstate__() method as previously described. If the object has no such method then, the value must be a dictionary and it will be added to the object's `__dict__` attribute.
- Optionally, an iterator (and not a sequence) yielding successive items. These items will be appended to the object either using `obj.append(item)` or, in batch, using `obj.extend(list_of_items)`. This is primarily used for list subclasses, but may be used by other classes as long as they have `append()` and `extend()` methods with the appropriate signature. (Whether `append()` or `extend()` is used depends on which pickle protocol version is used as well as the number of items to append, so both must be supported.)
- Optionally, an iterator (not a sequence) yielding successive key-value pairs. These items will be stored to the object using `obj[key] = value`. This is primarily used for dictionary subclasses, but may be used by other classes as long as they implement `__setitem__()`. 

Alternatively, a `__reduce_ex__(protocol)` method may be defined. The only difference is this method should take a single integer argument, the protocol version. When defined, pickle will prefer it over the `__reduce__( )` method. In addition, `__reduce__( )` automatically becomes a synonym for the extended version. The main use for this method is to provide backwards-compatible reduce values for older Python releases.

### 12.1.5.1. Persistence of External Objects

For the benefit of object persistence, the `pickle` module supports the notion of a reference to an object outside the pickled data stream. Such objects are referenced by a persistent ID, which should be either a string of alphanumeric characters (for protocol 0) [5] or just an arbitrary object (for any newer protocol).

The resolution of such persistent IDs is not defined by the `pickle` module; it will delegate this resolution to the user defined methods on the pickler and unpickler, `persistent_id()` and `persistent_load()` respectively.

To pickle objects that have an external persistent id, the pickler must have a custom `persistent_id()` method that takes an object as an argument and returns either None or the persistent id for that object. When None is returned, the pickler simply pickles the object as normal. When a persistent ID string is returned, the pickler will pickle that object, along with a marker so that the unpickler will recognize it as a persistent ID.

To unpickle external objects, the unpickler must have a custom
**persistent_load()** method that takes a persistent ID object and
returns the referenced object.

Here is a comprehensive example presenting how persistent ID can
be used to pickle external objects by reference.

```python
# Simple example presenting how persistent ID can be used to pickle external objects by reference.
import pickle
import sqlite3
from collections import namedtuple

# Simple class representing a record in our database.
MemoRecord = namedtuple("MemoRecord", "key, task")

class DBPickler(pickle.Pickler):
    def persistent_id(self, obj):
        # Instead of pickling MemoRecord as a regular class instance,
        # persistent ID.
        if isinstance(obj, MemoRecord):
            # Here, our persistent ID is simply a tuple:
            # key, which refers to a specific record.
            return ("MemoRecord", obj.key)
        else:
            # If obj does not have a persistent ID,
            # needs to be pickled as usual.
            return None

class DBUnpickler(pickle.Unpickler):
    def __init__(self, file, connection):
        super().__init__(file)
        self.connection = connection
```
def persistent_load(self, pid):
    # This method is invoked whenever a persistent ID is encountered.
    # Here, pid is the tuple returned by DBPickle.
    cursor = self.connection.cursor()
    type_tag, key_id = pid
    if type_tag == "MemoRecord":
        # Fetch the referenced record from the database.
        cursor.execute("SELECT * FROM memos WHERE key=?", (key_id,))
        task = cursor.fetchone()
        return MemoRecord(key_id, task)
    else:
        # Always raises an error if you cannot return the correct object.
        # Otherwise, the unpickler will think None is the object referenced
        # by the persistent ID.
        raise pickle.UnpicklingError("unsupported persistent object")

def main():
    import io
    import pprint

    # Initialize and populate our database.
    conn = sqlite3.connect(":memory:")
    cursor = conn.cursor()
    cursor.execute("CREATE TABLE memos(key INTEGER PRIMARY KEY, task TEXT)"

    tasks = ("give food to fish",
             "prepare group meeting",
             "fight with a zebra",
             )
    for task in tasks:
        cursor.execute("INSERT INTO memos VALUES(NULL, ?)

    # Fetch the records to be pickled.
    cursor.execute("SELECT * FROM memos")
    memos = [MemoRecord(key, task) for key, task in
```python
# Save the records using our custom DBPickler.
file = io.BytesIO()
DBPickler(file).dump(memos)

print("Pickled records:")
pprint.pprint(memos)

# Update a record, just for good measure.
cursor.execute("UPDATE memos SET task='learn italian' WHERE key=1")

# Load the records from the pickle data stream.
file.seek(0)
memos = DBUnpickler(file, conn).load()

print("Unpickled records:")
pprint.pprint(memos)
```

```python
if __name__ == '__main__':
    main()
```

### 12.1.5.2. Dispatch Tables

If one wants to customize pickling of some classes without disturbing any other code which depends on pickling, then one can create a pickler with a private dispatch table.

The global dispatch table managed by the `copyreg` module is available as `copyreg.dispatch_table`. Therefore, one may choose to use a modified copy of `copyreg.dispatch_table` as a private dispatch table.

For example
f = io.BytesIO()
p = pickle.Pickler(f)
p.dispatch_table = copyreg.dispatch_table.copy()
p.dispatch_table[SomeClass] = reduce_SomeClass

creates an instance of `pickle.Pickler` with a private dispatch table which handles the SomeClass class specially. Alternatively, the code

class MyPickler(pickle.Pickler):
    dispatch_table = copyreg.dispatch_table.copy()
    dispatch_table[SomeClass] = reduce_SomeClass
f = io.BytesIO()
p = MyPickler(f)

does the same, but all instances of MyPickler will by default share the same dispatch table. The equivalent code using the `copyreg` module is

copyreg.pickle(SomeClass, reduce_SomeClass)
f = io.BytesIO()
p = pickle.Pickler(f)

12.1.5.3. Handling Stateful Objects

Here’s an example that shows how to modify pickling behavior for a class. The TextReader class opens a text file, and returns the line number and line contents each time its `readline()` method is called. If a TextReader instance is pickled, all attributes except the file object member are saved. When the instance is unpickled, the file is reopened, and reading resumes from the last location. The `__setstate__()` and `__getstate__()` methods are used to implement this behavior.
class TextReader:
    """Print and number lines in a text file."""

    def __init__(self, filename):
        self.filename = filename
        self.file = open(filename)
        self.lineno = 0

    def readline(self):
        self.lineno += 1
        line = self.file.readline()
        if not line:
            return None
        if line.endswith(\n):
            line = line[:-1]
        return "%i: %s" % (self.lineno, line)

    def __getstate__(self):
        # Copy the object's state from self.__dict__ which contains
        # all our instance attributes. Always use the dict.copy()
        # method to avoid modifying the original state.
        state = self.__dict__.copy()
        # Remove the unpickleable entries.
        del state['file']
        return state

    def __setstate__(self, state):
        # Restore instance attributes (i.e., filename
        # and lineno).
        self.__dict__.update(state)
        # Restore the previously opened file's state
        # reopen it and read from it until the line
        file = open(self.filename)
        for _ in range(self.lineno):
            file.readline()
        # Finally, save the file.
        self.file = file
A sample usage might be something like this:

```python
>>> reader = TextReader("hello.txt")
>>> reader.readline()
'1: Hello world!
'2: I am line number two.'
>>> new_reader = pickle.loads(pickle.dumps(reader))
>>> new_reader.readline()
'3: Goodbye!'```
12.1.6. Restricting Globals

By default, unpickling will import any class or function that it finds in the pickle data. For many applications, this behaviour is unacceptable as it permits the unpickler to import and invoke arbitrary code. Just consider what this hand-crafted pickle data stream does when loaded:

```bash
>>> import pickle
>>> pickle.loads(b"cos
system\n(S'echo hello world'
hello world
0
```

In this example, the unpickler imports the `os.system()` function and then apply the string argument “echo hello world”. Although this example is inoffensive, it is not difficult to imagine one that could damage your system.

For this reason, you may want to control what gets unpickled by customizing `Unpickler.find_class()`. Unlike its name suggests, `Unpickler.find_class()` is called whenever a global (i.e., a class or a function) is requested. Thus it is possible to either completely forbid globals or restrict them to a safe subset.

Here is an example of an unpickler allowing only few safe classes from the `builtins` module to be loaded:

```python
import builtins
import io
import pickle

safe_builtins = {
    'range',
```
class RestrictedUnpickler(pickle.Unpickler):

def find_class(self, module, name):
    # Only allow safe classes from builtins.
    if module == "builtins" and name in safe_builtins:
        return getattr(builtins, name)
    # Forbid everything else.
    raise pickle.UnpicklingError("global '%s.%s' is forbidden" % (module, name))

def restricted_loads(s):
    """Helper function analogous to pickle.loads().""
    return RestrictedUnpickler(io.BytesIO(s)).load()

A sample usage of our unpickler working has intended:

>>> restricted_loads(pickle.dumps([1, 2, range(15)]))
[1, 2, range(0, 15)]
>>> restricted_loads(b"cos\nsystem\n(S'echo hello world')")
Traceback (most recent call last):
  File "", line 1, in restricted_loads
pickle.UnpicklingError: global 'os.system' is forbidden
>>> restricted_loads(b"cbuiltins\neval\n... b'(S'getattr(__import__('os'),"os")', ...
... b"'echo hello world')"')
Traceback (most recent call last):
  File "", line 1, in restricted_loads
pickle.UnpicklingError: global 'builtins.eval' is forbidden
As our examples shows, you have to be careful with what you allow to be unpickled. Therefore if security is a concern, you may want to consider alternatives such as the marshalling API in `xmlrpc.client` or third-party solutions.
12.1.7. Performance

Recent versions of the pickle protocol (from protocol 2 and upwards) feature efficient binary encodings for several common features and built-in types. Also, the pickle module has a transparent optimizer written in C.
12.1.8. Examples

For the simplest code, use the `dump()` and `load()` functions.

```python
import pickle

# An arbitrary collection of objects supported by pickle.
data = {
    'a': [1, 2.0, 3, 4+6j],
    'b': ("character string", b"byte string"),
    'c': {None, True, False}
}

with open('data.pickle', 'wb') as f:
    # Pickle the 'data' dictionary using the highest protocol available.
pickle.dump(data, f, pickle.HIGHEST_PROTOCOL)
```

The following example reads the resulting pickled data.

```python
import pickle

with open('data.pickle', 'rb') as f:
    # The protocol version used is detected automatically, so we do not have to specify it.
    data = pickle.load(f)
```

See also:

**Module copyreg**

Pickle interface constructor registration for extension types.

**Module pickletools**

Tools for working with and analyzing pickled data.
### Module `shelve`
Indexed databases of objects; uses `pickle`.

### Module `copy`
Shallow and deep object copying.

### Module `marshal`
High-performance serialization of built-in types.

---

**Footnotes**

[1] Don't confuse this with the `marshal` module.

[2] This is why `lambda` functions cannot be pickled: all `lambda` functions share the same name: `<lambda>`.

[3] The exception raised will likely be an `ImportError` or an `AttributeError` but it could be something else.


[5] The limitation on alphanumerical characters is due to the fact the persistent IDs, in protocol 0, are delimited by the newline character. Therefore if any kind of newline characters occurs in persistent IDs, the resulting pickle will become unreadable.
12.2. copyreg — Register pickle support functions

The copyreg module offers a way to define functions used while pickling specific objects. The pickle and copy modules use those functions when pickling/copying those objects. The module provides configuration information about object constructors which are not classes. Such constructors may be factory functions or class instances.

copyreg.constructor(object)
Declares object to be a valid constructor. If object is not callable (and hence not valid as a constructor), raises TypeError.

copyreg.pickle(type, function, constructor=None)
Declares that function should be used as a “reduction” function for objects of type type. function should return either a string or a tuple containing two or three elements.

The optional constructor parameter, if provided, is a callable object which can be used to reconstruct the object when called with the tuple of arguments returned by function at pickling time. TypeError will be raised if object is a class or constructor is not callable.

See the pickle module for more details on the interface expected of function and constructor. Note that the dispatch_table attribute of a pickler object or subclass of pickle.Pickler can also be used for declaring reduction functions.
12.2.1. Example

The example below would like to show how to register a pickle function and how it will be used:

```python
>>> import copyreg, copy, pickle
>>> class C(object):
...     def __init__(self, a):
...         self.a = a
...
>>> def pickle_c(c):
...     print("pickling a C instance...")
...     return C, (c.a,)
...
>>> copyreg.pickle(C, pickle_c)
>>> c = C(1)
>>> d = copy.copy(c)
pickling a C instance...
>>> p = pickle.dumps(c)
pickling a C instance...
```
12.3. **shelve** — Python object persistence

**Source code:** Lib/shelve.py

A “shelf” is a persistent, dictionary-like object. The difference with “dbm” databases is that the values (not the keys!) in a shelf can be essentially arbitrary Python objects — anything that the pickle module can handle. This includes most class instances, recursive data types, and objects containing lots of shared sub-objects. The keys are ordinary strings.

```python
shelve.open(filename, flag='c', protocol=None, writeback=False)
```

Open a persistent dictionary. The filename specified is the base filename for the underlying database. As a side-effect, an extension may be added to the filename and more than one file may be created. By default, the underlying database file is opened for reading and writing. The optional `flag` parameter has the same interpretation as the `flag` parameter of `dbm.open()`.

By default, version 3 pickles are used to serialize values. The version of the pickle protocol can be specified with the `protocol` parameter.

Because of Python semantics, a shelf cannot know when a mutable persistent-dictionary entry is modified. By default modified objects are written *only* when assigned to the shelf (see Example). If the optional `writeback` parameter is set to `True`, all entries accessed are also cached in memory, and written back on `sync()`.
and close(); this can make it handier to mutate mutable entries in the persistent dictionary, but, if many entries are accessed, it can consume vast amounts of memory for the cache, and it can make the close operation very slow since all accessed entries are written back (there is no way to determine which accessed entries are mutable, nor which ones were actually mutated).

**Note:** Do not rely on the shelf being closed automatically; always call close() explicitly when you don’t need it any more, or use `shelve.open()` as a context manager:

```python
with shelve.open('spam') as db:
    db['eggs'] = 'eggs'
```

**Warning:** Because the `shelve` module is backed by `pickle`, it is insecure to load a shelf from an untrusted source. Like with pickle, loading a shelf can execute arbitrary code.

Shelf objects support all methods supported by dictionaries. This eases the transition from dictionary based scripts to those requiring persistent storage.

Two additional methods are supported:

**Shelf.sync()**

Write back all entries in the cache if the shelf was opened with `writeback` set to True. Also empty the cache and synchronize the persistent dictionary on disk, if feasible. This is called automatically when the shelf is closed with close().

**Shelf.close()**

Synchronize and close the persistent dict object. Operations on a
closed shelf will fail with a `ValueError`.

**See also:**  Persistent dictionary recipe with widely supported storage formats and having the speed of native dictionaries.
12.3.1. Restrictions

- The choice of which database package will be used (such as `dbm.ndbm` or `dbm.gnu`) depends on which interface is available. Therefore it is not safe to open the database directly using `dbm`. The database is also (unfortunately) subject to the limitations of `dbm`, if it is used — this means that (the pickled representation of) the objects stored in the database should be fairly small, and in rare cases key collisions may cause the database to refuse updates.

- The `shelve` module does not support concurrent read/write access to shelved objects. (Multiple simultaneous read accesses are safe.) When a program has a shelf open for writing, no other program should have it open for reading or writing. Unix file locking can be used to solve this, but this differs across Unix versions and requires knowledge about the database implementation used.

```python
class shelve.Shelf(dict, protocol=None, writeback=False, keyencoding='utf-8')
```

A subclass of `collections.abc.MutableMapping` which stores pickled values in the `dict` object.

By default, version 0 pickles are used to serialize values. The version of the pickle protocol can be specified with the `protocol` parameter. See the `pickle` documentation for a discussion of the pickle protocols.

If the `writeback` parameter is True, the object will hold a cache of all entries accessed and write them back to the `dict` at sync and close times. This allows natural operations on mutable entries, but can consume much more memory and make sync and close take a
long time.

The `keyencoding` parameter is the encoding used to encode keys before they are used with the underlying dict.

A `Shelf` object can also be used as a context manager, in which case it will be automatically closed when the `with` block ends.

*Changed in version 3.2:* Added the `keyencoding` parameter; previously, keys were always encoded in UTF-8.

*Changed in version 3.4:* Added context manager support.

```python
class shelve.BsdDbShelf(dict, protocol=None, writeback=False, keyencoding='utf-8')
```
A subclass of `Shelf` which exposes `first()`, `next()`, `previous()`, `last()` and `set_location()` which are available in the third-party bsddb module from `pybsddb` but not in other database modules. The `dict` object passed to the constructor must support those methods. This is generally accomplished by calling one of `bsddb.hashopen()`, `bsddb.btopen()` or `bsddb.rnopen()`. The optional `protocol`, `writeback`, and `keyencoding` parameters have the same interpretation as for the `Shelf` class.

```python
class shelve.DbfilenameShelf(filename, flag='c', protocol=None, writeback=False)
```
A subclass of `Shelf` which accepts a `filename` instead of a dict-like object. The underlying file will be opened using `dbm.open()`. By default, the file will be created and opened for both read and write. The optional `flag` parameter has the same interpretation as for the `open()` function. The optional `protocol` and `writeback` parameters
have the same interpretation as for the `Shelf` class.
12.3.2. Example

To summarize the interface (key is a string, data is an arbitrary object):

```python
import shelve

d = shelve.open(filename)  # open -- file may get suffix added by low-level library

d[key] = data  # store data at key (overwrites old using an existing key)
data = d[key]  # retrieve a COPY of data at key (raise KeyError if no such key)
del d[key]  # delete data stored at key (raises KeyError if no such key)

flag = key in d  # true if the key exists
klist = list(d.keys())  # a list of all existing keys

# as d was opened WITHOUT writeback=True, beware:
d['xx'] = [0, 1, 2]  # this works as expected, but...
d['xx'].append(3)  # *this doesn't!* -- d['xx']

# having opened d without writeback=True, you need to
temp = d['xx']  # extracts the copy
temp.append(5)  # mutates the copy
d['xx'] = temp  # stores the copy right back, too

# or, d=shelve.open(filename,writeback=True) would let you d['xx'].append(5) and have it work as expected, but consume more memory and make the d.close() operation

d.close()  # close it
See also:

Module **dbm**
Generic interface to dbm-style databases.

Module **pickle**
Object serialization used by **shelve**.
12.4. **marshal** — Internal Python object serialization

This module contains functions that can read and write Python values in a binary format. The format is specific to Python, but independent of machine architecture issues (e.g., you can write a Python value to a file on a PC, transport the file to a Sun, and read it back there). Details of the format are undocumented on purpose; it may change between Python versions (although it rarely does). [1]

This is not a general “persistence” module. For general persistence and transfer of Python objects through RPC calls, see the modules **pickle** and **shelve**. The **marshal** module exists mainly to support reading and writing the “pseudo-compiled” code for Python modules of `.pyc` files. Therefore, the Python maintainers reserve the right to modify the marshal format in backward incompatible ways should the need arise. If you’re serializing and de-serializing Python objects, use the **pickle** module instead – the performance is comparable, version independence is guaranteed, and pickle supports a substantially wider range of objects than marshal.

**Warning:** The **marshal** module is not intended to be secure against erroneous or maliciously constructed data. Never unmarshal data received from an untrusted or unauthenticated source.

Not all Python object types are supported; in general, only objects whose value is independent from a particular invocation of Python can be written and read by this module. The following types are supported: booleans, integers, floating point numbers, complex numbers, strings, bytes, bytearrays, tuples, lists, sets, frozensets, dictionaries, and code
objects, where it should be understood that tuples, lists, sets, frozensets and dictionaries are only supported as long as the values contained therein are themselves supported. Singletons None, Ellipsis and StopIteration can also be marshalled and unmarshalled. For format version lower than 3, recursive lists, sets and dictionaries cannot be written (see below).

There are functions that read/write files as well as functions operating on strings.

The module defines these functions:

```python
marshal.dump(value, file[, version])
```
Write the value on the open file. The value must be a supported type. The file must be an open file object such as sys.stdout or returned by open() or os.popen(). It must be opened in binary mode ('wb' or 'w+b').

If the value has (or contains an object that has) an unsupported type, a ValueError exception is raised — but garbage data will also be written to the file. The object will not be properly read back by load().

The version argument indicates the data format that dump should use (see below).

```python
marshal.load(file)
```
Read one value from the open file and return it. If no valid value is read (e.g. because the data has a different Python version's incompatible marshal format), raise EOFError, ValueError or TypeError. The file must be an open file object opened in binary mode ('rb' or 'r+b').
Note: If an object containing an unsupported type was marshalled with \texttt{dump()}, \texttt{load()} will substitute None for the unmarshallable type.

\begin{verbatim}
marshal.dumps(value[, version])
\end{verbatim}

Return the string that would be written to a file by \texttt{dump(value, file)}. The value must be a supported type. Raise a \texttt{ValueError} exception if value has (or contains an object that has) an unsupported type.

The \texttt{version} argument indicates the data format that \texttt{dumps} should use (see below).

\begin{verbatim}
marshal.loads(string)
\end{verbatim}

Convert the string to a value. If no valid value is found, raise \texttt{EOFError}, \texttt{ValueError} or \texttt{TypeError}. Extra characters in the string are ignored.

In addition, the following constants are defined:

\begin{verbatim}
marshal.version
\end{verbatim}

Indicates the format that the module uses. Version 0 is the historical format, version 1 shares interned strings and version 2 uses a binary format for floating point numbers. Version 3 adds support for object instancing and recursion. The current version is 4.

Footnotes

The name of this module stems from a bit of terminology used by the designers of Modula-3 (amongst others), who use the term “marshalling” for shipping of data around in a self-
Strictly speaking, “to marshal” means to convert some data from internal to external form (in an RPC buffer for instance) and “unmarshalling” for the reverse process.
12.5. **dbm** — Interfaces to Unix “databases”

**dbm** is a generic interface to variants of the DBM database — **dbm.gnu** or **dbm.ndbm**. If none of these modules is installed, the slow-but-simple implementation in module **dbm.dumb** will be used. There is a third party interface to the Oracle Berkeley DB.

**exception dbm.error**

A tuple containing the exceptions that can be raised by each of the supported modules, with a unique exception also named **dbm.error** as the first item — the latter is used when **dbm.error** is raised.

**dbm.whichdb(filename)**

This function attempts to guess which of the several simple database modules available — **dbm.gnu**, **dbm.ndbm** or **dbm.dumb** — should be used to open a given file.

Returns one of the following values: None if the file can’t be opened because it’s unreadable or doesn’t exist; the empty string ('') if the file’s format can’t be guessed; or a string containing the required module name, such as 'dbm.ndbm' or 'dbm.gnu'.

**dbm.open(file, flag='r', mode=0o666)**

Open the database file **file** and return a corresponding object.

If the database file already exists, the **whichdb()** function is used to determine its type and the appropriate module is used; if it does not exist, the first module listed above that can be imported is
used.

The optional flag argument can be:

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'r'</td>
<td>Open existing database for reading only (default)</td>
</tr>
<tr>
<td>'w'</td>
<td>Open existing database for reading and writing</td>
</tr>
<tr>
<td>'c'</td>
<td>Open database for reading and writing, creating it if it doesn't exist</td>
</tr>
<tr>
<td>'n'</td>
<td>Always create a new, empty database, open for reading and writing</td>
</tr>
</tbody>
</table>

The optional mode argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal 0o666 (and will be modified by the prevailing umask).

The object returned by open() supports the same basic functionality as dictionaries; keys and their corresponding values can be stored, retrieved, and deleted, and the in operator and the keys() method are available, as well as get() and setdefault().

*Changed in version 3.2:* get() and setdefault() are now available in all database modules.

Key and values are always stored as bytes. This means that when strings are used they are implicitly converted to the default encoding before being stored.

These objects also support being used in a with statement, which will automatically close them when done.

*Changed in version 3.4:* Added native support for the context management protocol to the objects returned by open().
The following example records some hostnames and a corresponding title, and then prints out the contents of the database:

```python
import dbm

# Open database, creating it if necessary.
with dbm.open('cache', 'c') as db:
    # Record some values
    db[b'hello'] = b'there'
    db['www.python.org'] = 'Python Website'
    db['www.cnn.com'] = 'Cable News Network'

    # Note that the keys are considered bytes now.
    assert db[b'www.python.org'] == b'Python Website'

    # Notice how the value is now in bytes.
    assert db['www.cnn.com'] == b'Cable News Network'

    # Often-used methods of the dict interface work too.
    print(db.get('python.org', b'not present'))

    # Storing a non-string key or value will raise a
    # likely a TypeError).
    db['www.yahoo.com'] = 4

    # db is automatically closed when leaving the with statement.
```

**See also:**

**Module** `shelve`

Persistence module which stores non-string data.

The individual submodules are described in the following sections.
12.5.1. dbm.gnu — GNU’s reinterpretation of dbm

This module is quite similar to the dbm module, but uses the GNU library gdbm instead to provide some additional functionality. Please note that the file formats created by dbm.gnu and dbm.ndbm are incompatible.

The dbm.gnu module provides an interface to the GNU DBM library. dbm.gnu.gdbm objects behave like mappings (dictionaries), except that keys and values are always converted to bytes before storing. Printing a gdbm object doesn’t print the keys and values, and the items() and values() methods are not supported.

```
exception dbm.gnu.error

Raised on dbm.gnu-specific errors, such as I/O errors. KeyError is raised for general mapping errors like specifying an incorrect key.
```

```
dbm.gnu.open(filename[, flag[, mode]])

Open a gdbm database and return a gdbm object. The filename argument is the name of the database file.

The optional flag argument can be:
```

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'r'</td>
<td>Open existing database for reading only (default)</td>
</tr>
<tr>
<td>'w'</td>
<td>Open existing database for reading and writing</td>
</tr>
<tr>
<td>'c'</td>
<td>Open database for reading and writing, creating it if it doesn't exist</td>
</tr>
<tr>
<td>'n'</td>
<td>Always create a new, empty database, open for</td>
</tr>
</tbody>
</table>
```
The following additional characters may be appended to the flag to control how the database is opened:

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'f'</td>
<td>Open the database in fast mode. Writes to the database will not be synchronized.</td>
</tr>
<tr>
<td>'s'</td>
<td>Synchronized mode. This will cause changes to the database to be immediately written to the file.</td>
</tr>
<tr>
<td>'u'</td>
<td>Do not lock database.</td>
</tr>
</tbody>
</table>

Not all flags are valid for all versions of gdbm. The module constant open_flags is a string of supported flag characters. The exception error is raised if an invalid flag is specified.

The optional mode argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal 0o666.

In addition to the dictionary-like methods, gdbm objects have the following methods:

**gdbm.firstkey()**

It’s possible to loop over every key in the database using this method and the nextkey() method. The traversal is ordered by gdbm's internal hash values, and won’t be sorted by the key values. This method returns the starting key.

**gdbm.nextkey(key)**

Returns the key that follows key in the traversal. The following code prints every key in the database db, without having to create a list in memory that contains them all:
```
    k = db.firstkey()
    while k != None:
        print(k)
        k = db.nextkey(k)
```

gdbm.reorganize()

If you have carried out a lot of deletions and would like to shrink the space used by the gdbm file, this routine will reorganize the database. gdbm objects will not shorten the length of a database file except by using this reorganization; otherwise, deleted file space will be kept and reused as new (key, value) pairs are added.

gdbm.sync()

When the database has been opened in fast mode, this method forces any unwritten data to be written to the disk.

gdbm.close()

Close the gdbm database.
12.5.2. **dbm.ndbm** — Interface based on `ndbm`

The `dbm.ndbm` module provides an interface to the Unix “(n)dbm” library. Dbm objects behave like mappings (dictionaries), except that keys and values are always stored as bytes. Printing a dbm object doesn’t print the keys and values, and the `items()` and `values()` methods are not supported.

This module can be used with the “classic” `ndbm` interface or the GNU GDBM compatibility interface. On Unix, the `configure` script will attempt to locate the appropriate header file to simplify building this module.

**exception** `dbm.ndbm.error`

Raised on `dbm.ndbm`-specific errors, such as I/O errors. `KeyError` is raised for general mapping errors like specifying an incorrect key.

**`dbm.ndbm.library`**

Name of the `ndbm` implementation library used.

**`dbm.ndbm.open(filename[, flag[, mode]])`**

Open a dbm database and return a `ndbm` object. The `filename` argument is the name of the database file (without the `.dir` or `.pag` extensions).

The optional `flag` argument must be one of these values:

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'r'</td>
<td>Open existing database for reading only (default)</td>
</tr>
<tr>
<td>Mode</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>'w'</td>
<td>Open existing database for reading and writing</td>
</tr>
<tr>
<td>'c'</td>
<td>Open database for reading and writing, creating it if it doesn't exist</td>
</tr>
<tr>
<td>'n'</td>
<td>Always create a new, empty database, open for reading and writing</td>
</tr>
</tbody>
</table>

The optional *mode* argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal 0o666 (and will be modified by the prevailing umask).

In addition to the dictionary-like methods, ndbm objects provide the following method:

```python
ndbm.close()
```

Close the ndbm database.
12.5.3. dbm.dumb — Portable DBM implementation

**Note:** The dbm.dumb module is intended as a last resort fallback for the dbm module when a more robust module is not available. The dbm.dumb module is not written for speed and is not nearly as heavily used as the other database modules.

The dbm.dumb module provides a persistent dictionary-like interface which is written entirely in Python. Unlike other modules such as dbm.gnu no external library is required. As with other persistent mappings, the keys and values are always stored as bytes.

The module defines the following:

*exception* dbm.dumb.error

Raised on dbm.dumb-specific errors, such as I/O errors. KeyError is raised for general mapping errors like specifying an incorrect key.

```
dbm.dumb.open(filename[, flag[, mode]])
```

Open a dumbdbm database and return a dumbdbm object. The filename argument is the basename of the database file (without any specific extensions). When a dumbdbm database is created, files with .dat and .dir extensions are created.

The optional flag argument supports only the semantics of 'c' and 'n' values. Other values will default to database being always opened for update, and will be created if it does not exist.

The optional mode argument is the Unix mode of the file, used only
when the database has to be created. It defaults to octal 0o666 (and will be modified by the prevailing umask).

*Changed in version 3.5:* `open()` always creates a new database when the flag has the value 'n'.

In addition to the methods provided by the `collections.abc.MutableMapping` class, `dumbdbm` objects provide the following methods:

- `dumbdbm.sync()`
  Synchronize the on-disk directory and data files. This method is called by the `Shelve.sync()` method.

- `dumbdbm.close()`
  Close the `dumbdbm` database.
12.6. `sqlite3` — DB-API 2.0 interface for SQLite databases

SQLite is a C library that provides a lightweight disk-based database that doesn't require a separate server process and allows accessing the database using a nonstandard variant of the SQL query language. Some applications can use SQLite for internal data storage. It's also possible to prototype an application using SQLite and then port the code to a larger database such as PostgreSQL or Oracle.

The sqlite3 module was written by Gerhard Häring. It provides a SQL interface compliant with the DB-API 2.0 specification described by PEP 249.

To use the module, you must first create a `Connection` object that represents the database. Here the data will be stored in the example.db file:

```python
import sqlite3
conn = sqlite3.connect('example.db')
```

You can also supply the special name `:memory:` to create a database in RAM.

Once you have a `Connection`, you can create a `Cursor` object and call its `execute()` method to perform SQL commands:

```python
c = conn.cursor()
# Create table
c.execute('''CREATE TABLE stocks
```
(date text, trans text, symbol text, qty real, price real)

# Insert a row of data
c.execute("INSERT INTO stocks VALUES ('2006-01-05','BUY','RHAT',100,35.14)"

# Save (commit) the changes
conn.commit()

# We can also close the connection if we are done with it.
# Just be sure any changes have been committed or they will be lost.
conn.close()

The data you've saved is persistent and is available in subsequent sessions:

```python
import sqlite3
conn = sqlite3.connect('example.db')
c = conn.cursor()
```

Usually your SQL operations will need to use values from Python variables. You shouldn’t assemble your query using Python’s string operations because doing so is insecure; it makes your program vulnerable to an SQL injection attack (see http://xkcd.com/327/ for humorous example of what can go wrong).

Instead, use the DB-API’s parameter substitution. Put ? as a placeholder wherever you want to use a value, and then provide a tuple of values as the second argument to the cursor’s `execute()` method. (Other database modules may use a different placeholder, such as %s or :1.) For example:

```python
# Never do this -- insecure!
symbol = 'RHAT'
c.execute("SELECT * FROM stocks WHERE symbol = '%s'"
# Do this instead

t = ('RHAT',)
c.execute('SELECT * FROM stocks WHERE symbol=?', t)
print(c.fetchone())

# Larger example that inserts many records at a time

purchases = [('2006-03-28', 'BUY', 'IBM', 1000, 45.0),
             ('2006-04-05', 'BUY', 'MSFT', 1000, 72.0),
             ('2006-04-06', 'SELL', 'IBM', 500, 53.0),
             ]
c.executemany('INSERT INTO stocks VALUES (?,?,?,?,?)

To retrieve data after executing a SELECT statement, you can either treat the cursor as an iterator, call the cursor's `fetchone()` method to retrieve a single matching row, or call `fetchall()` to get a list of the matching rows.

This example uses the iterator form:

```python
>>> for row in c.execute('SELECT * FROM stocks ORDER BY price
               print(row)
               ('2006-01-05', 'BUY', 'RHAT', 100, 35.14)
               ('2006-03-28', 'BUY', 'IBM', 1000, 45.0)
               ('2006-04-06', 'SELL', 'IBM', 500, 53.0)
               ('2006-04-05', 'BUY', 'MSFT', 1000, 72.0)
```

See also:

https://github.com/ghaering/pysqLite

The pysqLite web page – sqlite3 is developed externally under the name “pysqLite”.

http://www.sqlite.org
The SQLite web page; the documentation describes the syntax and the available data types for the supported SQL dialect.

http://www.w3schools.com/sql/
Tutorial, reference and examples for learning SQL syntax.

PEP 249 - Database API Specification 2.0
PEP written by Marc-André Lemburg.
12.6.1. Module functions and constants

`sqlite3.version`
The version number of this module, as a string. This is not the version of the SQLite library.

`sqlite3.version_info`
The version number of this module, as a tuple of integers. This is not the version of the SQLite library.

`sqlite3.sqlite_version`
The version number of the run-time SQLite library, as a string.

`sqlite3.sqlite_version_info`
The version number of the run-time SQLite library, as a tuple of integers.

`sqlite3.PARSE_DECLTYPES`
This constant is meant to be used with the `detect_types` parameter of the `connect()` function.

Setting it makes the `sqlite3` module parse the declared type for each column it returns. It will parse out the first word of the declared type, i.e. for “integer primary key”, it will parse out “integer”, or for “number(10)” it will parse out “number”. Then for that column, it will look into the converters dictionary and use the converter function registered for that type there.

`sqlite3.PARSE_COLNAMES`
This constant is meant to be used with the `detect_types` parameter of the `connect()` function.
Setting this makes the SQLite interface parse the column name for each column it returns. It will look for a string formed [mytype] in there, and then decide that ‘mytype’ is the type of the column. It will try to find an entry of ‘mytype’ in the converters dictionary and then use the converter function found there to return the value. The column name found in `Cursor.description` is only the first word of the column name, i.e. if you use something like 'as "x [datetime]"' in your SQL, then we will parse out everything until the first blank for the column name: the column name would simply be “x”.

```python
sqlite3.connect(database[, timeout, detect_types,
            isolation_level, check_same_thread, factory, cached_statements, uri])
```

Opens a connection to the SQLite database file `database`. You can use `":memory:"` to open a database connection to a database that resides in RAM instead of on disk.

When a database is accessed by multiple connections, and one of the processes modifies the database, the SQLite database is locked until that transaction is committed. The `timeout` parameter specifies how long the connection should wait for the lock to go away until raising an exception. The default for the timeout parameter is 5.0 (five seconds).

For the `isolation_level` parameter, please see the `Connection.isolation_level` property of `Connection` objects.

SQLite natively supports only the types TEXT, INTEGER, REAL, BLOB and NULL. If you want to use other types you must add support for them yourself. The `detect_types` parameter and the using custom `converters` registered with the module-level
**register_converter()** function allow you to easily do that.

**detect_types** defaults to 0 (i.e. off, no type detection), you can set it to any combination of **PARSE_DECLTYPES** and **PARSE_COLNAMES** to turn type detection on.

By default, the **sqlite3** module uses its **Connection** class for the connect call. You can, however, subclass the **Connection** class and make **connect()** use your class instead by providing your class for the **factory** parameter.

Consult the section **SQLite and Python types** of this manual for details.

The **sqlite3** module internally uses a statement cache to avoid SQL parsing overhead. If you want to explicitly set the number of statements that are cached for the connection, you can set the **cached_statements** parameter. The currently implemented default is to cache 100 statements.

If **uri** is true, **database** is interpreted as a URI. This allows you to specify options. For example, to open a database in read-only mode you can use:

```python
db = sqlite3.connect('file:path/to/database?mode=ro')
```

More information about this feature, including a list of recognized options, can be found in the SQLite URI documentation.

*Changed in version 3.4:* Added the **uri** parameter.

**sqlite3.register_converter**(typename, callable)

Registers a callable to convert a bytestring from the database into
a custom Python type. The callable will be invoked for all database values that are of the type `typename`. Confer the parameter `detect_types` of the `connect()` function for how the type detection works. Note that the case of `typename` and the name of the type in your query must match!

`sqlite3.register_adapter(type, callable)`

Registers a callable to convert the custom Python type `type` into one of SQLite's supported types. The callable `callable` accepts as single parameter the Python value, and must return a value of the following types: int, float, str or bytes.

`sqlite3.complete_statement(sql)`

Returns `True` if the string `sql` contains one or more complete SQL statements terminated by semicolons. It does not verify that the SQL is syntactically correct, only that there are no unclosed string literals and the statement is terminated by a semicolon.

This can be used to build a shell for SQLite, as in the following example:

```python
# A minimal SQLite shell for experiments
import sqlite3
con = sqlite3.connect(":memory:"
con.isolation_level = None
cur = con.cursor()

buffer = ""

print("Enter your SQL commands to execute in sqlite3.
print("Enter a blank line to exit."
```
```python
while True:
    line = input()
    if line == "":
        break
    buffer += line
    if sqlite3.complete_statement(buffer):
        try:
            buffer = buffer.strip()
            cur.execute(buffer)
            if buffer.lstrip().upper().startswith('PRINT '):
                print(cur.fetchall())
        except sqlite3.Error as e:
            print("An error occurred: ", e.args[0])
        buffer = ""
con.close()
```

`sqlite3.enable_callback_tracebacks(flag)`

By default you will not get any tracebacks in user-defined functions, aggregates, converters, authorizer callbacks etc. If you want to debug them, you can call this function with `flag` set to True. Afterwards, you will get tracebacks from callbacks on `sys.stderr`. Use `False` to disable the feature again.
12.6.2. Connection Objects

class sqlite3.Connection

A SQLite database connection has the following attributes and methods:

isolation_level
Get or set the current isolation level. None for autocommit mode or one of “DEFERRED”, “IMMEDIATE” or “EXCLUSIVE”. See section Controlling Transactions for a more detailed explanation.

in_transaction
True if a transaction is active (there are uncommitted changes), False otherwise. Read-only attribute.

New in version 3.2.

cursor([cursorClass])
The cursor method accepts a single optional parameter cursorClass. If supplied, this must be a custom cursor class that extends sqlite3.Cursor.

commit()
This method commits the current transaction. If you don’t call this method, anything you did since the last call to commit() is not visible from other database connections. If you wonder why you don’t see the data you’ve written to the database, please check you didn’t forget to call this method.

rollback()
This method rolls back any changes to the database since the last call to `commit()`.

`close()`
This closes the database connection. Note that this does not automatically call `commit()`. If you just close your database connection without calling `commit()` first, your changes will be lost!

`execute(sql[, parameters])`
This is a nonstandard shortcut that creates an intermediate cursor object by calling the cursor method, then calls the cursor’s `execute` method with the parameters given.

`executemany(sql[, parameters])`
This is a nonstandard shortcut that creates an intermediate cursor object by calling the cursor method, then calls the cursor’s `executemany` method with the parameters given.

`executescript(sql_script)`
This is a nonstandard shortcut that creates an intermediate cursor object by calling the cursor method, then calls the cursor’s `executescript` method with the parameters given.

`create_function(name, num_params, func)`
Creates a user-defined function that you can later use from within SQL statements under the function name `name`. `num_params` is the number of parameters the function accepts, and `func` is a Python callable that is called as the SQL function.

The function can return any of the types supported by SQLite: bytes, str, int, float and None.
Example:

```python
import sqlite3
import hashlib

def md5sum(t):
    return hashlib.md5(t).hexdigest()

con = sqlite3.connect(":memory:")
con.create_function("md5", 1, md5sum)
cur = con.cursor()
cur.execute("select md5(?)", (b"foo",))
print(cur.fetchone()[0])
```

create_aggregate(name, num_params, aggregate_class)

Creates a user-defined aggregate function.

The aggregate class must implement a step method, which accepts the number of parameters num_params, and a finalize method which will return the final result of the aggregate.

The finalize method can return any of the types supported by SQLite: bytes, str, int, float and None.

Example:

```python
import sqlite3

class MySum:
    def __init__(self):
        self.count = 0

    def step(self, value):
        self.count += value
```
```python
def finalize(self):
    return self.count

con = sqlite3.connect(":memory:")
con.create_aggregate("mysum", 1, MySum)
cur = con.cursor()
cur.execute("create table test(i)")
cur.execute("insert into test(i) values (1)")
cur.execute("insert into test(i) values (2)")
cur.execute("select mysum(i) from test")
print(cur.fetchone()[0])
```

**create_collation**(name, callable)

Creates a collation with the specified name and callable. The callable will be passed two string arguments. It should return -1 if the first is ordered lower than the second, 0 if they are ordered equal and 1 if the first is ordered higher than the second. Note that this controls sorting (ORDER BY in SQL) so your comparisons don't affect other SQL operations.

Note that the callable will get its parameters as Python bytestrings, which will normally be encoded in UTF-8.

The following example shows a custom collation that sorts “the wrong way”:

```python
import sqlite3

def collate_reverse(string1, string2):
    if string1 == string2:
        return 0
    elif string1 < string2:
        return 1
    else:
```
return -1

con = sqlite3.connect(":memory:")
con.create_collation("reverse", collate_reverse

cur = con.cursor()
cur.execute("create table test(x")
cur.executemany("insert into test(x) values (?)")
cur.execute("select x from test order by x coll
for row in cur:
    print(row)
con.close()

To remove a collation, call create_collation with None as callable:

con.create_collation("reverse", None)

interrupt()

You can call this method from a different thread to abort any queries that might be executing on the connection. The query will then abort and the caller will get an exception.

set_authorizer(authorizer_callback)

This routine registers a callback. The callback is invoked for each attempt to access a column of a table in the database. The callback should return SQLITE_OK if access is allowed, SQLITE_DENY if the entire SQL statement should be aborted with an error and SQLITE_IGNORE if the column should be treated as a NULL value. These constants are available in the sqlite3 module.

The first argument to the callback signifies what kind of
operation is to be authorized. The second and third argument will be arguments or \texttt{None} depending on the first argument. The 4th argument is the name of the database ("main", "temp", etc.) if applicable. The 5th argument is the name of the inner-most trigger or view that is responsible for the access attempt or \texttt{None} if this access attempt is directly from input SQL code.

Please consult the SQLite documentation about the possible values for the first argument and the meaning of the second and third argument depending on the first one. All necessary constants are available in the \texttt{sqlite3} module.

\textbf{set\_progress\_handler}(\texttt{handler}, \texttt{n})

This routine registers a callback. The callback is invoked for every \texttt{n} instructions of the SQLite virtual machine. This is useful if you want to get called from SQLite during long-running operations, for example to update a GUI.

If you want to clear any previously installed progress handler, call the method with \texttt{None} for \texttt{handler}.

\textbf{set\_trace\_callback}(\texttt{trace\_callback})

Registers \texttt{trace\_callback} to be called for each SQL statement that is actually executed by the SQLite backend.

The only argument passed to the callback is the statement (as string) that is being executed. The return value of the callback is ignored. Note that the backend does not only run statements passed to the \texttt{Cursor.execute()} methods. Other sources include the transaction management of the Python module and the execution of triggers defined in the current database.

Passing \texttt{None} as \texttt{trace\_callback} will disable the trace callback.
**New in version 3.3.**

**enable_load_extension**(enabled)

This routine allows/disallows the SQLite engine to load SQLite extensions from shared libraries. SQLite extensions can define new functions, aggregates or whole new virtual table implementations. One well-known extension is the fulltext-search extension distributed with SQLite.

Loadable extensions are disabled by default. See [1].

**New in version 3.2.**

```python
import sqlite3

con = sqlite3.connect(":memory:")

# enable extension loading
con.enable_load_extension(True)

# Load the fulltext search extension
con.execute("select load_extension('./fts3.so')")

# alternatively you can load the extension using
# con.load_extension('./fts3.so')

# disable extension loading again
con.enable_load_extension(False)

# example from SQLite wiki
con.execute("create virtual table recipe using fts3(name, ingredients)"
con.executescript(""
    insert into recipe (name, ingredients) values
    insert into recipe (name, ingredients) values
    insert into recipe (name, ingredients) values
    insert into recipe (name, ingredients) values
```
for row in con.execute("select rowid, name, ingredients from recipe where name match 'pie'")
print(row)

load_extension(path)

This routine loads a SQLite extension from a shared library. You have to enable extension loading with enable_load_extension() before you can use this routine.

Loadable extensions are disabled by default. See [1].

New in version 3.2.

row_factory

You can change this attribute to a callable that accepts the cursor and the original row as a tuple and will return the real result row. This way, you can implement more advanced ways of returning results, such as returning an object that can also access columns by name.

Example:

```python
import sqlite3
def dict_factory(cursor, row):
    d = {}
    for idx, col in enumerate(cursor.description):
        d[col[0]] = row[idx]
    return d
con = sqlite3.connect(":memory:")
con.row_factory = dict_factory
cur = con.cursor()
cur.execute("select 1 as a")
```
If returning a tuple doesn’t suffice and you want name-based access to columns, you should consider setting `row_factory` to the highly-optimized `sqlite3.Row` type. `Row` provides both index-based and case-insensitive name-based access to columns with almost no memory overhead. It will probably be better than your own custom dictionary-based approach or even a `db_row` based solution.

**text_factory**

Using this attribute you can control what objects are returned for the TEXT data type. By default, this attribute is set to `str` and the `sqlite3` module will return Unicode objects for TEXT. If you want to return bytestrings instead, you can set it to `bytes`.

For efficiency reasons, there's also a way to return `str` objects only for non-ASCII data, and `bytes` otherwise. To activate it, set this attribute to `sqlite3.OptimizedUnicode`.

You can also set it to any other callable that accepts a single bytestring parameter and returns the resulting object.

See the following example code for illustration:

```python
import sqlite3

con = sqlite3.connect(":memory:")
cur = con.cursor()

AUSTRIA = "\xd6sterreich"
```
# by default, rows are returned as Unicode
cur.execute("select ?", (AUSTRIA,))
row = cur.fetchone()
assert row[0] == AUSTRIA

# but we can make sqlite3 always return bytestrings ...
con.text_factory = bytes
cur.execute("select ?", (AUSTRIA,))
row = cur.fetchone()
assert type(row[0]) is bytes
# the bytestrings will be encoded in UTF-8, unless...
assert row[0] == AUSTRIA.encode("utf-8")

# we can also implement a custom text_factory ...
# here we implement one that appends "foo" to a string
con.text_factory = lambda x: x.decode("utf-8")
cur.execute("select ?", ("bar",))
row = cur.fetchone()
assert row[0] == "barfoo"

**total_changes**

Returns the total number of database rows that have been modified, inserted, or deleted since the database connection was opened.

**iterdump**

Returns an iterator to dump the database in an SQL text format. Useful when saving an in-memory database for later restoration. This function provides the same capabilities as the .dump command in the sqlite3 shell.

Example:

# Convert file existing_db.db to SQL dump file
import sqlite3, os

con = sqlite3.connect('existing_db.db')

with open('dump.sql', 'w') as f:
    for line in con.iterdump():
        f.write('%s
' % line)
12.6.3. Cursor Objects

*class* sqlite3.*Cursor*

A *Cursor* instance has the following attributes and methods.

**execute**(sql[, parameters])**

Executes an SQL statement. The SQL statement may be parameterized (i.e. placeholders instead of SQL literals). The *sqlite3* module supports two kinds of placeholders: question marks (qmark style) and named placeholders (named style).

Here's an example of both styles:

```python
import sqlite3

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.execute("create table people (name_last, age)

who = "Yeltsin"
age = 72

# This is the qmark style:
cur.execute("insert into people values (?, ?)",

# And this is the named style:
cur.execute("select * from people where name_last=:who and age=:age"

print(cur.fetchone())
```

**execute()** will only execute a single SQL statement. If you try to execute more than one statement with it, it will raise a Warning. Use **executescript()** if you want to execute
multiple SQL statements with one call.

**executemany**(sql, seq_of_parameters)

Executes an SQL command against all parameter sequences or mappings found in the sequence sql. The sqlite3 module also allows using an iterator yielding parameters instead of a sequence.

```python
import sqlite3
class IterChars:
    def __init__(self):
        self.count = ord('a')

    def __iter__(self):
        return self

    def __next__(self):
        if self.count > ord('z'):
            raise StopIteration
        self.count += 1
        return (chr(self.count - 1),) # this is a 1-tuple

con = sqlite3.connect(':memory:)
cur = con.cursor()
cur.execute("create table characters(c)"

theIter = IterChars()
cur.executemany("insert into characters(c) values (?)")

cur.execute("select c from characters")
print(cur.fetchall())
```

Here's a shorter example using a generator:
import sqlite3
import string

def char_generator():
    for c in string.ascii_lowercase:
        yield (c,)

con = sqlite3.connect(":memory:"
cur = con.cursor()
cur.execute("create table characters(c)"
cur.executemany("insert into characters(c) val
cur.execute("select c from characters"
print(cur.fetchall())

executescript(sql_script)
This is a nonstandard convenience method for executing
multiple SQL statements at once. It issues a COMMIT statement
first, then executes the SQL script it gets as a parameter.

sql_script can be an instance of str or bytes.

Example:

import sqlite3

con = sqlite3.connect(":memory:"
cur = con.cursor()
cur.executescript(""
create table person(
    firstname,
    lastname,
    age
);""
```sql
create table book(
    title,
    author,
    published
);

insert into book(title, author, published)
values ('Dirk Gently''s Holistic Detective Agency',
        'Douglas Adams',
        1987);
```

**fetchone()**

Fetches the next row of a query result set, returning a single sequence, or **None** when no more data is available.

**fetchmany(size=cursor.arraysize)**

Fetches the next set of rows of a query result, returning a list. An empty list is returned when no more rows are available.

The number of rows to fetch per call is specified by the `size` parameter. If it is not given, the cursor’s `arraysize` determines the number of rows to be fetched. The method should try to fetch as many rows as indicated by the `size` parameter. If this is not possible due to the specified number of rows not being available, fewer rows may be returned.

Note there are performance considerations involved with the `size` parameter. For optimal performance, it is usually best to use the `arraysize` attribute. If the `size` parameter is used, then it is best for it to retain the same value from one `fetchmany()`
call to the next.

**fetchall()**

Fetches all (remaining) rows of a query result, returning a list. Note that the cursor's arraysize attribute can affect the performance of this operation. An empty list is returned when no rows are available.

**rowcount**

Although the `Cursor` class of the `sqlite3` module implements this attribute, the database engine's own support for the determination of “rows affected”/”rows selected” is quirky.

For `executemany()` statements, the number of modifications are summed up into `rowcount`.

As required by the Python DB API Spec, the `rowcount` attribute “is -1 in case no `executeXX()` has been performed on the cursor or the rowcount of the last operation is not determinable by the interface”. This includes `SELECT` statements because we cannot determine the number of rows a query produced until all rows were fetched.

With SQLite versions before 3.6.5, `rowcount` is set to 0 if you make a DELETE FROM table without any condition.

**lastrowid**

This read-only attribute provides the rowid of the last modified row. It is only set if you issued an INSERT statement using the `execute()` method. For operations other than INSERT or when `executemany()` is called, `lastrowid` is set to None.

description
This read-only attribute provides the column names of the last query. To remain compatible with the Python DB API, it returns a 7-tuple for each column where the last six items of each tuple are `None`.

It is set for SELECT statements without any matching rows as well.
12.6.4. Row Objects

class sqlite3.Row

A Row instance serves as a highly optimized row_factory for Connection objects. It tries to mimic a tuple in most of its features.

It supports mapping access by column name and index, iteration, representation, equality testing and \texttt{len()}.

If two \texttt{Row} objects have exactly the same columns and their members are equal, they compare equal.

\textbf{keys()}

This method returns a list of column names. Immediately after a query, it is the first member of each tuple in \texttt{Cursor.description}.

*Changed in version 3.5:* Added support of slicing.

Let's assume we initialize a table as in the example given above:

```python
conn = sqlite3.connect(":memory:")
c = conn.cursor()
c.execute('''create table stocks
    (date text, trans text, symbol text,
     qty real, price real)''')
c.execute("""insert into stocks
    values ('2006-01-05','BUY','RHAT',100,35.14)"")
conn.commit()
c.close()
```
Now we plug `Row` in:

```python
>>> conn.row_factory = sqlite3.Row
>>> c = conn.cursor()
>>> c.execute('select * from stocks')
<sqlite3.Cursor object at 0x7f4e7dd8fa80>
>>> r = c.fetchone()
>>> type(r)
<class 'sqlite3.Row'>
>>> tuple(r)
('2006-01-05', 'BUY', 'RHAT', 100.0, 35.14)
>>> len(r)
5
>>> r[2]
'RHAT'
>>> r.keys()
['date', 'trans', 'symbol', 'qty', 'price']
>>> r['qty']
100.0
>>> for member in r:
...     print(member)
...
2006-01-05
BUY
RHAT
100.0
35.14
```
12.6.5. SQLite and Python types

12.6.5.1. Introduction

SQLite natively supports the following types: NULL, INTEGER, REAL, TEXT, BLOB.

The following Python types can thus be sent to SQLite without any problem:

<table>
<thead>
<tr>
<th>Python type</th>
<th>SQLite type</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>NULL</td>
</tr>
<tr>
<td>int</td>
<td>INTEGER</td>
</tr>
<tr>
<td>float</td>
<td>REAL</td>
</tr>
<tr>
<td>str</td>
<td>TEXT</td>
</tr>
<tr>
<td>bytes</td>
<td>BLOB</td>
</tr>
</tbody>
</table>

This is how SQLite types are converted to Python types by default:

<table>
<thead>
<tr>
<th>SQLite type</th>
<th>Python type</th>
</tr>
</thead>
<tbody>
<tr>
<td>NULL</td>
<td>None</td>
</tr>
<tr>
<td>INTEGER</td>
<td>int</td>
</tr>
<tr>
<td>REAL</td>
<td>float</td>
</tr>
<tr>
<td>TEXT</td>
<td>depends on <code>text_factory</code>, str by default</td>
</tr>
<tr>
<td>BLOB</td>
<td>bytes</td>
</tr>
</tbody>
</table>

The type system of the `sqlite3` module is extensible in two ways: you can store additional Python types in a SQLite database via object
adaptation, and you can let the sqlite3 module convert SQLite types to different Python types via converters.

12.6.5.2. Using adapters to store additional Python types in SQLite databases

As described before, SQLite supports only a limited set of types natively. To use other Python types with SQLite, you must adapt them to one of the sqlite3 module’s supported types for SQLite: one of NoneType, int, float, str, bytes.

There are two ways to enable the sqlite3 module to adapt a custom Python type to one of the supported ones.

12.6.5.2.1. Letting your object adapt itself

This is a good approach if you write the class yourself. Let’s suppose you have a class like this:

```python
class Point:
    def __init__(self, x, y):
        self.x, self.y = x, y
```

Now you want to store the point in a single SQLite column. First you’ll have to choose one of the supported types first to be used for representing the point. Let’s just use str and separate the coordinates using a semicolon. Then you need to give your class a method `__conform__` which must return the converted value. The parameter `protocol` will be `PrepareProtocol`.

```python
import sqlite3
```
class Point:
    def __init__(self, x, y):
        self.x, self.y = x, y

    def __conform__(self, protocol):
        if protocol is sqlite3.PrepareProtocol:
            return "%f;%f" % (self.x, self.y)

con = sqlite3.connect(":memory:")
cur = con.cursor()

p = Point(4.0, -3.2)
cur.execute("select ?", (p,))
print(cur.fetchone()[0])

12.6.5.2.2. Registering an adapter callable

The other possibility is to create a function that converts the type to the string representation and register the function with register_adapter().

import sqlite3

class Point:
    def __init__(self, x, y):
        self.x, self.y = x, y

    def adapt_point(point):
        return "%f;%f" % (point.x, point.y)

sqlite3.register_adapter(Point, adapt_point)

con = sqlite3.connect(":memory:")
cur = con.cursor()

p = Point(4.0, -3.2)
The `sqlite3` module has two default adapters for Python's built-in `datetime.date` and `datetime.datetime` types. Now let's suppose we want to store `datetime.datetime` objects not in ISO representation, but as a Unix timestamp.

```python
import sqlite3
import datetime
import time

def adapt_datetime(ts):
    return time.mktime(ts.timetuple())

sqlite3.register_adapter(datetime.datetime, adapt_datetime)

con = sqlite3.connect(':memory:)
cur = con.cursor()

now = datetime.datetime.now()
cur.execute("select ?", (now,))
print(cur.fetchone()[0])
```

12.6.5.3. Converting SQLite values to custom Python types

Writing an adapter lets you send custom Python types to SQLite. But to make it really useful we need to make the Python to SQLite to Python roundtrip work.

Enter converters.
Let's go back to the Point class. We stored the x and y coordinates separated via semicolons as strings in SQLite.

First, we'll define a converter function that accepts the string as a parameter and constructs a Point object from it.

**Note:** Converter functions *always* get called with a `bytes` object, no matter under which data type you sent the value to SQLite.

```python
def convert_point(s):
    x, y = map(float, s.split(b";"))
    return Point(x, y)
```

Now you need to make the `sqlite3` module know that what you select from the database is actually a point. There are two ways of doing this:

- Implicitly via the declared type
- Explicitly via the column name

Both ways are described in section `Module functions and constants`, in the entries for the constants `PARSEDECLTYPES` and `PARSE_COLNAMES`.

The following example illustrates both approaches.

```python
import sqlite3
class Point:
    def __init__(self, x, y):
        self.x, self.y = x, y

    def __repr__(self):
        return "(%f,%f)" % (self.x, self.y)
```
def adapt_point(point):
    return ('%f;%f' % (point.x, point.y)).encode('ascii')

def convert_point(s):
    x, y = list(map(float, s.split(b';')))
    return Point(x, y)

# Register the adapter
sqlite3.register_adapter(Point, adapt_point)

# Register the converter
sqlite3.register_converter('point', convert_point)

p = Point(4.0, -3.2)

# Using declared types
con = sqlite3.connect(':memory:', detect_types=sqlite3.PARSE_DECLTYPES)
cur = con.cursor()
cur.execute("create table test(p point)"

cur.execute("insert into test(p) values (?)", (p,))
cur.execute("select p from test")
print("with declared types:", cur.fetchone()[0])
cur.close()
con.close()

# Using column names
con = sqlite3.connect(':memory:', detect_types=sqlite3.PARSE_DECLTYPES)
cur = con.cursor()
cur.execute("create table test(p)"

cur.execute("insert into test(p) values (?)", (p,))
cur.execute('select p as "p [point]" from test')
print("with column names:", cur.fetchone()[0])
12.6.5.4. Default adapters and converters

There are default adapters for the date and datetime types in the datetime module. They will be sent as ISO dates/ISO timestamps to SQLite.

The default converters are registered under the name “date” for `datetime.date` and under the name “timestamp” for `datetime.datetime`.

This way, you can use date/timestamps from Python without any additional fiddling in most cases. The format of the adapters is also compatible with the experimental SQLite date/time functions.

The following example demonstrates this.

```python
import sqlite3
import datetime

con = sqlite3.connect(":memory:", detect_types=sqlite3.PARSE_DECLTYPES)
cur = con.cursor()
cur.execute("create table test(d date, ts timestamp)"

today = datetime.date.today()
now = datetime.datetime.now()

cur.execute("insert into test(d, ts) values (?, ?)",
cur.execute("select d, ts from test")
row = cur.fetchone()
print(today, "=>", row[0], type(row[0]))
print(now, "=>", row[1], type(row[1]))
```
cur.execute('select current_date as "d [date]", current_timestamp as "ts [timestamp]"')
row = cur.fetchone()
print("current_date", row[0], type(row[0]))
print("current_timestamp", row[1], type(row[1]))

If a timestamp stored in SQLite has a fractional part longer than 6 numbers, its value will be truncated to microsecond precision by the timestamp converter.
12.6.6. Controlling Transactions

By default, the sqlite3 module opens transactions implicitly before a Data Modification Language (DML) statement (i.e. INSERT/UPDATE/DELETE/REPLACE), and commits transactions implicitly before a non-DML, non-query statement (i.e. anything other than SELECT or the aforementioned).

So if you are within a transaction and issue a command like CREATE TABLE ..., VACUUM, PRAGMA, the sqlite3 module will commit implicitly before executing that command. There are two reasons for doing that. The first is that some of these commands don’t work within transactions. The other reason is that sqlite3 needs to keep track of the transaction state (if a transaction is active or not). The current transaction state is exposed through the Connection.in_transaction attribute of the connection object.

You can control which kind of BEGIN statements sqlite3 implicitly executes (or none at all) via the isolation_level parameter to the connect() call, or via the isolation_level property of connections.

If you want autocommit mode, then set isolation_level to None.

Otherwise leave it at its default, which will result in a plain “BEGIN” statement, or set it to one of SQLite’s supported isolation levels: “DEFERRED”, “IMMEDIATE” or “EXCLUSIVE”.
12.6.7. Using `sqlite3` efficiently

12.6.7.1. Using shortcut methods

Using the nonstandard `execute()`, `executemany()` and `executescript()` methods of the `Connection` object, your code can be written more concisely because you don't have to create the (often superfluous) `Cursor` objects explicitly. Instead, the `Cursor` objects are created implicitly and these shortcut methods return the cursor objects. This way, you can execute a SELECT statement and iterate over it directly using only a single call on the `Connection` object.

```python
import sqlite3

persons = [  
    ("Hugo", "Boss"),  
    ("Calvin", "Klein")  
]

con = sqlite3.connect(':memory:)

# Create the table
con.execute("create table person(firstname, lastname)"

# Fill the table
con.executemany("insert into person(firstname, lastname) values (?, ?)"

# Print the table contents
for row in con.execute("select firstname, lastname from person"

print(row)

print("I just deleted", con.execute("delete from person"))
```
12.6.7.2. Accessing columns by name instead of by index

One useful feature of the sqlite3 module is the built-in sqlite3.Row class designed to be used as a row factory.

Rows wrapped with this class can be accessed both by index (like tuples) and case-insensitively by name:

```python
import sqlite3
con = sqlite3.connect(":memory:")
con.row_factory = sqlite3.Row

cur = con.cursor()
cur.execute("select 'John' as name, 42 as age")
for row in cur:
    assert row[0] == row["name"]
    assert row["name"] == row["nAmE"]
    assert row[1] == row["age"]
    assert row[1] == row["AgE"]
```

12.6.7.3. Using the connection as a context manager

Connection objects can be used as context managers that automatically commit or rollback transactions. In the event of an exception, the transaction is rolled back; otherwise, the transaction is committed:

```python
import sqlite3
con = sqlite3.connect(":memory:")
```
con.execute("create table person (id integer primary key, firstname varchar unique)"

# Successful, con.commit() is called automatically and afterwards
with con:
    con.execute("insert into person(firstname) values (?)")

# con.rollback() is called after the with block finishes, so the
# exception is still raised and must be caught
try:
    with con:
        con.execute("insert into person(firstname) values (?)")
except sqlite3.IntegrityError:
    print("couldn't add Joe twice")
12.6.8. Common issues

12.6.8.1. Multithreading

Older SQLite versions had issues with sharing connections between threads. That's why the Python module disallows sharing connections and cursors between threads. If you still try to do so, you will get an exception at runtime.

The only exception is calling the `interrupt()` method, which only makes sense to call from a different thread.

Footnotes

(1, 2) The `sqlite3` module is not built with loadable extension support by default, because some platforms (notably Mac OS X) have SQLite libraries which are compiled without this feature. To get loadable extension support, you must pass –enable-loadable-sqlite-extensions to configure.
13. Data Compression and Archiving

The modules described in this chapter support data compression with the zlib, gzip, bzip2 and lzma algorithms, and the creation of ZIP- and tar-format archives. See also Archiving operations provided by the shutil module.

- **13.1. zlib** — Compression compatible with gzip
- **13.2. gzip** — Support for gzip files
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13.6.6. Unicode issues
13.1. zlib — Compression compatible with gzip

For applications that require data compression, the functions in this module allow compression and decompression, using the zlib library. The zlib library has its own home page at http://www.zlib.net. There are known incompatibilities between the Python module and versions of the zlib library earlier than 1.1.3; 1.1.3 has a security vulnerability, so we recommend using 1.1.4 or later.

zlib’s functions have many options and often need to be used in a particular order. This documentation doesn’t attempt to cover all of the permutations; consult the zlib manual at http://www.zlib.net/manual.html for authoritative information.

For reading and writing .gz files see the gzip module.

The available exception and functions in this module are:

- **exception zlib.error**
  
  Exception raised on compression and decompression errors.

- **zlib.adler32(data[, value])**

  Computes an Adler-32 checksum of data. (An Adler-32 checksum is almost as reliable as a CRC32 but can be computed much more quickly.) If value is present, it is used as the starting value of the checksum; otherwise, a fixed default value is used. This allows computing a running checksum over the concatenation of several inputs. The algorithm is not cryptographically strong, and should not be used for authentication or digital signatures. Since the
algorithm is designed for use as a checksum algorithm, it is not suitable for use as a general hash algorithm.

Always returns an unsigned 32-bit integer.

**Note:** To generate the same numeric value across all Python versions and platforms use adler32(data) & 0xffffffff. If you are only using the checksum in packed binary format this is not necessary as the return value is the correct 32bit binary representation regardless of sign.

```python
zlib.compress(data[, level])
```
Compresses the bytes in `data`, returning a bytes object containing compressed data. `level` is an integer from 0 to 9 controlling the level of compression; 1 is fastest and produces the least compression, 9 is slowest and produces the most. 0 is no compression. The default value is 6. Raises the `error` exception if any error occurs.

```python
zlib.compressobj(level=-1, method=DEFLATED, wbits=15, memLevel=8, strategy=Z_DEFAULT_STRATEGY[, zdict])
```
Returns a compression object, to be used for compressing data streams that won’t fit into memory at once.

`level` is the compression level – an integer from 0 to 9. A value of 1 is fastest and produces the least compression, while a value of 9 is slowest and produces the most. 0 is no compression. The default value is 6.

`method` is the compression algorithm. Currently, the only supported value is DEFLATED.
**wbits** is the base two logarithm of the size of the window buffer. This should be an integer from 8 to 15. Higher values give better compression, but use more memory.

The **memLevel** argument controls the amount of memory used for the internal compression state. Valid values range from 1 to 9. Higher values use more memory, but are faster and produce smaller output.

**strategy** is used to tune the compression algorithm. Possible values are **Z_DEFAULT_STRATEGY**, **Z_FILTERED**, and **Z_HUFFMAN_ONLY**.

**zdict** is a predefined compression dictionary. This is a sequence of bytes (such as a **bytes** object) containing subsequences that are expected to occur frequently in the data that is to be compressed. Those subsequences that are expected to be most common should come at the end of the dictionary.

*Changed in version 3.3:* Added the **zdict** parameter and keyword argument support.

**zlib**.**crc32**(data[, value])

Computes a CRC (Cyclic Redundancy Check) checksum of **data**. If **value** is present, it is used as the starting value of the checksum; otherwise, a fixed default value is used. This allows computing a running checksum over the concatenation of several inputs. The algorithm is not cryptographically strong, and should not be used for authentication or digital signatures. Since the algorithm is designed for use as a checksum algorithm, it is not suitable for use as a general hash algorithm.

Always returns an unsigned 32-bit integer.
Note: To generate the same numeric value across all Python versions and platforms, use \texttt{crc32(data) & 0xffffffff}. If you are only using the checksum in packed binary format this is not necessary as the return value is the correct 32-bit binary representation regardless of sign.

\texttt{zlib.decompress(data[, wbits[, bufsize]])}

Decompresses the bytes in \texttt{data}, returning a bytes object containing the uncompressed data. The \texttt{wbits} parameter controls the size of the window buffer, and is discussed further below. If \texttt{bufsize} is given, it is used as the initial size of the output buffer. Raises the \texttt{error} exception if any error occurs.

The absolute value of \texttt{wbits} is the base two logarithm of the size of the history buffer (the “window size”) used when compressing data. Its absolute value should be between 8 and 15 for the most recent versions of the zlib library, larger values resulting in better compression at the expense of greater memory usage. When decompressing a stream, \texttt{wbits} must not be smaller than the size originally used to compress the stream; using a too-small value will result in an exception. The default value is therefore the highest value, 15. When \texttt{wbits} is negative, the standard \texttt{gzip} header is suppressed.

\texttt{bufsize} is the initial size of the buffer used to hold decompressed data. If more space is required, the buffer size will be increased as needed, so you don’t have to get this value exactly right; tuning it will only save a few calls to malloc(). The default size is 16384.

\texttt{zlib.decompressobj(wbits=15[, zdict])}

Returns a decompression object, to be used for decompressing
data streams that won’t fit into memory at once.

The \textit{wbits} parameter controls the size of the window buffer.

The \textit{zdict} parameter specifies a predefined compression dictionary. If provided, this must be the same dictionary as was used by the compressor that produced the data that is to be decompressed.

\textbf{Note:} If \textit{zdict} is a mutable object (such as a \texttt{bytearray}), you must not modify its contents between the call to \texttt{decompressobj()} and the first call to the decompressor’s \texttt{decompress()} method.

\textit{Changed in version 3.3: Added the \textit{zdict} parameter.}

Compression objects support the following methods:

\texttt{Compress.compress(data)}

Compress \textit{data}, returning a bytes object containing compressed data for at least part of the data in \textit{data}. This data should be concatenated to the output produced by any preceding calls to the \texttt{compress()} method. Some input may be kept in internal buffers for later processing.

\texttt{Compress.flush([mode])}

All pending input is processed, and a bytes object containing the remaining compressed output is returned. \textit{mode} can be selected from the constants \texttt{Z\_SYNC\_FLUSH}, \texttt{Z\_FULL\_FLUSH}, or \texttt{Z\_FINISH}, defaulting to \texttt{Z\_FINISH}. \texttt{Z\_SYNC\_FLUSH} and \texttt{Z\_FULL\_FLUSH} allow compressing further bytestrings of data, while \texttt{Z\_FINISH} finishes the compressed stream and prevents compressing any more data. After calling \texttt{flush()} with \textit{mode} set
to Z_FINISH, the `compress()` method cannot be called again; the only realistic action is to delete the object.

**Compress.copy()**

Returns a copy of the compression object. This can be used to efficiently compress a set of data that share a common initial prefix.

Decompression objects support the following methods and attributes:

**Decompress.unused_data**

A bytes object which contains any bytes past the end of the compressed data. That is, this remains b"" until the last byte that contains compression data is available. If the whole bytestring turned out to contain compressed data, this is b"", an empty bytes object.

**Decompress.unconsumed_tail**

A bytes object that contains any data that was not consumed by the last `decompress()` call because it exceeded the limit for the uncompressed data buffer. This data has not yet been seen by the zlib machinery, so you must feed it (possibly with further data concatenated to it) back to a subsequent `decompress()` method call in order to get correct output.

**Decompress.eof**

A boolean indicating whether the end of the compressed data stream has been reached.

This makes it possible to distinguish between a properly-formed compressed stream, and an incomplete or truncated one.

*New in version 3.3.*
Decompress.\texttt{decompress}(data[, \textit{max\_length}])

Decompress \textit{data}, returning a bytes object containing the uncompresssed data corresponding to at least part of the data in \textit{string}. This data should be concatenated to the output produced by any preceding calls to the \texttt{decompress()} method. Some of the input data may be preserved in internal buffers for later processing.

If the optional parameter \textit{max\_length} is non-zero then the return value will be no longer than \textit{max\_length}. This may mean that not all of the compressed input can be processed; and unconsumed data will be stored in the attribute \texttt{unconsumed\_tail}. This bytestring must be passed to a subsequent call to \texttt{decompress()} if decompression is to continue. If \textit{max\_length} is not supplied then the whole input is decompressed, and \texttt{unconsumed\_tail} is empty.

Decompress.\texttt{flush}([\textit{length}])

All pending input is processed, and a bytes object containing the remaining uncompressed output is returned. After calling \texttt{flush()}, the \texttt{decompress()} method cannot be called again; the only realistic action is to delete the object.

The optional parameter \textit{length} sets the initial size of the output buffer.

Decompress.\texttt{copy}()

Returns a copy of the decompression object. This can be used to save the state of the decompressor midway through the data stream in order to speed up random seeks into the stream at a future point.

Information about the version of the zlib library in use is available
through the following constants:

**zlib.ZLIB_VERSION**
The version string of the zlib library that was used for building the module. This may be different from the zlib library actually used at runtime, which is available as **ZLIB_RUNTIME_VERSION**.

**zlib.ZLIB_RUNTIME_VERSION**
The version string of the zlib library actually loaded by the interpreter.

*New in version 3.3.*

See also:

**Module gzip**
Reading and writing gzip-format files.

http://www.zlib.net
The zlib library home page.

http://www.zlib.net/manual.html
The zlib manual explains the semantics and usage of the library's many functions.
13.2. **gzip** — Support for **gzip** files

**Source code:** Lib/gzip.py

This module provides a simple interface to compress and decompress files just like the GNU programs **gzip** and **gunzip** would.

The data compression is provided by the **zlib** module.

The **gzip** module provides the **GzipFile** class, as well as the **open()**, **compress()** and **decompress()** convenience functions. The **GzipFile** class reads and writes **gzip**-format files, automatically compressing or decompressing the data so that it looks like an ordinary file object.

Note that additional file formats which can be decompressed by the **gzip** and **gunzip** programs, such as those produced by **compress** and **pack**, are not supported by this module.

The module defines the following items:

```python
gzip.open(filename, mode='rb', compresslevel=9, encoding=None, errors=None, newline=None)
```

Open a gzip-compressed file in binary or text mode, returning a file object.

The **filename** argument can be an actual filename (a **str** or **bytes** object), or an existing file object to read from or write to.

The **mode** argument can be any of 'r', 'rb', 'a', 'ab', 'w',

```bash
gzip -V
```

```
gzip 1.11  Copyright (C) 1996-2020 Free Software Foundation, Inc.
      This is free software; see the source for copying conditions.  There is
      NO warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR
```
'wb', 'x' or 'xb' for binary mode, or 'rt', 'at', 'wt', or 'xt' for text mode. The default is 'rb'.

The `compresslevel` argument is an integer from 0 to 9, as for the `GzipFile` constructor.

For binary mode, this function is equivalent to the `GzipFile` constructor: `GzipFile(filename, mode, compresslevel)`. In this case, the `encoding`, `errors` and `newline` arguments must not be provided.

For text mode, a `GzipFile` object is created, and wrapped in an `io.TextIOWrapper` instance with the specified encoding, error handling behavior, and line ending(s).

*Changed in version 3.3:* Added support for `filename` being a file object, support for text mode, and the `encoding`, `errors` and `newline` arguments.

*Changed in version 3.4:* Added support for the 'x', 'xb' and 'xt' modes.

```python
class gzip.GzipFile(filename=None, mode=None, compresslevel=9, fileobj=None, mtime=None)

Constructor for the `GzipFile` class, which simulates most of the methods of a `file object`, with the exception of the `truncate()` method. At least one of `fileobj` and `filename` must be given a non-trivial value.

The new class instance is based on `fileobj`, which can be a regular file, an `io.BytesIO` object, or any other object which simulates a file. It defaults to None, in which case `filename` is opened to provide a file object.
When `fileobj` is not None, the `filename` argument is only used to be included in the `gzip` file header, which may include the original filename of the uncompressed file. It defaults to the filename of `fileobj`, if discernible; otherwise, it defaults to the empty string, and in this case the original filename is not included in the header.

The `mode` argument can be any of `'r'`, `'rb'`, `'a'`, `'ab'`, `'w'`, `'wb'`, `'x'`, or `'xb'`, depending on whether the file will be read or written. The default is the mode of `fileobj` if discernible; otherwise, the default is `'rb'`.

Note that the file is always opened in binary mode. To open a compressed file in text mode, use `open()` (or wrap your `GzipFile` with an `io.TextIOWrapper`).

The `compresslevel` argument is an integer from 0 to 9 controlling the level of compression; 1 is fastest and produces the least compression, and 9 is slowest and produces the most compression. 0 is no compression. The default is 9.

The `mtime` argument is an optional numeric timestamp to be written to the last modification time field in the stream when compressing. It should only be provided in compression mode. If omitted or None, the current time is used. See the `mtime` attribute for more details.

Calling a `GzipFile` object's `close()` method does not close `fileobj`, since you might wish to append more material after the compressed data. This also allows you to pass an `io.BytesIO` object opened for writing as `fileobj`, and retrieve the resulting memory buffer using the `io.BytesIO` object's `getvalue()` method.
**GzipFile** supports the *io.BufferedIOBase* interface, including iteration and the *with* statement. Only the *truncate()* method isn't implemented.

**GzipFile** also provides the following method and attribute:

**peek(n)**
Read *n* uncompressed bytes without advancing the file position. At most one single read on the compressed stream is done to satisfy the call. The number of bytes returned may be more or less than requested.

**Note:** While calling *peek()* does not change the file position of the **GzipFile**, it may change the position of the underlying file object (e.g. if the **GzipFile** was constructed with the *fileobj* parameter).

*New in version 3.2.*

**mtime**
When decompressing, the value of the last modification time field in the most recently read header may be read from this attribute, as an integer. The initial value before reading any headers is *None*.

All **gzip** compressed streams are required to contain this timestamp field. Some programs, such as **gunzip**, make use of the timestamp. The format is the same as the return value of *time.time()* and the *st_mtime* attribute of the object returned by *os.stat()*.

*Changed in version 3.1:* Support for the *with* statement was
added, along with the *mtime* constructor argument and *mtime* attribute.

*Changed in version 3.2:* Support for zero-padded and unseekable files was added.

*Changed in version 3.3:* The `io.BufferedIOBase.read1()` method is now implemented.

*Changed in version 3.4:* Added support for the 'x' and 'xb' modes.

*Changed in version 3.5:* Added support for writing arbitrary bytes-like objects. The `read()` method now accepts an argument of None.

gzip.**compress**(data, compresslevel=9)

Compress the data, returning a bytes object containing the compressed data. *compresslevel* has the same meaning as in the `GzipFile` constructor above.

*New in version 3.2.*

gzip.**decompress**(data)

Decompress the data, returning a bytes object containing the uncompressed data.

*New in version 3.2.*
13.2.1. Examples of usage

Example of how to read a compressed file:

```python
import gzip
with gzip.open('/home/joe/file.txt.gz', 'rb') as f:
    file_content = f.read()
```

Example of how to create a compressed GZIP file:

```python
import gzip
content = b"Lots of content here"
with gzip.open('/home/joe/file.txt.gz', 'wb') as f:
    f.write(content)
```

Example of how to GZIP compress an existing file:

```python
import gzip
import shutil
with open('/home/joe/file.txt', 'rb') as f_in:
    with gzip.open('/home/joe/file.txt.gz', 'wb') as f_out:
        shutil.copyfileobj(f_in, f_out)
```

Example of how to GZIP compress a binary string:

```python
import gzip
s_in = b"Lots of content here"
s_out = gzip.compress(s_in)
```

See also:

**Module zlib**

The basic data compression module needed to support the `gzip`
file format.
13.3. bz2 — Support for bzip2 compression

This module provides a comprehensive interface for compressing and decompressing data using the bzip2 compression algorithm.

The bz2 module contains:

- The open() function and BZ2File class for reading and writing compressed files.
- The BZ2Compressor and BZ2Decompressor classes for incremental (de)compression.
- The compress() and decompress() functions for one-shot (de)compression.

All of the classes in this module may safely be accessed from multiple threads.
13.3.1. (De)compression of files

bz2. open(filename, mode='r', compresslevel=9, encoding=None, errors=None, newline=None)

Open a bzip2-compressed file in binary or text mode, returning a file object.

As with the constructor for BZ2File, the filename argument can be an actual filename (a str or bytes object), or an existing file object to read from or write to.

The mode argument can be any of 'r', 'rb', 'w', 'wb', 'x', 'xb', 'a' or 'ab' for binary mode, or 'rt', 'wt', 'xt', or 'at' for text mode. The default is 'rb'.

The compresslevel argument is an integer from 1 to 9, as for the BZ2File constructor.

For binary mode, this function is equivalent to the BZ2File constructor: BZ2File(filename, mode, compresslevel=compresslevel). In this case, the encoding, errors and newline arguments must not be provided.

For text mode, a BZ2File object is created, and wrapped in an io.TextIOWrapper instance with the specified encoding, error handling behavior, and line ending(s).

New in version 3.3.

Changed in version 3.4: The 'x' (exclusive creation) mode was added.
class bz2.BZ2File(filename, mode='r', buffering=None, compresslevel=9)

Open a bzip2-compressed file in binary mode.

If filename is a str or bytes object, open the named file directly. Otherwise, filename should be a file object, which will be used to read or write the compressed data.

The mode argument can be either 'r' for reading (default), 'w' for overwriting, 'x' for exclusive creation, or 'a' for appending. These can equivalently be given as 'rb', 'wb', 'xb' and 'ab' respectively.

If filename is a file object (rather than an actual file name), a mode of 'w' does not truncate the file, and is instead equivalent to 'a'.

The buffering argument is ignored. Its use is deprecated.

If mode is 'w' or 'a', compresslevel can be a number between 1 and 9 specifying the level of compression: 1 produces the least compression, and 9 (default) produces the most compression.

If mode is 'r', the input file may be the concatenation of multiple compressed streams.

BZ2File provides all of the members specified by the io.BufferedIOBase, except for detach() and truncate(). Iteration and the with statement are supported.

BZ2File also provides the following method:

peek([n])

Return buffered data without advancing the file position. At least
one byte of data will be returned (unless at EOF). The exact number of bytes returned is unspecified.

**Note:** While calling `peek()` does not change the file position of the `BZ2File`, it may change the position of the underlying file object (e.g. if the `BZ2File` was constructed by passing a file object for `filename`).

*New in version 3.3.*

*Changed in version 3.1:* Support for the `with` statement was added.

*Changed in version 3.3:* The `fileno()`, `readable()`, `seekable()`, `writable()`, `read1()` and `readinto()` methods were added.

*Changed in version 3.3:* Support was added for `filename` being a `file object` instead of an actual filename.

*Changed in version 3.3:* The 'a' (append) mode was added, along with support for reading multi-stream files.

*Changed in version 3.4:* The 'x' (exclusive creation) mode was added.

*Changed in version 3.5:* The `read()` method now accepts an argument of `None`. 
13.3.2. Incremental (de)compression

class bz2.BZ2Compressor(compresslevel=9)
    Create a new compressor object. This object may be used to compress data incrementally. For one-shot compression, use the \texttt{compress()} function instead.

    \textit{compresslevel}, if given, must be a number between 1 and 9. The default is 9.

\textbf{compress(\textit{data})}
    Provide data to the compressor object. Returns a chunk of compressed data if possible, or an empty byte string otherwise.

    When you have finished providing data to the compressor, call the \texttt{flush()} method to finish the compression process.

\textbf{flush()}
    Finish the compression process. Returns the compressed data left in internal buffers.

    The compressor object may not be used after this method has been called.

class bz2.BZ2Decompressor
    Create a new decompressor object. This object may be used to decompress data incrementally. For one-shot compression, use the \texttt{decompress()} function instead.

\textbf{Note:} This class does not transparently handle inputs containing multiple compressed streams, unlike \texttt{decompress()} and \texttt{BZ2File}. If you need to decompress a multi-stream input with
**BZ2Decompressor**, you must use a new decompressor for each stream.

**decompress**(data, max_length=-1)

Decompress data (a bytes-like object), returning uncompressed data as bytes. Some of data may be buffered internally, for use in later calls to decompress(). The returned data should be concatenated with the output of any previous calls to decompress().

If max_length is nonnegative, returns at most max_length bytes of decompressed data. If this limit is reached and further output can be produced, the needs_input attribute will be set to False. In this case, the next call to decompress() may provide data as b'' to obtain more of the output.

If all of the input data was decompressed and returned (either because this was less than max_length bytes, or because max_length was negative), the needs_input attribute will be set to True.

Attempting to decompress data after the end of stream is reached raises an EOFError. Any data found after the end of the stream is ignored and saved in the unused_data attribute.

*Changed in version 3.5:* Added the max_length parameter.

**eof**

True if the end-of-stream marker has been reached.

*New in version 3.3.*

**unused_data**
Data found after the end of the compressed stream.

If this attribute is accessed before the end of the stream has been reached, its value will be b''.

**needs_input**
False if the `decompress()` method can provide more decompressed data before requiring new uncompressed input.

*New in version 3.5.*
13.3.3. One-shot (de)compression

bz2.**compress**(data, compresslevel=9)

Compress *data*.

`compresslevel`, if given, must be a number between 1 and 9. The default is 9.

For incremental compression, use a **BZ2Compressor** instead.

bz2.**decompress**(data)

Decompress *data*.

If *data* is the concatenation of multiple compressed streams, decompress all of the streams.

For incremental decompression, use a **BZ2Decompressor** instead.

*Changed in version 3.3:* Support for multi-stream inputs was added.
13.4. **lzma** — Compression using the LZMA algorithm

New in version 3.3.

This module provides classes and convenience functions for compressing and decompressing data using the LZMA compression algorithm. Also included is a file interface supporting the .xz and legacy .lzma file formats used by the `xz` utility, as well as raw compressed streams.

The interface provided by this module is very similar to that of the `bz2` module. However, note that `LZMAFile` is not thread-safe, unlike `bz2.BZ2File`, so if you need to use a single `LZMAFile` instance from multiple threads, it is necessary to protect it with a lock.

*exception* `lzma.LZMAError`

This exception is raised when an error occurs during compression or decompression, or while initializing the compressor/decompressor state.
13.4.1. Reading and writing compressed files

```
lzma.open(filename, mode="rb", *, format=None, check=-1, preset=None, filters=None, encoding=None, errors=None, newline=None)
```

Open an LZMA-compressed file in binary or text mode, returning a file object.

The `filename` argument can be either an actual file name (given as a `str` or `bytes` object), in which case the named file is opened, or it can be an existing file object to read from or write to.

The `mode` argument can be any of "r", "rb", "w", "wb", "x", "xb", "a" or "ab" for binary mode, or "rt", "wt", "xt", or "at" for text mode. The default is "rb".

When opening a file for reading, the `format` and `filters` arguments have the same meanings as for `LZMADecompressor`. In this case, the `check` and `preset` arguments should not be used.

When opening a file for writing, the `format`, `check`, `preset` and `filters` arguments have the same meanings as for `LZMACompressor`.

For binary mode, this function is equivalent to the `LZMAFile` constructor: LZMAFile(filename, mode, ...). In this case, the `encoding`, `errors` and `newline` arguments must not be provided.

For text mode, a `LZMAFile` object is created, and wrapped in an `io.TextIOWrapper` instance with the specified encoding, error handling behavior, and line ending(s).
Changed in version 3.4: Added support for the "x", "xb" and "xt" modes.

```python
class lzma.LZMAFile(filename=None, mode="r", *, format=None, check=-1, preset=None, filters=None)
```

Open an LZMA-compressed file in binary mode.

An `LZMAFile` can wrap an already-open file object, or operate directly on a named file. The `filename` argument specifies either the file object to wrap, or the name of the file to open (as a `str` or `bytes` object). When wrapping an existing file object, the wrapped file will not be closed when the `LZMAFile` is closed.

The `mode` argument can be either "r" for reading (default), "w" for overwriting, "x" for exclusive creation, or "a" for appending. These can equivalently be given as "rb", "wb", "xb" and "ab" respectively.

If `filename` is a file object (rather than an actual file name), a mode of "w" does not truncate the file, and is instead equivalent to "a".

When opening a file for reading, the input file may be the concatenation of multiple separate compressed streams. These are transparently decoded as a single logical stream.

When opening a file for reading, the `format` and `filters` arguments have the same meanings as for `LZMAFile`. In this case, the `check` and `preset` arguments should not be used.

When opening a file for writing, the `format`, `check`, `preset` and `filters` arguments have the same meanings as for `LZMAFile`. `LZMAFile` supports all the members specified by
**io.BufferedIOBase**, except for `detach()` and `truncate()`. Iteration and the `with` statement are supported.

The following method is also provided:

**`peek(size=-1)`**

Return buffered data without advancing the file position. At least one byte of data will be returned, unless EOF has been reached. The exact number of bytes returned is unspecified (the `size` argument is ignored).

**Note:** While calling `peek()` does not change the file position of the `LZMAFile`, it may change the position of the underlying file object (e.g. if the `LZMAFile` was constructed by passing a file object for `filename`).

*Changed in version 3.4:* Added support for the "x" and "xb" modes.

*Changed in version 3.5:* The `read()` method now accepts an argument of None.
13.4.2. Compressing and decompressing data in memory

```python
class lzma.LZMACompressor(format=FORMAT_XZ, check=-1, preset=None, filters=None)
```

Create a compressor object, which can be used to compress data incrementally.

For a more convenient way of compressing a single chunk of data, see `compress()`.

The `format` argument specifies what container format should be used. Possible values are:

- **FORMAT_XZ**: The `.xz` container format. This is the default format.
- **FORMAT_ALONE**: The legacy `.lzma` container format. This format is more limited than `.xz` – it does not support integrity checks or multiple filters.
- **FORMAT_RAW**: A raw data stream, not using any container format. This format specifier does not support integrity checks, and requires that you always specify a custom filter chain (for both compression and decompression). Additionally, data compressed in this manner cannot be decompressed using `FORMAT_AUTO` (see `LZMADecompressor`).

The `check` argument specifies the type of integrity check to include in the compressed data. This check is used when decompressing, to ensure that the data has not been corrupted. Possible values
are:

- **CHECK_NONE**: No integrity check. This is the default (and the only acceptable value) for FORMAT_ALONE and FORMAT_RAW.
- **CHECK_CRC32**: 32-bit Cyclic Redundancy Check.
- **CHECK_CRC64**: 64-bit Cyclic Redundancy Check. This is the default for FORMAT_XZ.
- **CHECK_SHA256**: 256-bit Secure Hash Algorithm.

If the specified check is not supported, an `LZMAError` is raised.

The compression settings can be specified either as a preset compression level (with the `preset` argument), or in detail as a custom filter chain (with the `filters` argument).

The `preset` argument (if provided) should be an integer between 0 and 9 (inclusive), optionally OR-ed with the constant `PRESET_EXTREME`. If neither `preset` nor `filters` are given, the default behavior is to use `PRESET_DEFAULT` (preset level 6). Higher presets produce smaller output, but make the compression process slower.

**Note:** In addition to being more CPU-intensive, compression with higher presets also requires much more memory (and produces output that needs more memory to decompress). With preset 9 for example, the overhead for an `LZMACompressor` object can be as high as 800 MiB. For this reason, it is generally best to stick with the default preset.

The `filters` argument (if provided) should be a filter chain specifier. See [Specifying custom filter chains](#) for details.

`compress(data)`
Compress *data* (a *bytes* object), returning a *bytes* object containing compressed data for at least part of the input. Some of *data* may be buffered internally, for use in later calls to `compress()` and `flush()`. The returned data should be concatenated with the output of any previous calls to `compress()`.

### flush()
Finish the compression process, returning a *bytes* object containing any data stored in the compressor’s internal buffers.

The compressor cannot be used after this method has been called.

```python
class lzma.LZMADecompressor(format=FORMAT_AUTO, memlimit=None, filters=None)

Create a decompressor object, which can be used to decompress data incrementally.

For a more convenient way of decompressing an entire compressed stream at once, see `decompress()`.

The *format* argument specifies the container format that should be used. The default is FORMAT_AUTO, which can decompress both `.xz` and `.lzma` files. Other possible values are FORMAT_XZ, FORMAT_ALONE, and FORMAT_RAW.

The *memlimit* argument specifies a limit (in bytes) on the amount of memory that the decompressor can use. When this argument is used, decompression will fail with an `LZMAError` if it is not possible to decompress the input within the given memory limit.

The *filters* argument specifies the filter chain that was used to
create the stream being decompressed. This argument is required if `format` is `FORMAT_RAW`, but should not be used for other formats. See Specifying custom filter chains for more information about filter chains.

**Note:** This class does not transparently handle inputs containing multiple compressed streams, unlike `decompress()` and `LZMAFile`. To decompress a multi-stream input with `LZMADecompressor`, you must create a new decompressor for each stream.

decompress(data, max_length=-1)

Decompress `data` (a bytes-like object), returning uncompressed data as bytes. Some of `data` may be buffered internally, for use in later calls to `decompress()`. The returned data should be concatenated with the output of any previous calls to `decompress()`.

If `max_length` is nonnegative, returns at most `max_length` bytes of decompressed data. If this limit is reached and further output can be produced, the `needs_input` attribute will be set to False. In this case, the next call to `decompress()` may provide `data` as b'' to obtain more of the output.

If all of the input data was decompressed and returned (either because this was less than `max_length` bytes, or because `max_length` was negative), the `needs_input` attribute will be set to True.

Attempting to decompress data after the end of stream is reached raises an `EOFError`. Any data found after the end of the stream is ignored and saved in the `unused_data` attribute.
Changed in version 3.5: Added the `max_length` parameter.

**check**

The ID of the integrity check used by the input stream. This may be `CHECK_UNKNOWN` until enough of the input has been decoded to determine what integrity check it uses.

**eof**

True if the end-of-stream marker has been reached.

**unused_data**

Data found after the end of the compressed stream.

Before the end of the stream is reached, this will be `b""`.

**needs_input**

False if the `decompress()` method can provide more decompressed data before requiring new uncompressed input.

New in version 3.5.

```python
lzma.compress(data, format=FORMAT_XZ, check=-1, preset=None, filters=None)
```

Compress `data` (a `bytes` object), returning the compressed data as a `bytes` object.

See `LZMACompressor` above for a description of the `format`, `check`, `preset` and `filters` arguments.

```python
lzma.decompress(data, format=FORMAT_AUTO, memlimit=None, filters=None)
```

Decompress `data` (a `bytes` object), returning the uncompressed data as a `bytes` object.
If data is the concatenation of multiple distinct compressed streams, decompress all of these streams, and return the concatenation of the results.

See LZMADecompressor above for a description of the format, memlimit and filters arguments.
13.4.3. Miscellaneous

```python
lzma.is_check_supported(check)
```

Returns true if the given integrity check is supported on this system.

CHECK_NONE and CHECK_CRC32 are always supported. CHECK_CRC64 and CHECK_SHA256 may be unavailable if you are using a version of liblzma that was compiled with a limited feature set.
13.4.4. Specifying custom filter chains

A filter chain specifier is a sequence of dictionaries, where each dictionary contains the ID and options for a single filter. Each dictionary must contain the key "id", and may contain additional keys to specify filter-dependent options. Valid filter IDs are as follows:

- Compression filters:
  - FILTER_LZMA1 (for use with FORMAT_ALONE)
  - FILTER_LZMA2 (for use with FORMAT_XZ and FORMAT_RAW)

- Delta filter:
  - FILTER_DELTA

- Branch-Call-Jump (BCJ) filters:
  - FILTER_X86
  - FILTER_IA64
  - FILTER_ARM
  - FILTER_ARMTHUMB
  - FILTER_POWERPC
  - FILTER_SPARC

A filter chain can consist of up to 4 filters, and cannot be empty. The last filter in the chain must be a compression filter, and any other filters must be delta or BCJ filters.

Compression filters support the following options (specified as additional entries in the dictionary representing the filter):

- preset: A compression preset to use as a source of default values for options that are not specified explicitly.
- dict_size: Dictionary size in bytes. This should be between
4 KiB and 1.5 GiB (inclusive).

- lc: Number of literal context bits.
- lp: Number of literal position bits. The sum lc + lp must be at most 4.
- pb: Number of position bits; must be at most 4.
- mode: MODE_FAST or MODE_NORMAL.
- nice_len: What should be considered a “nice length” for a match. This should be 273 or less.
- depth: Maximum search depth used by match finder. 0 (default) means to select automatically based on other filter options.

The delta filter stores the differences between bytes, producing more repetitive input for the compressor in certain circumstances. It only supports a single The delta filter supports only one option, dist. This indicates the distance between bytes to be subtracted. The default is 1, i.e. take the differences between adjacent bytes.

The BCJ filters are intended to be applied to machine code. They convert relative branches, calls and jumps in the code to use absolute addressing, with the aim of increasing the redundancy that can be exploited by the compressor. These filters support one option, start_offset. This specifies the address that should be mapped to the beginning of the input data. The default is 0.
13.4.5. Examples

Reading in a compressed file:

```python
import lzma
with lzma.open("file.xz") as f:
    file_content = f.read()
```

Creating a compressed file:

```python
import lzma
data = b"Insert Data Here"
with lzma.open("file.xz", "w") as f:
    f.write(data)
```

Compressing data in memory:

```python
import lzma
data_in = b"Insert Data Here"
data_out = lzma.compress(data_in)
```

Incremental compression:

```python
import lzma
lzc = lzma.LZMACompressor()
out1 = lzc.compress(b"Some data\n")
out2 = lzc.compress(b"Another piece of data\n")
out3 = lzc.compress(b"Even more data\n")
out4 = lzc.flush()
# Concatenate all the partial results:
result = b"".join([out1, out2, out3, out4])
```

Writing compressed data to an already-open file:
import lzma
with open("file.xz", "wb") as f:
    f.write(b"This data will not be compressed\n")
    with lzma.open(f, "w") as lzf:
        lzf.write(b"This *will* be compressed\n")
    f.write(b"Not compressed\n")

Creating a compressed file using a custom filter chain:

import lzma
my_filters = [
    {"id": lzma.FILTER_DELTA, "dist": 5},
    {"id": lzma.FILTER_LZMA2, "preset": 7 | lzma.PRESET_EXTREME}
]
with lzma.open("file.xz", "w", filters=my_filters) as f:
    f.write(b"blah blah blah")
13.5. zipfile — Work with ZIP archives

Source code: Lib/zipfile.py

The ZIP file format is a common archive and compression standard. This module provides tools to create, read, write, append, and list a ZIP file. Any advanced use of this module will require an understanding of the format, as defined in PKZIP Application Note.

This module does not currently handle multi-disk ZIP files. It can handle ZIP files that use the ZIP64 extensions (that is ZIP files that are more than 4 GiB in size). It supports decryption of encrypted files in ZIP archives, but it currently cannot create an encrypted file. Decryption is extremely slow as it is implemented in native Python rather than C.

The module defines the following items:

exception zipfile.BadZipFile
The error raised for bad ZIP files.

   New in version 3.2.

exception zipfile.BadZipfile
Alias of BadZipFile, for compatibility with older Python versions.

   Deprecated since version 3.2.

exception zipfile.LargeZipFile
The error raised when a ZIP file would require ZIP64 functionality
but that has not been enabled.

**class zipfile.ZipFile**

The class for reading and writing ZIP files. See section [ZipFile Objects](#) for constructor details.

**class zipfile.PyZipFile**

Class for creating ZIP archives containing Python libraries.

**class zipfile.ZipInfo(filename='NoName', date_time=(1980, 1, 1, 0, 0, 0))**

Class used to represent information about a member of an archive. Instances of this class are returned by the `getinfo()` and `infolist()` methods of `ZipFile` objects. Most users of the zipfile module will not need to create these, but only use those created by this module. `filename` should be the full name of the archive member, and `date_time` should be a tuple containing six fields which describe the time of the last modification to the file; the fields are described in section [ZipInfo Objects](#).

**zipfile.is_zipfile(filename)**

Returns True if `filename` is a valid ZIP file based on its magic number, otherwise returns False. `filename` may be a file or file-like object too.

*Changed in version 3.1:* Support for file and file-like objects.

**zipfile.ZIP_STORED**

The numeric constant for an uncompressed archive member.

**zipfile.ZIP_DEFLATED**

The numeric constant for the usual ZIP compression method. This requires the zlib module.
zipfile.ZIP_BZIP2
The numeric constant for the BZIP2 compression method. This requires the bz2 module.

New in version 3.3.

zipfile.ZIP_LZMA
The numeric constant for the LZMA compression method. This requires the lzma module.

New in version 3.3.

Note: The ZIP file format specification has included support for bzip2 compression since 2001, and for LZMA compression since 2006. However, some tools (including older Python releases) do not support these compression methods, and may either refuse to process the ZIP file altogether, or fail to extract individual files.

See also:

PKZIP Application Note
Documentation on the ZIP file format by Phil Katz, the creator of the format and algorithms used.

Info-ZIP Home Page
Information about the Info-ZIP project's ZIP archive programs and development libraries.
13.5.1. ZipFile Objects

```python
class zipfile.ZipFile(file, mode='r',
                      compression=ZIP_STORED, allowZip64=True)
```

Open a ZIP file, where `file` can be either a path to a file (a string) or a file-like object. The `mode` parameter should be 'r' to read an existing file, 'w' to truncate and write a new file, 'x' to exclusive create and write a new file, or 'a' to append to an existing file. If `mode` is 'x' and `file` refers to an existing file, a `FileExistsError` will be raised. If `mode` is 'a' and `file` refers to an existing ZIP file, then additional files are added to it. If `file` does not refer to a ZIP file, then a new ZIP archive is appended to the file. This is meant for adding a ZIP archive to another file (such as `python.exe`). If `mode` is a and the file does not exist at all, it is created. If `mode` is r or a, the file should be seekable. `compression` is the ZIP compression method to use when writing the archive, and should be `ZIP_STORED`, `ZIP_DEFLATED`, `ZIP_BZIP2` or `ZIP_LZMA`; unrecognized values will cause `RuntimeError` to be raised. If `ZIP_DEFLATED`, `ZIP_BZIP2` or `ZIP_LZMA` is specified but the corresponding module (`zlib`, `bz2` or `lzma`) is not available, `RuntimeError` is also raised. The default is `ZIP_STORED`. If `allowZip64` is True (the default) zipfile will create ZIP files that use the ZIP64 extensions when the zipfile is larger than 2 GiB. If it is false `zipfile` will raise an exception when the ZIP file would require ZIP64 extensions.

If the file is created with mode 'w', 'x' or 'a' and then `closed` without adding any files to the archive, the appropriate ZIP structures for an empty archive will be written to the file.
ZipFile is also a context manager and therefore supports the `with` statement. In the example, `myzip` is closed after the `with` statement’s suite is finished—even if an exception occurs:

```python
with ZipFile('spam.zip', 'w') as myzip:
    myzip.write('eggs.txt')
```

*New in version 3.2:* Added the ability to use `ZipFile` as a context manager.

*Changed in version 3.3:* Added support for `bzip2` and `lzma` compression.

*Changed in version 3.4:* ZIP64 extensions are enabled by default.

*Changed in version 3.5:* Added support for writing to unseekable streams. Added support for the 'x' mode.

`ZipFile.close()`

Close the archive file. You must call `close()` before exiting your program or essential records will not be written.

`ZipFile.getinfo(name)`

Return a `ZipInfo` object with information about the archive member `name`. Calling `getinfo()` for a name not currently contained in the archive will raise a `KeyError`.

`ZipFile.infolist()`

Return a list containing a `ZipInfo` object for each member of the archive. The objects are in the same order as their entries in the actual ZIP file on disk if an existing archive was opened.

`ZipFile.namelist()`
Return a list of archive members by name.

**ZipFile.open(name, mode='r', pwd=None)**

Extract a member from the archive as a file-like object (ZipExtFile). `name` is the name of the file in the archive, or a `ZipInfo` object. The `mode` parameter, if included, must be one of the following: 'r' (the default), 'U', or 'rU'. Choosing 'U' or 'rU' will enable universal newlines support in the read-only object. `pwd` is the password used for encrypted files. Calling `open()` on a closed ZipFile will raise a `RuntimeError`.

`open()` is also a context manager and therefore supports the `with` statement:

```python
with ZipFile('spam.zip') as myzip:
    with myzip.open('eggs.txt') as myfile:
        print(myfile.read())
```

**Note:** The file-like object is read-only and provides the following methods: `read()`, `readline()`, `readlines()`, `__iter__()`, `__next__()`.  

**Note:** Objects returned by `open()` can operate independently of the ZipFile. 

**Note:** The `open()`, `read()` and `extract()` methods can take a filename or a `ZipInfo` object. You will appreciate this when trying to read a ZIP file that contains members with duplicate names.

*Deprecated since version 3.4, will be removed in version 3.6:* The 'U' or 'rU' mode. Use `io.TextIOWrapper` for reading.
compressed text files in **universal newlines** mode.

**ZipFile.extract(member, path=None, pwd=None)**

Extract a member from the archive to the current working directory; *member* must be its full name or a *ZipInfo* object. Its file information is extracted as accurately as possible. *path* specifies a different directory to extract to. *member* can be a filename or a *ZipInfo* object. *pwd* is the password used for encrypted files.

Returns the normalized path created (a directory or new file).

---

**Note:** If a member filename is an absolute path, a drive/UNC sharepoint and leading (back)slashes will be stripped, e.g.: ///foo/bar becomes foo/bar on Unix, and C:\foo\bar becomes foo\bar on Windows. And all ".." components in a member filename will be removed, e.g.: ../../foo../../ba..r becomes foo../ba..r. On Windows illegal characters (:\,<,>,|,"?, and *) replaced by underscore (_).

**ZipFile.extractall(path=None, members=None, pwd=None)**

Extract all members from the archive to the current working directory. *path* specifies a different directory to extract to. *members* is optional and must be a subset of the list returned by namelist(). *pwd* is the password used for encrypted files.

---

**Warning:** Never extract archives from untrusted sources without prior inspection. It is possible that files are created outside of *path*, e.g. members that have absolute filenames starting with "/" or filenames with two dots ".". This module attempts to prevent that. See extract() note.
ZipFile.printdir()

Print a table of contents for the archive to sys.stdout.

ZipFile.setpassword(pwd)

Set pwd as default password to extract encrypted files.

ZipFile.read(name, pwd=None)

Return the bytes of the file name in the archive. name is the name of the file in the archive, or a ZipInfo object. The archive must be open for read or append. pwd is the password used for encrypted files and, if specified, it will override the default password set with setpassword(). Calling read() on a closed ZipFile will raise a RuntimeError. Calling read() on a ZipFile that uses a compression method other than ZIP_STORED, ZIP_DEFLATED, ZIP_BZIP2 or ZIP_LZMA will raise a NotImplementedError. An error will also be raised if the corresponding compression module is not available.

ZipFile.testzip()

Read all the files in the archive and check their CRC’s and file headers. Return the name of the first bad file, or else return None. Calling testzip() on a closed ZipFile will raise a RuntimeError.

ZipFile.write(filename, arcname=None, compress_type=None)

Write the file named filename to the archive, giving it the archive name arcname (by default, this will be the same as filename, but without a drive letter and with leading path separators removed). If given, compress_type overrides the value given for the compression parameter to the constructor for the new entry. The archive must be open with mode 'w', 'x' or 'a' – calling
write() on a ZipFile created with mode 'r' will raise a RuntimeError. Calling write() on a closed ZipFile will raise a RuntimeError.

**Note:** There is no official file name encoding for ZIP files. If you have unicode file names, you must convert them to byte strings in your desired encoding before passing them to write(). WinZip interprets all file names as encoded in CP437, also known as DOS Latin.

**Note:** Archive names should be relative to the archive root, that is, they should not start with a path separator.

**Note:** If arcname (or filename, if arcname is not given) contains a null byte, the name of the file in the archive will be truncated at the null byte.

```python
ZipFile.writestr(zinfo_or_arcname, bytes[, compress_type])
```
Write the string bytes to the archive; zinfo_or_arcname is either the file name it will be given in the archive, or a ZipInfo instance. If it's an instance, at least the filename, date, and time must be given. If it's a name, the date and time is set to the current date and time. The archive must be opened with mode 'w', 'x' or 'a' – calling writestr() on a ZipFile created with mode 'r' will raise a RuntimeError. Calling writestr() on a closed ZipFile will raise a RuntimeError.

If given, compress_type overrides the value given for the compression parameter to the constructor for the new entry, or in the zinfo_or_arcname (if that is a ZipInfo instance).
Note: When passing a `ZipInfo` instance as the `zinfo_or_arcname` parameter, the compression method used will be that specified in the `compress_type` member of the given `ZipInfo` instance. By default, the `ZipInfo` constructor sets this member to `ZIP_STORED`.

*Changed in version 3.2:* The `compress_type` argument.

The following data attributes are also available:

**ZipFile.** `debug`

   The level of debug output to use. This may be set from 0 (the default, no output) to 3 (the most output). Debugging information is written to `sys.stdout`.

**ZipFile.** `comment`

   The comment text associated with the ZIP file. If assigning a comment to a `ZipFile` instance created with mode 'w', 'x' or 'a', this should be a string no longer than 65535 bytes. Comments longer than this will be truncated in the written archive when `close()` is called.
13.5.2. PyZipFile Objects

The PyZipFile constructor takes the same parameters as the ZipFile constructor, and one additional parameter, optimize.

```python
class zipfile.PyZipFile(file, mode='r',
compression=ZIP_STORED, allowZip64=True, optimize=-1)

New in version 3.2: The optimize parameter.

Changed in version 3.4: ZIP64 extensions are enabled by default.
```

Instances have one method in addition to those of ZipFile objects:

```python
writepy(pathname, basename='', filterfunc=None)
```

Search for files *.py and add the corresponding file to the archive.

If the optimize parameter to PyZipFile was not given or -1, the corresponding file is a *.pyc file, compiling if necessary.

If the optimize parameter to PyZipFile was 0, 1 or 2, only files with that optimization level (see compile()) are added to the archive, compiling if necessary.

If pathname is a file, the filename must end with .py, and just the (corresponding *.py[co]) file is added at the top level (no path information). If pathname is a file that does not end with .py, a RuntimeError will be raised. If it is a directory, and the directory is not a package directory, then all the files *.py[co] are added at the top level. If the directory is a package directory, then all *.py[co] are added under the package
name as a file path, and if any subdirectories are package directories, all of these are added recursively.

`basename` is intended for internal use only.

`filterfunc`, if given, must be a function taking a single string argument. It will be passed each path (including each individual full file path) before it is added to the archive. If `filterfunc` returns a false value, the path will not be added, and if it is a directory its contents will be ignored. For example, if our test files are all either in test directories or start with the string `test_`, we can use a `filterfunc` to exclude them:

```python
>>> zf = PyZipFile('myprog.zip')
>>> def notests(s):
...     fn = os.path.basename(s)
...     return (not (fn == 'test' or fn.startswith('test_')))
>>> zf.writepy('myprog', filterfunc=notests)
```

The `writepy()` method makes archives with file names like this:

```
string.pyc          # Top level name
test/__init__.pyc  # Package directory
test/testall.pyc   # Module test.test
```

New in version 3.4: The `filterfunc` parameter.
13.5.3. ZipInfo Objects

Instances of the `ZipInfo` class are returned by the `getinfo()` and `infolist()` methods of `ZipFile` objects. Each object stores information about a single member of the ZIP archive.

Instances have the following attributes:

**ZipInfo.filename**
Name of the file in the archive.

**ZipInfo.date_time**
The time and date of the last modification to the archive member. This is a tuple of six values:

<table>
<thead>
<tr>
<th>Index</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Year (&gt;= 1980)</td>
</tr>
<tr>
<td>1</td>
<td>Month (one-based)</td>
</tr>
<tr>
<td>2</td>
<td>Day of month (one-based)</td>
</tr>
<tr>
<td>3</td>
<td>Hours (zero-based)</td>
</tr>
<tr>
<td>4</td>
<td>Minutes (zero-based)</td>
</tr>
<tr>
<td>5</td>
<td>Seconds (zero-based)</td>
</tr>
</tbody>
</table>

*Note:* The ZIP file format does not support timestamps before 1980.

**ZipInfo.compress_type**
Type of compression for the archive member.

**ZipInfo.comment**
Comment for the individual archive member.

ZipInfo\texttt{.extra}
Expansion field data. The PKZIP Application Note contains some comments on the internal structure of the data contained in this string.

ZipInfo\texttt{.create\_system}
System which created ZIP archive.

ZipInfo\texttt{.create\_version}
PKZIP version which created ZIP archive.

ZipInfo\texttt{.extract\_version}
PKZIP version needed to extract archive.

ZipInfo\texttt{.reserved}
Must be zero.

ZipInfo\texttt{.flag\_bits}
ZIP flag bits.

ZipInfo\texttt{.volume}
Volume number of file header.

ZipInfo\texttt{.internal\_attr}
Internal attributes.

ZipInfo\texttt{.external\_attr}
External file attributes.

ZipInfo\texttt{.header\_offset}
Byte offset to the file header.
ZipInfo.CRC
CRC-32 of the uncompressed file.

ZipInfo.compress_size
Size of the compressed data.

ZipInfo.file_size
Size of the uncompressed file.
13.6. `tarfile` — Read and write tar archive files

Source code: `Lib/tarfile.py`

The `tarfile` module makes it possible to read and write tar archives, including those using gzip, bz2 and lzma compression. Use the `zipfile` module to read or write `.zip` files, or the higher-level functions in `shutil`.

Some facts and figures:

- reads and writes `gzip`, `bz2` and `lzma` compressed archives if the respective modules are available.
- read/write support for the POSIX.1-1988 (ustar) format.
- read/write support for the GNU tar format including `longname` and `longlink` extensions, read-only support for all variants of the `sparse` extension including restoration of sparse files.
- read/write support for the POSIX.1-2001 (pax) format.
- handles directories, regular files, hardlinks, symbolic links, fifos, character devices and block devices and is able to acquire and restore file information like timestamp, access permissions and owner.

*Changed in version 3.3:* Added support for `lzma` compression.

tarfile.open(`name=None, mode='r', fileobj=None, bufsize=10240, **kwargs`)  

Return a `TarFile` object for the pathname `name`. For detailed information on `TarFile` objects and the keyword arguments that
are allowed, see TarFile Objects.

*mode* has to be a string of the form 'filemode[:compression]', it defaults to 'r'. Here is a full list of mode combinations:

<table>
<thead>
<tr>
<th>mode</th>
<th>action</th>
</tr>
</thead>
<tbody>
<tr>
<td>'r' or 'r:*'</td>
<td>Open for reading with transparent compression (recommended).</td>
</tr>
<tr>
<td>'r:'</td>
<td>Open for reading exclusively without compression.</td>
</tr>
<tr>
<td>'r:gz'</td>
<td>Open for reading with gzip compression.</td>
</tr>
<tr>
<td>'r:bz2'</td>
<td>Open for reading with bzip2 compression.</td>
</tr>
<tr>
<td>'r:xz'</td>
<td>Open for reading with lzma compression.</td>
</tr>
<tr>
<td>'x' or 'x:'</td>
<td>Create a tarfile exclusively without compression. Raise an FileExistsError exception if it is already exists.</td>
</tr>
<tr>
<td>'x:gz'</td>
<td>Create a tarfile with gzip compression. Raise an FileExistsError exception if it is already exists.</td>
</tr>
<tr>
<td>'x:bz2'</td>
<td>Create a tarfile with bzip2 compression. Raise an FileExistsError exception if it is already exists.</td>
</tr>
<tr>
<td>'x:xz'</td>
<td>Create a tarfile with lzma compression. Raise an FileExistsError exception if it is already exists.</td>
</tr>
<tr>
<td>'a' or 'a:'</td>
<td>Open for appending with no compression. The file is created if it does not exist.</td>
</tr>
<tr>
<td>'w' or 'w:'</td>
<td>Open for uncompressed writing.</td>
</tr>
<tr>
<td>'w:gz'</td>
<td>Open for gzip compressed writing.</td>
</tr>
<tr>
<td>Mode</td>
<td>Action</td>
</tr>
<tr>
<td>----------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>'w:bz2'</td>
<td>Open for bzip2 compressed writing.</td>
</tr>
<tr>
<td>'w:xz'</td>
<td>Open for lzma compressed writing.</td>
</tr>
</tbody>
</table>

Note that 'a:gz', 'a:bz2' or 'a:xz' is not possible. If `mode` is not suitable to open a certain (compressed) file for reading, `ReadError` is raised. Use `mode` 'r' to avoid this. If a compression method is not supported, `CompressionError` is raised.

If `fileobj` is specified, it is used as an alternative to a file object opened in binary mode for `name`. It is supposed to be at position 0.

For modes 'w:gz', 'r:gz', 'w:bz2', 'r:bz2', 'x:gz', 'x:bz2', `tarfile.open()` accepts the keyword argument `compresslevel` to specify the compression level of the file.

For special purposes, there is a second format for `mode`: 'filemode|[compression]'. `tarfile.open()` will return a `TarFile` object that processes its data as a stream of blocks. No random seeking will be done on the file. If given, `fileobj` may be any object that has a `read()` or `write()` method (depending on the `mode`). `bufsize` specifies the blocksize and defaults to 20 * 512 bytes. Use this variant in combination with e.g. `sys.stdin`, a socket file object or a tape device. However, such a `TarFile` object is limited in that it does not allow to be accessed randomly, see Examples. The currently possible modes:
| 'r|gz'     | Open a gzip compressed stream for reading. |
| 'r|bz2'    | Open a bzip2 compressed stream for reading. |
| 'r|xz'     | Open a lzma compressed stream for reading. |
| 'w|'       | Open an uncompressed stream for writing. |
| 'w|gz'     | Open a gzip compressed stream for writing. |
| 'w|bz2'    | Open a bzip2 compressed stream for writing. |
| 'w|xz'     | Open an lzma compressed stream for writing. |

Changed in version 3.5: The 'x' (exclusive creation) mode was added.

class tarfile.TarFile
Class for reading and writing tar archives. Do not use this class directly, better use tarfile.open() instead. See TarFile Objects.

tarfile.is_tarfile(name)
Return True if name is a tar archive file, that the tarfile module can read.

The tarfile module defines the following exceptions:

exception tarfile.TarError
Base class for all tarfile exceptions.

exception tarfile.ReadError
Is raised when a tar archive is opened, that either cannot be handled by the tarfile module or is somehow invalid.

exception tarfile.CompressionError
Is raised when a compression method is not supported or when the
data cannot be decoded properly.

*exception* `tarfile.StreamError`

Is raised for the limitations that are typical for stream-like `TarFile` objects.

*exception* `tarfile.ExtractError`

Is raised for *non-fatal* errors when using `TarFile.extract()`, but only if `TarFile.errorlevel==2`.

*exception* `tarfile.HeaderError`

Is raised by `TarInfo.frombuf()` if the buffer it gets is invalid.

The following constants are available at the module level:

`tarfile.ENCODING`

The default character encoding: 'utf-8' on Windows, the value returned by `sys.getfilesystemencoding()` otherwise.

Each of the following constants defines a tar archive format that the `tarfile` module is able to create. See section Supported tar formats for details.

`tarfile.USTAR_FORMAT`

POSIX.1-1988 (ustar) format.

`tarfile.GNU_FORMAT`

GNU tar format.

`tarfile.PAX_FORMAT`

POSIX.1-2001 (pax) format.

`tarfile.DEFAULT_FORMAT`
The default format for creating archives. This is currently **GNU_FORMAT**.

**See also:**

**Module zipfile**
Documentation of the `zipfile` standard module.

**Archiving operations**
Documentation of the higher-level archiving facilities provided by the standard `shutil` module.

**GNU tar manual, Basic Tar Format**
Documentation for tar archive files, including GNU tar extensions.
13.6.1. TarFile Objects

The **TarFile** object provides an interface to a tar archive. A tar archive is a sequence of blocks. An archive member (a stored file) is made up of a header block followed by data blocks. It is possible to store a file in a tar archive several times. Each archive member is represented by a **TarInfo** object, see [TarInfo Objects](#) for details.

A **TarFile** object can be used as a context manager in a `with` statement. It will automatically be closed when the block is completed. Please note that in the event of an exception an archive opened for writing will not be finalized; only the internally used file object will be closed. See the [Examples](#) section for a use case.

*New in version 3.2:* Added support for the context management protocol.

```python
class tarfile.TarFile(name=None, mode='r', fileobj=None, format=DEFAULT_FORMAT, tarinfo=TarInfo, dereference=False, ignore_zeros=False, encoding=ENCODING, errors='surrogateescape', pax_headers=None, debug=0, errorlevel=0)
```

All following arguments are optional and can be accessed as instance attributes as well.

*name* is the pathname of the archive. It can be omitted if *fileobj* is given. In this case, the file object’s name attribute is used if it exists.

*mode* is either 'r' to read from an existing archive, 'a' to append data to an existing file, 'w' to create a new file overwriting an existing one or 'x' to create a new file only if it's not exists.
If `fileobj` is given, it is used for reading or writing data. If it can be determined, `mode` is overridden by `fileobj`’s mode. `fileobj` will be used from position 0.

**Note:** `fileobj` is not closed, when `TarFile` is closed.

`format` controls the archive format. It must be one of the constants `USTAR_FORMAT`, `GNU_FORMAT` or `PAX_FORMAT` that are defined at module level.

The `tarinfo` argument can be used to replace the default `TarInfo` class with a different one.

If `dereference` is `False`, add symbolic and hard links to the archive. If it is `True`, add the content of the target files to the archive. This has no effect on systems that do not support symbolic links.

If `ignore_zeros` is `False`, treat an empty block as the end of the archive. If it is `True`, skip empty (and invalid) blocks and try to get as many members as possible. This is only useful for reading concatenated or damaged archives.

`debug` can be set from 0 (no debug messages) up to 3 (all debug messages). The messages are written to `sys.stderr`.

If `errorlevel` is 0, all errors are ignored when using `TarFile.extract()`. Nevertheless, they appear as error messages in the debug output, when debugging is enabled. If 1, all fatal errors are raised as `OSError` exceptions. If 2, all non-fatal errors are raised as `TarError` exceptions as well.

The `encoding` and `errors` arguments define the character encoding
to be used for reading or writing the archive and how conversion errors are going to be handled. The default settings will work for most users. See section Unicode issues for in-depth information.

The pax_headers argument is an optional dictionary of strings which will be added as a pax global header if format is PAX_FORMAT.

Changed in version 3.2: Use 'surrogateescape' as the default for the errors argument.

Changed in version 3.5: The 'x' (exclusive creation) mode was added.

classmethod TarFile.open(...)  
Alternative constructor. The tarfile.open() function is actually a shortcut to this classmethod.

TarFile.getmember(name)  
Return a TarInfo object for member name. If name can not be found in the archive, KeyError is raised.

Note: If a member occurs more than once in the archive, its last occurrence is assumed to be the most up-to-date version.

TarFile.getmembers()  
Return the members of the archive as a list of TarInfo objects.
The list has the same order as the members in the archive.

TarFile.getnames()  
Return the members as a list of their names. It has the same order as the list returned by getmembers().
TarFile.**list**(*verbose=**True**, *, **members=**None*)

Print a table of contents to sys.stdout. If verbose is **False**, only the names of the members are printed. If it is **True**, output similar to that of `ls -l` is produced. If optional **members** is given, it must be a subset of the list returned by **getmembers()**.

*Changed in version 3.5:* Added the **members** parameter.

TarFile.**next**()

Return the next member of the archive as a **TarInfo** object, when TarFile is opened for reading. Return **None** if there is no more available.

TarFile.**extractall**(*path=":.", **members=**None, *, **numeric_owner=**False*)

Extract all members from the archive to the current working directory or directory path. If optional **members** is given, it must be a subset of the list returned by **getmembers()**. Directory information like owner, modification time and permissions are set after all members have been extracted. This is done to work around two problems: A directory's modification time is reset each time a file is created in it. And, if a directory's permissions do not allow writing, extracting files to it will fail.

If **numeric_owner** is **True**, the uid and gid numbers from the tarfile are used to set the owner/group for the extracted files. Otherwise, the named values from the tarfile are used.

**Warning:** Never extract archives from untrusted sources without prior inspection. It is possible that files are created outside of **path**, e.g. members that have absolute filenames starting with "/" or filenames with two dots " .. ".

Changed in version 3.5: Added the `numeric_only` parameter.

```
TarFile.extract(member, path="", setAttrs=True, *
numeric_owner=False)
```

Extract a member from the archive to the current working directory, using its full name. Its file information is extracted as accurately as possible. `member` may be a filename or a `TarInfo` object. You can specify a different directory using `path`. File attributes (owner, mtime, mode) are set unless `setAttrs` is false.

If `numeric_owner` is `True`, the uid and gid numbers from the tarfile are used to set the owner/group for the extracted files. Otherwise, the named values from the tarfile are used.

**Note:** The `extract()` method does not take care of several extraction issues. In most cases you should consider using the `extractall()` method.

**Warning:** See the warning for `extractall()`.

Changed in version 3.2: Added the `setAttrs` parameter.

```
TarFile.extractfile(member)
```

Extract a member from the archive as a file object. `member` may be a filename or a `TarInfo` object. If `member` is a regular file or a link, an `io.BufferedReader` object is returned. Otherwise, `None` is returned.

**Changed in version 3.3:** Return an `io.BufferedReader` object.

```
TarFile.add(name, arcname=None, recursive=True,
```
Add the file name to the archive. name may be any type of file (directory, fifo, symbolic link, etc.). If given, arcname specifies an alternative name for the file in the archive. Directories are added recursively by default. This can be avoided by setting recursive to False. If exclude is given, it must be a function that takes one filename argument and returns a boolean value. Depending on this value the respective file is either excluded (True) or added (False). If filter is specified it must be a keyword argument. It should be a function that takes a TarInfo object argument and returns the changed TarInfo object. If it instead returns None the TarInfo object will be excluded from the archive. See Examples for an example.

* Changed in version 3.2: Added the filter parameter.

* Deprecated since version 3.2: The exclude parameter is deprecated, please use the filter parameter instead.

TarFile.addfile(tarinfo, fileobj=None)

Add the TarInfo object tarinfo to the archive. If fileobj is given, tarinfo.size bytes are read from it and added to the archive. You can create TarInfo objects using gettarinfo().

**Note:** On Windows platforms, fileobj should always be opened with mode 'rb' to avoid irritation about the file size.

TarFile.gettarinfo(name=None, arcname=None, fileobj=None)

Create a TarInfo object for either the file name or the file object fileobj (using os.fstat() on its file descriptor). You can modify
some of the **TarInfo**'s attributes before you add it using `addfile()`. If given, `arcname` specifies an alternative name for the file in the archive.

**TarFile**.`close()`

Close the **TarFile**. In write mode, two finishing zero blocks are appended to the archive.

**TarFile**.`pax_headers`

A dictionary containing key-value pairs of pax global headers.
13.6.2. TarInfo Objects

A TarInfo object represents one member in a TarFile. Aside from storing all required attributes of a file (like file type, size, time, permissions, owner etc.), it provides some useful methods to determine its type. It does not contain the file's data itself.

TarInfo objects are returned by TarFile's methods getmember(), getmembers() and gettarinfo().

class tarfile.TarInfo(name="")
    Create a TarInfo object.

classmethod TarInfo.frombuf(buf, encoding, errors)
    Create and return a TarInfo object from string buffer buf.
    Raises HeaderError if the buffer is invalid.

classmethod TarInfo.fromtarfile(tarfile)
    Read the next member from the TarFile object tarfile and return it as a TarInfo object.

TarInfo.tobuf(format=DEFAULT_FORMAT, encoding=ENCODING, errors='surrogateescape')
    Create a string buffer from a TarInfo object. For information on the arguments see the constructor of the TarFile class.
    Changed in version 3.2: Use 'surrogateescape' as the default for the errors argument.

A TarInfo object has the following public data attributes:
TarInfo.name
    Name of the archive member.

TarInfo.size
    Size in bytes.

TarInfo.mtime
    Time of last modification.

TarInfo.mode
    Permission bits.

TarInfo.type
    File type. type is usually one of these constants: REGTYPE, AREGTYPE, LNKTYPE, SYMTYPE, DIRTYPE, FIFOTYPE, CONTTYPE, CHRTYPE, BLKTYPE, GNUTYPE_SPARSE. To determine the type of a TarInfo object more conveniently, use the is*() methods below.

TarInfo.linkname
    Name of the target file name, which is only present in TarInfo objects of type LNKTYPE and SYMTYPE.

TarInfo.uid
    User ID of the user who originally stored this member.

TarInfo.gid
    Group ID of the user who originally stored this member.

TarInfo.uname
    User name.

TarInfo.gname
Group name.

**TarInfo.pax_headers**

A dictionary containing key-value pairs of an associated pax extended header.

A **TarInfo** object also provides some convenient query methods:

**TarInfo.isfile()**

Return *True* if the Tarinfo object is a regular file.

**TarInfo.isreg()**

Same as `isfile()`.

**TarInfo.isdir()**

Return *True* if it is a directory.

**TarInfo.issym()**

Return *True* if it is a symbolic link.

**TarInfo.islink()**

Return *True* if it is a hard link.

**TarInfo.ischr()**

Return *True* if it is a character device.

**TarInfo.isblk()**

Return *True* if it is a block device.

**TarInfo.isfifo()**

Return *True* if it is a FIFO.

**TarInfo.isdev()**
Return True if it is one of character device, block device or FIFO.
13.6.3. Command Line Interface

New in version 3.4.

The `tarfile` module provides a simple command line interface to interact with tar archives.

If you want to create a new tar archive, specify its name after the `-c` option and then list the filename(s) that should be included:

$$
\texttt{python \ -m \ tarfile \ -c \ monty.tar \ \ spam.txt \ eggs.txt}
$$

Passing a directory is also acceptable:

$$
\texttt{python \ -m \ tarfile \ -c \ monty.tar \ \ life-of-brian_1979/}
$$

If you want to extract a tar archive into the current directory, use the `-e` option:

$$
\texttt{python \ -m \ tarfile \ -e \ monty.tar}
$$

You can also extract a tar archive into a different directory by passing the directory's name:

$$
\texttt{python \ -m \ tarfile \ -e \ monty.tar \ \ other-dir/}
$$

For a list of the files in a tar archive, use the `-l` option:

$$
\texttt{python \ -m \ tarfile \ -l \ monty.tar}
$$

13.6.3.1. Command line options
List files in a tarfile.

Create tarfile from source files.

Extract tarfile into the current directory if output_dir is not specified.

Test whether the tarfile is valid or not.

Verbose output
13.6.4. Examples

How to extract an entire tar archive to the current working directory:

```python
import tarfile
tar = tarfile.open("sample.tar.gz")
tar.extractall()
tar.close()
```

How to extract a subset of a tar archive with `TarFile.extractall()` using a generator function instead of a list:

```python
import os
import tarfile

def py_files(members):
    for tarinfo in members:
        if os.path.splitext(tarinfo.name)[1] == ".py"
            yield tarinfo

tar = tarfile.open("sample.tar.gz")
tar.extractall(members=py_files(tar))
tar.close()
```

How to create an uncompressed tar archive from a list of filenames:

```python
import tarfile
tar = tarfile.open("sample.tar", "w")
for name in ["foo", "bar", "quux"]:
    tar.add(name)
tar.close()
```

The same example using the `with` statement:
```python
import tarfile
with tarfile.open("sample.tar", "w") as tar:
    for name in ["foo", "bar", "quux"]:
        tar.add(name)
```

How to read a gzip compressed tar archive and display some member information:

```python
import tarfile
tar = tarfile.open("sample.tar.gz", "r:gz")
for tarinfo in tar:
    print(tarinfo.name, "is", tarinfo.size, "bytes in size and is"
          if tarinfo.isreg() :
            print("a regular file.")
        elif tarinfo.isdir() :
            print("a directory.")
        else:
            print("something else.")
tar.close()
```

How to create an archive and reset the user information using the `filter` parameter in `TarFile.add()`:

```python
import tarfile
def reset(tarinfo):
    tarinfo.uid = tarinfo.gid = 0
    tarinfo.uname = tarinfo.gname = "root"
    return tarinfo
tar = tarfile.open("sample.tar.gz", "w:gz")
tar.add("foo", filter=reset)
tar.close()
```
13.6.5. Supported tar formats

There are three tar formats that can be created with the `tarfile` module:

- The POSIX.1-1988 ustar format (`USTAR_FORMAT`). It supports filenames up to a length of at best 256 characters and linknames up to 100 characters. The maximum file size is 8 GiB. This is an old and limited but widely supported format.

- The GNU tar format (`GNU_FORMAT`). It supports long filenames and linknames, files bigger than 8 GiB and sparse files. It is the de facto standard on GNU/Linux systems. `tarfile` fully supports the GNU tar extensions for long names, sparse file support is read-only.

- The POSIX.1-2001 pax format (`PAX_FORMAT`). It is the most flexible format with virtually no limits. It supports long filenames and linknames, large files and stores pathnames in a portable way. However, not all tar implementations today are able to handle pax archives properly.

  The `pax` format is an extension to the existing `ustar` format. It uses extra headers for information that cannot be stored otherwise. There are two flavours of pax headers: Extended headers only affect the subsequent file header, global headers are valid for the complete archive and affect all following files. All the data in a pax header is encoded in UTF-8 for portability reasons.

There are some more variants of the tar format which can be read, but not created:
The ancient V7 format. This is the first tar format from Unix Seventh Edition, storing only regular files and directories. Names must not be longer than 100 characters, there is no user/group name information. Some archives have miscalculated header checksums in case of fields with non-ASCII characters.

The SunOS tar extended format. This format is a variant of the POSIX.1-2001 pax format, but is not compatible.
13.6.6. Unicode issues

The tar format was originally conceived to make backups on tape drives with the main focus on preserving file system information. Nowadays tar archives are commonly used for file distribution and exchanging archives over networks. One problem of the original format (which is the basis of all other formats) is that there is no concept of supporting different character encodings. For example, an ordinary tar archive created on a UTF-8 system cannot be read correctly on a Latin-1 system if it contains non-ASCII characters. Textual metadata (like filenames, linknames, user/group names) will appear damaged. Unfortunately, there is no way to autodetect the encoding of an archive. The pax format was designed to solve this problem. It stores non-ASCII metadata using the universal character encoding UTF-8.

The details of character conversion in tarfile are controlled by the encoding and errors keyword arguments of the TarFile class.

encoding defines the character encoding to use for the metadata in the archive. The default value is sys.getfilesystemencoding() or 'ascii' as a fallback. Depending on whether the archive is read or written, the metadata must be either decoded or encoded. If encoding is not set appropriately, this conversion may fail.

The errors argument defines how characters are treated that cannot be converted. Possible values are listed in section Error Handlers. The default scheme is 'surrogateescape' which Python also uses for its file system calls, see File Names, Command Line Arguments, and Environment Variables.

In case of PAX_FORMAT archives, encoding is generally not needed
because all the metadata is stored using UTF-8. encoding is only used in the rare cases when binary pax headers are decoded or when strings with surrogate characters are stored.
14. File Formats

The modules described in this chapter parse various miscellaneous file formats that aren’t markup languages and are not related to e-mail.

- **14.1. csv — CSV File Reading and Writing**
  - 14.1.1. Module Contents
  - 14.1.2. Dialects and Formatting Parameters
  - 14.1.3. Reader Objects
  - 14.1.4. Writer Objects
  - 14.1.5. Examples

- **14.2. configparser — Configuration file parser**
  - 14.2.1. Quick Start
  - 14.2.2. Supported Datatypes
  - 14.2.3. Fallback Values
  - 14.2.4. Supported INI File Structure
  - 14.2.5. Interpolation of values
  - 14.2.6. Mapping Protocol Access
  - 14.2.7. Customizing Parser Behaviour
  - 14.2.8. Legacy API Examples
  - 14.2.9. ConfigParser Objects
  - 14.2.10. RawConfigParser Objects
  - 14.2.11. Exceptions

- **14.3. netrc — netrc file processing**
  - 14.3.1. netrc Objects

- **14.4. xdrlib — Encode and decode XDR data**
  - 14.4.1. Packer Objects
  - 14.4.2. Unpacker Objects
  - 14.4.3. Exceptions

- **14.5. plistlib — Generate and parse Mac OS X .plist files**
  - 14.5.1. Examples
14.1. **csv** — CSV File Reading and Writing

**Source code:** Lib/csv.py

The so-called CSV (Comma Separated Values) format is the most common import and export format for spreadsheets and databases. CSV format was used for many years prior to attempts to describe the format in a standardized way in **RFC 4180**. The lack of a well-defined standard means that subtle differences often exist in the data produced and consumed by different applications. These differences can make it annoying to process CSV files from multiple sources. Still, while the delimiters and quoting characters vary, the overall format is similar enough that it is possible to write a single module which can efficiently manipulate such data, hiding the details of reading and writing the data from the programmer.

The **csv** module implements classes to read and write tabular data in CSV format. It allows programmers to say, “write this data in the format preferred by Excel,” or “read data from this file which was generated by Excel,” without knowing the precise details of the CSV format used by Excel. Programmers can also describe the CSV formats understood by other applications or define their own special-purpose CSV formats.

The **csv** module’s **reader** and **writer** objects read and write sequences. Programmers can also read and write data in dictionary form using the **DictReader** and **DictWriter** classes.

**See also:**
<table>
<thead>
<tr>
<th><strong>PEP 305 - CSV File API</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The Python Enhancement Proposal which proposed this addition to Python.</td>
</tr>
</tbody>
</table>
14.1.1. Module Contents

The csv module defines the following functions:

csv.\texttt{reader}(\texttt{csvfile}, \texttt{dialect}='\texttt{excel}', **\texttt{fmtparams})

Return a reader object which will iterate over lines in the given \texttt{csvfile}. \texttt{csvfile} can be any object which supports the \texttt{iterator} protocol and returns a string each time its \texttt{\_\_next\_()} method is called — \texttt{file objects} and list objects are both suitable. If \texttt{csvfile} is a file object, it should be opened with \texttt{newline=''} [1] An optional \texttt{dialect} parameter can be given which is used to define a set of parameters specific to a particular CSV dialect. It may be an instance of a subclass of the \texttt{Dialect} class or one of the strings returned by the \texttt{list_dialects()} function. The other optional \texttt{fmtparams} keyword arguments can be given to override individual formatting parameters in the current dialect. For full details about the dialect and formatting parameters, see section \texttt{Dialects and Formatting Parameters}.

Each row read from the csv file is returned as a list of strings. No automatic data type conversion is performed unless the \texttt{QUOTE\_NONNUMERIC} format option is specified (in which case unquoted fields are transformed into floats).

A short usage example:

\begin{verbatim}
>>> import csv
>>> with open('eggs.csv', newline='') as csvfile:
...     spamreader = csv.reader(csvfile, delimiter=' ', quotechar='|', quoting=csv.QUOTE_MINIMAL)
...     for row in spamreader:
...         print(', '.join(row))
Spam, Spam, Spam, Spam, Spam, Baked Beans
\end{verbatim}
csv.writer(csvfile, dialect='excel', **fmtparams)

Return a writer object responsible for converting the user’s data into delimited strings on the given file-like object. csvfile can be any object with a write() method. If csvfile is a file object, it should be opened with newline='' [1]. An optional dialect parameter can be given which is used to define a set of parameters specific to a particular CSV dialect. It may be an instance of a subclass of the Dialect class or one of the strings returned by the list_dialects() function. The other optional fmtparams keyword arguments can be given to override individual formatting parameters in the current dialect. For full details about the dialect and formatting parameters, see section Dialects and Formatting Parameters. To make it as easy as possible to interface with modules which implement the DB API, the value None is written as the empty string. While this isn’t a reversible transformation, it makes it easier to dump SQL NULL data values to CSV files without preprocessing the data returned from a cursor.fetchall() call. All other non-string data are stringified with str() before being written.

A short usage example:

```python
import csv
with open('eggs.csv', 'w', newline='') as csvfile:
    spamwriter = csv.writer(csvfile, delimiter=' ', quotechar='|', quoting=csv.QUOTE_MINIMAL)
    spamwriter.writerow(['Spam'] * 5 + ['Baked Beans'])
    spamwriter.writerow(['Spam', 'Lovely Spam', 'Wonderful Spam'])
```
csv.register_dialect(name[, dialect[, **fmtparams]])

Associate dialect with name. name must be a string. The dialect can be specified either by passing a sub-class of Dialect, or by fmtparams keyword arguments, or both, with keyword arguments overriding parameters of the dialect. For full details about the dialect and formatting parameters, see section Dialects and Formatting Parameters.

csv.unregister_dialect(name)

Delete the dialect associated with name from the dialect registry. An Error is raised if name is not a registered dialect name.

csv.get_dialect(name)

Return the dialect associated with name. An Error is raised if name is not a registered dialect name. This function returns an immutable Dialect.

csv.list_dialects()

Return the names of all registered dialects.

csv.field_size_limit([new_limit])

Returns the current maximum field size allowed by the parser. If new_limit is given, this becomes the new limit.

The csv module defines the following classes:

class csv.DictReader(csvfile, fieldnames=None, restkey=None, restval=None, dialect='excel', *args, **kwds)

Create an object which operates like a regular reader but maps the information read into a dict whose keys are given by the optional fieldnames parameter. The fieldnames parameter is a sequence whose elements are associated with the fields of the input data in
order. These elements become the keys of the resulting dictionary. If the fieldnames parameter is omitted, the values in the first row of the csvfile will be used as the fieldnames. If the row read has more fields than the fieldnames sequence, the remaining data is added as a sequence keyed by the value of restkey. If the row read has fewer fields than the fieldnames sequence, the remaining keys take the value of the optional restval parameter. Any other optional or keyword arguments are passed to the underlying reader instance.

A short usage example:

```python
>>> import csv
>>> with open('names.csv') as csvfile:
...     reader = csv.DictReader(csvfile)
...     for row in reader:
...         print(row['first_name'], row['last_name'])
Baked Beans
Lovely Spam
Wonderful Spam
```

The `csv.DictReader` class is a file reader which operates like a regular reader but maps dictionaries onto output rows. The fieldnames parameter is a sequence of keys that identify the order in which values in the dictionary passed to the writerow() method are written to the csvfile. The optional restval parameter specifies the value to be written if the dictionary is missing a key in fieldnames. If the dictionary passed to the writerow() method contains a key not found in fieldnames, the optional extrasaction parameter indicates what action to take. If it is set to 'raise' a ValueError is raised.
If it is set to 'ignore', extra values in the dictionary are ignored. Any other optional or keyword arguments are passed to the underlying writer instance.

Note that unlike the DictReader class, the fieldnames parameter of the DictWriter is not optional. Since Python’s dict objects are not ordered, there is not enough information available to deduce the order in which the row should be written to the csvfile.

A short usage example:

```python
import csv

with open('names.csv', 'w') as csvfile:
    fieldnames = ['first_name', 'last_name']
    writer = csv.DictWriter(csvfile, fieldnames=fieldnames)
    writer.writeheader()
    writer.writerow({'first_name': 'Baked', 'last_name': 'Btc'})
    writer.writerow({'first_name': 'Lovely', 'last_name': 'Blossom'})
    writer.writerow({'first_name': 'Wonderful', 'last_name': 'Baker'})
```

**class csv.Dialect**

The Dialect class is a container class relied on primarily for its attributes, which are used to define the parameters for a specific reader or writer instance.

**class csv.excel**

The excel class defines the usual properties of an Excel-generated CSV file. It is registered with the dialect name 'excel'.

**class csv.excel_tab**

The excel_tab class defines the usual properties of an Excel-
generated TAB-delimited file. It is registered with the dialect name 'excel-tab'.

**class csv.unix_dialect**

The `unix_dialect` class defines the usual properties of a CSV file generated on UNIX systems, i.e. using '\n' as line terminator and quoting all fields. It is registered with the dialect name 'unix'.

*New in version 3.2.*

**class csv.Sniffer**

The `Sniffer` class is used to deduce the format of a CSV file.

The `Sniffer` class provides two methods:

`sniff(sample, delimiters=None)`

Analyze the given `sample` and return a `Dialect` subclass reflecting the parameters found. If the optional `delimiters` parameter is given, it is interpreted as a string containing possible valid delimiter characters.

`has_header(sample)`

Analyze the sample text (presumed to be in CSV format) and return `True` if the first row appears to be a series of column headers.

An example for `Sniffer` use:

```python
with open('example.csv') as csvfile:
    dialect = csv.Sniffer().sniff(csvfile.read(1024))
    csvfile.seek(0)
    reader = csv.reader(csvfile, dialect)
    # ... process CSV file contents here ...
```
The `csv` module defines the following constants:

**csv.QUOTE_ALL**

Instructs `writer` objects to quote all fields.

**csv.QUOTE_MINIMAL**

Instructs `writer` objects to only quote those fields which contain special characters such as *delimiter*, *quotechar* or any of the characters in *lineterminator*.

**csv.QUOTE_NONNUMERIC**

Instructs `writer` objects to quote all non-numeric fields.

Instructs the reader to convert all non-quoted fields to type `float`.

**csv.QUOTE_NONE**

Instructs `writer` objects to never quote fields. When the current *delimiter* occurs in output data it is preceded by the current *escapechar* character. If *escapechar* is not set, the writer will raise *Error* if any characters that require escaping are encountered.

Instructs `reader` to perform no special processing of quote characters.

The `csv` module defines the following exception:

**exception csv.Error**

Raised by any of the functions when an error is detected.
14.1.2. Dialects and Formatting Parameters

To make it easier to specify the format of input and output records, specific formatting parameters are grouped together into dialects. A dialect is a subclass of the `Dialect` class having a set of specific methods and a single `validate()` method. When creating `reader` or `writer` objects, the programmer can specify a string or a subclass of the `Dialect` class as the dialect parameter. In addition to, or instead of, the `dialect` parameter, the programmer can also specify individual formatting parameters, which have the same names as the attributes defined below for the `Dialect` class.

Dialects support the following attributes:

**Dialect**.`delimiter`
A one-character string used to separate fields. It defaults to ','.

**Dialect**.`doublequote`
Controls how instances of `quotechar` appearing inside a field should themselves be quoted. When `True`, the character is doubled. When `False`, the `escapechar` is used as a prefix to the `quotechar`. It defaults to `True`.

On output, if `doublequote` is `False` and no `escapechar` is set, `Error` is raised if a `quotechar` is found in a field.

**Dialect**.`escapechar`
A one-character string used by the writer to escape the `delimiter` if `quoting` is set to `QUOTE_NONE` and the `quotechar` if `doublequote` is `False`. On reading, the `escapechar` removes any special meaning
from the following character. It defaults to `None`, which disables escaping.

**Dialect.** `lineterminator`

The string used to terminate lines produced by the `writer`. It defaults to `\r\n`.

**Note:** The `reader` is hard-coded to recognise either `\r` or `\n` as end-of-line, and ignores `lineterminator`. This behavior may change in the future.

**Dialect.** `quotechar`

A one-character string used to quote fields containing special characters, such as the `delimiter` or `quotechar`, or which contain new-line characters. It defaults to `''`.

**Dialect.** `quoting`

Controls when quotes should be generated by the writer and recognised by the reader. It can take on any of the `QUOTE_*` constants (see section `Module Contents`) and defaults to `QUOTE_MINIMAL`.

**Dialect.** `skipinitialspace`

When `True`, whitespace immediately following the `delimiter` is ignored. The default is `False`.

**Dialect.** `strict`

When `True`, raise exception `Error` on bad CSV input. The default is `False`. 
14.1.3. Reader Objects

Reader objects (DictReader instances and objects returned by the reader() function) have the following public methods:

`csvreader.__next__()`

Return the next row of the reader’s iterable object as a list, parsed according to the current dialect. Usually you should call this as `next(reader)`.

Reader objects have the following public attributes:

`csvreader.dialect`

A read-only description of the dialect in use by the parser.

`csvreader.line_num`

The number of lines read from the source iterator. This is not the same as the number of records returned, as records can span multiple lines.

DictReader objects have the following public attribute:

`csvreader.fieldnames`

If not passed as a parameter when creating the object, this attribute is initialized upon first access or when the first record is read from the file.
14.1.4. Writer Objects

Writer objects (DictWriter instances and objects returned by the writer() function) have the following public methods. A row must be an iterable of strings or numbers for Writer objects and a dictionary mapping fieldnames to strings or numbers (by passing them through str() first) for DictWriter objects. Note that complex numbers are written out surrounded by parens. This may cause some problems for other programs which read CSV files (assuming they support complex numbers at all).

csvwriter.writerow(row)

Write the row parameter to the writer’s file object, formatted according to the current dialect.

   Changed in version 3.5: Added support of arbitrary iterables.

csvwriter.writerows(rows)

Write all the rows parameters (a list of row objects as described above) to the writer’s file object, formatted according to the current dialect.

Writer objects have the following public attribute:

csvwriter.dialect

A read-only description of the dialect in use by the writer.

DictWriter objects have the following public method:

DictWriter.writeheader()

Write a row with the field names (as specified in the constructor).
New in version 3.2.
14.1.5. Examples

The simplest example of reading a CSV file:

```python
import csv
with open('some.csv', newline='') as f:
    reader = csv.reader(f)
    for row in reader:
        print(row)
```

Reading a file with an alternate format:

```python
import csv
with open('passwd', newline='') as f:
    reader = csv.reader(f, delimiter=':', quoting=csv.QUOTE_ALL)
    for row in reader:
        print(row)
```

The corresponding simplest possible writing example is:

```python
import csv
with open('some.csv', 'w', newline='') as f:
    writer = csv.writer(f)
    writer.writerows(someiterable)
```

Since `open()` is used to open a CSV file for reading, the file will by default be decoded into unicode using the system default encoding (see `locale.getpreferredencoding()`). To decode a file using a different encoding, use the encoding argument of `open`:

```python
import csv
with open('some.csv', newline='', encoding='utf-8') as f:
    reader = csv.reader(f)
```
The same applies to writing in something other than the system default encoding: specify the encoding argument when opening the output file.

Registering a new dialect:

```python
import csv
csv.register_dialect('unixpwd', delimiter=':', quoting=csv.QUOTE_ALL)
with open('passwd', newline='') as f:
    reader = csv.reader(f, 'unixpwd')
```

A slightly more advanced use of the reader — catching and reporting errors:

```python
import csv, sys
filename = 'some.csv'
with open(filename, newline='') as f:
    reader = csv.reader(f)
    try:
        for row in reader:
            print(row)
    except csv.Error as e:
        sys.exit('file {}, line {}: {}'.format(filename, e.line, e))
```

And while the module doesn’t directly support parsing strings, it can easily be done:

```python
import csv
for row in csv.reader(['one,two,three']):
    print(row)
```
Footnotes

(1, 2) If newline='' is not specified, newlines embedded inside quoted fields will not be interpreted correctly, and on platforms that use \r\n linendings on write an extra \r will be added. It should always be safe to specify newline='', since the csv module does its own (universal) newline handling.
14.2. `configparser` — Configuration file parser

**Source code:** `Lib/configparser.py`

This module provides the `ConfigParser` class which implements a basic configuration language which provides a structure similar to what's found in Microsoft Windows INI files. You can use this to write Python programs which can be customized by end users easily.

**Note:** This library does *not* interpret or write the value-type prefixes used in the Windows Registry extended version of INI syntax.

**See also:**

**Module** `shlex`

Support for a creating Unix shell-like mini-languages which can be used as an alternate format for application configuration files.

**Module** `json`

The `json` module implements a subset of JavaScript syntax which can also be used for this purpose.
14.2.1. Quick Start

Let's take a very basic configuration file that looks like this:

```
[DEFAULT]
ServerAliveInterval = 45
Compression = yes
CompressionLevel = 9
ForwardX11 = yes

[bitbucket.org]
User = hg

[topsecret.server.com]
Port = 50022
ForwardX11 = no
```

The structure of INI files is described in the following section. Essentially, the file consists of sections, each of which contains keys with values. `configparser` classes can read and write such files. Let's start by creating the above configuration file programatically.

```python
>>> import configparser
>>> config = configparser.ConfigParser()
>>> config['DEFAULT'] = {'ServerAliveInterval': '45',
...                       'Compression': 'yes',
...                       'CompressionLevel': '9'}
>>> config['bitbucket.org'] = {}
>>> config['bitbucket.org']['User'] = 'hg'
>>> config['topsecret.server.com'] = {}
>>> topsecret = config['topsecret.server.com']
>>> topsecret['Port'] = '50022'  # mutates the parser
>>> topsecret['ForwardX11'] = 'no'  # same here
>>> config['DEFAULT']['ForwardX11'] = 'yes'
>>> with open('example.ini', 'w') as configfile:
```
As you can see, we can treat a config parser much like a dictionary. There are differences, outlined later, but the behavior is very close to what you would expect from a dictionary.

Now that we have created and saved a configuration file, let's read it back and explore the data it holds.

```python
>>> import configparser
>>> config = configparser.ConfigParser()
>>> config.sections()
[]
>>> config.read('example.ini')
['example.ini']
>>> config.sections()
['bitbucket.org', 'topsecret.server.com']
>>> 'bitbucket.org' in config
True
>>> 'bytebong.com' in config
False
>>> config['bitbucket.org']['User']
'hg'
>>> config['DEFAULT']['Compression']
'yes'
>>> topsecret = config['topsecret.server.com']
>>> topsecret['ForwardX11']
'no'
>>> topsecret['Port']
'50022'
>>> for key in config['bitbucket.org']: print(key)
... user
  compressionlevel
  serveraliveinterval
```
As we can see above, the API is pretty straightforward. The only bit of magic involves the DEFAULT section which provides default values for all other sections [1]. Note also that keys in sections are case-insensitive and stored in lowercase [1].
14.2.2. Supported Datatypes

Config parsers do not guess datatypes of values in configuration files, always storing them internally as strings. This means that if you need other datatypes, you should convert on your own:

```python
>>> int(topsecret['Port'])
50022
>>> float(topsecret['CompressionLevel'])
9.0
```

Since this task is so common, config parsers provide a range of handy getter methods to handle integers, floats and booleans. The last one is the most interesting because simply passing the value to `bool()` would do no good since `bool('False')` is still True. This is why config parsers also provide `getboolean()`. This method is case-insensitive and recognizes Boolean values from 'yes'/"no", 'on'/"off", 'true'/"false" and '1'/"0" [1]. For example:

```python
>>> topsecret.getboolean('ForwardX11')
False
>>> config['bitbucket.org'].getboolean('ForwardX11')
True
>>> config.getboolean('bitbucket.org', 'Compression')
True
```

Apart from `getboolean()`, config parsers also provide equivalent `getint()` and `getfloat()` methods. You can register your own converters and customize the provided ones. [1]
14.2.3. Fallback Values

As with a dictionary, you can use a section’s `get()` method to provide fallback values:

```
>>> topsecret.get('Port')
'50022'
>>> topsecret.get('CompressionLevel')
'9'
>>> topsecret.get('Cipher')
>>> topsecret.get('Cipher', '3des-cbc')
'3des-cbc'
```

Please note that default values have precedence over fallback values. For instance, in our example the 'CompressionLevel' key was specified only in the 'DEFAULT' section. If we try to get it from the section 'topsecret.server.com', we will always get the default, even if we specify a fallback:

```
>>> topsecret.get('CompressionLevel', '3')
'9'
```

One more thing to be aware of is that the parser-level `get()` method provides a custom, more complex interface, maintained for backwards compatibility. When using this method, a fallback value can be provided via the `fallback` keyword-only argument:

```
>>> config.get('bitbucket.org', 'monster', ...
    fallback=No such things as monsters
'No such things as monsters'
```

The same fallback argument can be used with the `getint()`,
getfloat() and getboolean() methods, for example:

```python
>>> 'BatchMode' in topsecret
False
>>> topsecret.getboolean('BatchMode', fallback=True)
True
>>> config['DEFAULT']['BatchMode'] = 'no'
>>> topsecret.getboolean('BatchMode', fallback=True)
False
```
14.2.4. Supported INI File Structure

A configuration file consists of sections, each led by a `[section]` header, followed by key/value entries separated by a specific string ( = or : by default [1]). By default, section names are case sensitive but keys are not [1]. Leading and trailing whitespace is removed from keys and values. Values can be omitted, in which case the key/value delimiter may also be left out. Values can also span multiple lines, as long as they are indented deeper than the first line of the value. Depending on the parser’s mode, blank lines may be treated as parts of multiline values or ignored.

Configuration files may include comments, prefixed by specific characters (# and ; by default [1]). Comments may appear on their own on an otherwise empty line, possibly indented. [1]

For example:

```
[Simp[Simple Values]e Values]
key=value
spaces in keys=allowed
spaces in values=allowed as well
spaces around the delimiter = obviously
you can also use : to delimit keys from values

[All Values Are Strings]
values like this: 1000000
or this: 3.14159265359
are they treated as numbers? : no
integers, floats and booleans are held as: strings
can use the API to get converted values directly: tr

[Multiline Values]
```
chorus: I'm a lumberjack, and I'm okay
       I sleep all night and I work all day

[No Values]
key_without_value
empty_string_value_here =

[You can use comments]
  # like this
  ; or this

  # By default only in an empty line.
  # Inline comments can be harmful because they prevent
  # from using the delimiting characters as parts of values.
  # That being said, this can be customized.

  [Sections Can Be Indented]
    can_values_be_as_well = True
    does_that_mean_anything_special = False
    purpose = formatting for readability
    multiline_values = are
    handled just fine as
    long as they are indented
    deeper than the first line
    of a value
    # Did I mention we can indent comments, too?
14.2.5. Interpolation of values

On top of the core functionality, ConfigParser supports interpolation. This means values can be preprocessed before returning them from get() calls.

class configparser.BasicInterpolation

The default implementation used by ConfigParser. It enables values to contain format strings which refer to other values in the same section, or values in the special default section [1]. Additional default values can be provided on initialization.

For example:

```
[Paths]
home_dir: /Users
my_dir: %(home_dir)s/lumberjack
my_pictures: %(my_dir)s/Pictures
```

In the example above, ConfigParser with interpolation set to BasicInterpolation() would resolve %(home_dir)s to the value of home_dir (/Users in this case). %(my_dir)s in effect would resolve to /Users/lumberjack. All interpolations are done on demand so keys used in the chain of references do not have to be specified in any specific order in the configuration file.

With interpolation set to None, the parser would simply return %(my_dir)s/Pictures as the value of my_pictures and %(home_dir)s/lumberjack as the value of my_dir.

class configparser.ExtendedInterpolation

An alternative handler for interpolation which implements a more
advanced syntax, used for instance in zc.buildout. Extended interpolation is using ${section:option} to denote a value from a foreign section. Interpolation can span multiple levels. For convenience, if the section: part is omitted, interpolation defaults to the current section (and possibly the default values from the special section).

For example, the configuration specified above with basic interpolation, would look like this with extended interpolation:

```
[Paths]
home_dir: /Users
my_dir: ${home_dir}/lumberjack
my_pictures: ${my_dir}/Pictures
```

Values from other sections can be fetched as well:

```
[Common]
home_dir: /Users
library_dir: /Library
system_dir: /System
macports_dir: /opt/local

[Frameworks]
Python: 3.2
path: ${Common:system_dir}/Library/Frameworks/

[Arthur]
nickname: Two Sheds
last_name: Jackson
my_dir: ${Common:home_dir}/twosheds
my_pictures: ${my_dir}/Pictures
python_dir: ${Frameworks:path}/Python/Versions/${}
14.2.6. Mapping Protocol Access

New in version 3.2.

Mapping protocol access is a generic name for functionality that enables using custom objects as if they were dictionaries. In case of `configparser`, the mapping interface implementation is using the `parser['section'][option]` notation.

`parser['section']` in particular returns a proxy for the section's data in the parser. This means that the values are not copied but they are taken from the original parser on demand. What's even more important is that when values are changed on a section proxy, they are actually mutated in the original parser.

`configparser` objects behave as close to actual dictionaries as possible. The mapping interface is complete and adheres to the `MutableMapping` ABC. However, there are a few differences that should be taken into account:

- By default, all keys in sections are accessible in a case-insensitive manner [1]. E.g. for `option in parser["section"]` yields only `optionxform'ed` option key names. This means lowercased keys by default. At the same time, for a section that holds the key 'a', both expressions return True:

```
"a" in parser["section"]
"A" in parser["section"]
```

- All sections include DEFAULTSECT values as well which means that `clear()` on a section may not leave the section visibly empty. This is because default values cannot be deleted from the
section (because technically they are not there). If they are overridden in the section, deleting causes the default value to be visible again. Trying to delete a default value causes a KeyError.

- DEFAULTSECT cannot be removed from the parser:
  - trying to delete it raises ValueError,
  - parser.clear() leaves it intact,
  - parser.popitem() never returns it.

- parser.get(section, option, **kwargs) - the second argument is not a fallback value. Note however that the section-level get() methods are compatible both with the mapping protocol and the classic configparser API.

- parser.items() is compatible with the mapping protocol (returns a list of section_name, section_proxy pairs including the DEFAULTSECT). However, this method can also be invoked with arguments: parser.items(section, raw, vars). The latter call returns a list of option, value pairs for a specified section, with all interpolations expanded (unless raw=True is provided).

The mapping protocol is implemented on top of the existing legacy API so that subclasses overriding the original interface still should have mappings working as expected.
14.2.7. Customizing Parser Behaviour

There are nearly as many INI format variants as there are applications using it. `configparser` goes a long way to provide support for the largest sensible set of INI styles available. The default functionality is mainly dictated by historical background and it’s very likely that you will want to customize some of the features.

The most common way to change the way a specific config parser works is to use the `__init__()` options:

- `defaults`, default value: None

  This option accepts a dictionary of key-value pairs which will be initially put in the DEFAULT section. This makes for an elegant way to support concise configuration files that don’t specify values which are the same as the documented default.

  Hint: if you want to specify default values for a specific section, use `read_dict()` before you read the actual file.

- `dict_type`, default value: `collections.OrderedDict`

  This option has a major impact on how the mapping protocol will behave and how the written configuration files look. With the default ordered dictionary, every section is stored in the order they were added to the parser. Same goes for options within sections.

  An alternative dictionary type can be used for example to sort sections and options on write-back. You can also use a regular dictionary for performance reasons.

  Please note: there are ways to add a set of key-value pairs in a
single operation. When you use a regular dictionary in those operations, the order of the keys may be random. For example:

```python
>>> parser = configparser.ConfigParser()
>>> parser.read_dict({'section1': {'key1': 'value1', 'key2': 'value2', 'key3': 'value3'},
                    'section2': {'keyA': 'valueA', 'keyB': 'valueB', 'keyC': 'valueC'},
                    'section3': {'foo': 'x', 'bar': 'y', 'baz': 'z'}})
>>> parser.sections()
['section3', 'section2', 'section1']
>>> [option for option in parser['section3']]  
['baz', 'foo', 'bar']
```

In these operations you need to use an ordered dictionary as well:

```python
>>> from collections import OrderedDict
>>> parser = configparser.ConfigParser()
>>> parser.read_dict(
...     OrderedDict((
...         ('s1',
...             OrderedDict((
...                 ('1', '2'),
...                 ('3', '4'),
...                 ('5', '6'))),
...         ('s2',
...             OrderedDict((
...                 ('a', 'b'),
...                 ('c', 'd'))),
...     )))
... )
```
allow_no_value, default value: False

Some configuration files are known to include settings without values, but which otherwise conform to the syntax supported by configparser. The allow_no_value parameter to the constructor can be used to indicate that such values should be accepted:

```python
>>> import configparser

>>> sample_config = ""
... [mysqld]
...    user = mysql
...    pid-file = /var/run/mysqld/mysqld.pid
...    skip-external-locking
...    old_passwords = 1
...    skip-bdb
...    # we don't need ACID today
...    skip-innodb
... ""

>>> config = configparser.ConfigParser(allow_no_value=True)

>>> config.read_string(sample_config)
```
• **delimiters**, default value: `( = , : )`

Delimiters are substrings that delimit keys from values within a section. The first occurrence of a delimiting substring on a line is considered a delimiter. This means values (but not keys) can contain the delimiters.

See also the `space_around_delimiters` argument to `ConfigParser.write()`.

• **comment_prefixes**, default value: `( # , ; ; )`

• **inline_comment_prefixes**, default value: None

Comment prefixes are strings that indicate the start of a valid comment within a config file. `comment_prefixes` are used only on otherwise empty lines (optionally indented) whereas `inline_comment_prefixes` can be used after every valid value (e.g. section names, options and empty lines as well). By default inline comments are disabled and `'#'` and `';'` are used as prefixes for whole line comments.
Changed in version 3.2: In previous versions of `configparser` behaviour matched `comment_prefixes=('#',';')` and `inline_comment_prefixes=(';',)`. Please note that config parsers don’t support escaping of comment prefixes so using `inline_comment_prefixes` may prevent users from specifying option values with characters used as comment prefixes. When in doubt, avoid setting `inline_comment_prefixes`. In any circumstances, the only way of storing comment prefix characters at the beginning of a line in multiline values is to interpolate the prefix, for example:

```python
>>> from configparser import ConfigParser, ExtendedInterpolation
>>> parser = ConfigParser(interpolation=ExtendedInterpolation()
>>> # the default BasicInterpolation could be used
>>> parser.read_string('"
... [DEFAULT]
... hash = #
...
... [hashes]
... shebang =
... ${hash}!/usr/bin/env python
... ${hash} -*- coding: utf-8 -*-
...
... extensions =
... enabled_extension
... another_extension
... #disabled_by_comment
... yet_another_extension
...
... interpolation not necessary = if # is not at
... even in multiline values = line #1
... line #2
... line #3
... """
')
```
>>> print(parser["hashes"]["shebang")

#!/usr/bin/env python
# -*- coding: utf-8 -*-

>>> print(parser["hashes"]["extensions")

enabled_extension
another_extension
yet_another_extension

>>> print(parser["hashes"]["interpolation not need")

if # is not at line start

>>> print(parser["hashes"]["even in multiline value")

line #1
line #2
line #3

strict, default value: True

When set to True, the parser will not allow for any section or option duplicates while reading from a single source (using read_file(), read_string() or read_dict()). It is recommended to use strict parsers in new applications.

Changed in version 3.2: In previous versions of configparser, behaviour matched strict=False.

empty_lines_in_values, default value: True

In config parsers, values can span multiple lines as long as they are indented more than the key that holds them. By default parsers also let empty lines to be parts of values. At the same time, keys can be arbitrarily indented themselves to improve readability. In consequence, when configuration files get big and complex, it is easy for the user to lose track of the file structure.
Take for instance:

```
[Section]
key = multiline
    value with a gotcha

this = is still a part of the multiline value of 'key'
```

This can be especially problematic for the user to see if she's using a proportional font to edit the file. That is why when your application does not need values with empty lines, you should consider disallowing them. This will make empty lines split keys every time. In the example above, it would produce two keys, key and this.

- `default_section`, default value: `configparser.DEFAULTSECT` (that is: "DEFAULT")

The convention of allowing a special section of default values for other sections or interpolation purposes is a powerful concept of this library, letting users create complex declarative configurations. This section is normally called "DEFAULT" but this can be customized to point to any other valid section name. Some typical values include: "general" or "common". The name provided is used for recognizing default sections when reading from any source and is used when writing configuration back to a file. Its current value can be retrieved using the `parser_instance.default_section` attribute and may be modified at runtime (i.e. to convert files from one format to another).

- `interpolation`, default value:
Interpolation behaviour may be customized by providing a custom handler through the *interpolation* argument. None can be used to turn off interpolation completely, ExtendedInterpolation() provides a more advanced variant inspired by zc.buildout. More on the subject in the dedicated documentation section. RawConfigParser has a default value of None.

- *converters*, default value: not set

Config parsers provide option value getters that perform type conversion. By default getint(), getfloat(), and getboolean() are implemented. Should other getters be desirable, users may define them in a subclass or pass a dictionary where each key is a name of the converter and each value is a callable implementing said conversion. For instance, passing {'decimal': decimal.Decimal} would add getdecimal() on both the parser object and all section proxies. In other words, it will be possible to write both parser_instance.getdecimal('section', 'key', fallback=0) and parser_instance['section'].getdecimal('key', 0).

If the converter needs to access the state of the parser, it can be implemented as a method on a config parser subclass. If the name of this method starts with get, it will be available on all section proxies, in the dict-compatible form (see the getdecimal() example above). More advanced customization may be achieved by overriding default values of these parser attributes. The defaults are defined on the
classes, so they may be overridden by subclasses or by attribute assignment.

`configparser.BOOLEAN_STATES`

By default when using `getboolean()`, config parsers consider the following values True: '1', 'yes', 'true', 'on' and the following values False: '0', 'no', 'false', 'off'. You can override this by specifying a custom dictionary of strings and their Boolean outcomes. For example:

```python
>>> custom = configparser.ConfigParser()
>>> custom['section1'] = {'funky': 'nope'}
>>> custom['section1'].getboolean('funky')
Traceback (most recent call last):
...
ValueError: Not a boolean: nope
>>> custom.BOOLEAN_STATES = {'sure': True, 'nope'
>>> custom['section1'].getboolean('funky')
False
```

Other typical Boolean pairs include accept/reject or enabled/disabled.

`configparser.optionxform(option)`

This method transforms option names on every read, get, or set operation. The default converts the name to lowercase. This also means that when a configuration file gets written, all keys will be lowercase. Override this method if that’s unsuitable. For example:

```python
>>> config = ""
... [Section1]
... Key = Value
...""
configparser.SECTCRE

A compiled regular expression used to parse section headers. The default matches [section] to the name "section". Whitespace is considered part of the section name, thus ['larch'] will be read as a section of name "larch". Override this attribute if that's unsuitable. For example:

```python
>>> config = """
... [Section 1]
... option = value
...
... [ Section 2 ]
... another = val
... """

>>> typical = ConfigParser()
>>> typical.read_string(config)
>>> typical.sections()
['Section 1', 'Section 2']
>>> custom = ConfigParser()
```
```python
>>> custom.SECTCRE = re.compile(r'\[	*(?P<header>.*?)\]
>>> custom.read_string(config)
>>> custom.sections()
['Section 1', 'Section 2']
```

**Note:** While ConfigParser objects also use an OPTCRE attribute for recognizing option lines, it's not recommended to override it because that would interfere with constructor options `allow_no_value` and `delimiters`. 
14.2.8. Legacy API Examples

Mainly because of backwards compatibility concerns, `configparser` provides also a legacy API with explicit get/set methods. While there are valid use cases for the methods outlined below, mapping protocol access is preferred for new projects. The legacy API is at times more advanced, low-level and downright counterintuitive.

An example of writing to a configuration file:

```python
import configparser

config = configparser.RawConfigParser()

# Please note that using RawConfigParser's set function on non-string values to keys internally, but will report an error when attempting to write to a file or when you get it into a non-raw mode.
# such assignments to take place.
config.add_section('Section1')
config.set('Section1', 'an_int', '15')
config.set('Section1', 'a_bool', 'true')
config.set('Section1', 'a_float', '3.1415')
config.set('Section1', 'baz', 'fun')
config.set('Section1', 'bar', 'Python')
config.set('Section1', 'foo', '%(bar)s is %(baz)s!')

# Writing our configuration file to 'example.cfg'
with open('example.cfg', 'w') as configfile:
    config.write(configfile)
```

An example of reading the configuration file again:

```python
import configparser
```
```python
config = configparser.RawConfigParser()
config.read('example.cfg')

# getfloat() raises an exception if the value is not a float.
# getint() and getboolean() also do this for their respective types.
a_float = config.getfloat('Section1', 'a_float')
an_int = config.getint('Section1', 'an_int')
print(a_float + an_int)

# Notice that the next output does not interpolate '%(bar)s' or '%(baz)s'.
# This is because we are using a RawConfigParser().
if config.getboolean('Section1', 'a_bool'):
    print(config.get('Section1', 'foo'))

To get interpolation, use ConfigParser:

```python
import configparser
cfg = configparser.ConfigParser()
cfg.read('example.cfg')

# Set the optional *raw* argument of get() to True in a single get operation.
print(cfg.get('Section1', 'foo', raw=False))  # -> "Python is fun!"
print(cfg.get('Section1', 'foo', raw=True))  # -> "%(bar)s is %(baz)s!"

# The optional *vars* argument is a dict with members that take precedence in interpolation.
print(cfg.get('Section1', 'foo', vars={'bar': 'Documentation', 'baz': 'evil'}))

# The optional *fallback* argument can be used to provide a fallback value.
print(cfg.get('Section1', 'foo'))
# -> "Python is fun!"
```
Default values are available in both types of ConfigParsers. They are used in interpolation if an option used is not defined elsewhere.

```python
import configparser

# New instance with 'bar' and 'baz' defaulting to 'Life'
config = configparser.ConfigParser({'bar': 'Life', 'baz': 'hard'})
config.read('example.cfg')

print(config.get('Section1', 'foo'))  # -> "Python is fun!"
config.remove_option('Section1', 'bar')
config.remove_option('Section1', 'baz')
print(config.get('Section1', 'foo'))  # -> "Life is hard!"
```
14.2.9. ConfigParser Objects

class configparser.ConfigParser(defaults=None, dict_type=collections.OrderedDict, allow_no_value=False, delimiters=('=', ':'), comment_prefixes=('#', ';'), inline_comment_prefixes=None, strict=True, empty_lines_in_values=True, default_section=configparser.DEFAULTSECT, interpolation=BasicInterpolation(), converters={})

The main configuration parser. When defaults is given, it is initialized into the dictionary of intrinsic defaults. When dict_type is given, it will be used to create the dictionary objects for the list of sections, for the options within a section, and for the default values.

When delimiters is given, it is used as the set of substrings that divide keys from values. When comment_prefixes is given, it will be used as the set of substrings that prefix comments in otherwise empty lines. Comments can be indented. When inline_comment_prefixes is given, it will be used as the set of substrings that prefix comments in non-empty lines.

When strict is True (the default), the parser won’t allow for any section or option duplicates while reading from a single source (file, string or dictionary), raising DuplicateSectionError or DuplicateOptionError. When empty_lines_in_values is False (default: True), each empty line marks the end of an option. Otherwise, internal empty lines of a multiline option are kept as part of the value. When allow_no_value is True (default: False), options without values are accepted; the value held for these is None and they are serialized without the trailing delimiter.

When default_section is given, it specifies the name for the special section holding default values for other sections and interpolation
purposes (normally named "DEFAULT"). This value can be retrieved and changed on runtime using the default_section instance attribute.

Interpolation behaviour may be customized by providing a custom handler through the interpolation argument. None can be used to turn off interpolation completely, ExtendedInterpolation() provides a more advanced variant inspired by zc.buildout. More on the subject in the dedicated documentation section.

All option names used in interpolation will be passed through the optionxform() method just like any other option name reference. For example, using the default implementation of optionxform() (which converts option names to lower case), the values foo %(bar)s and foo %(BAR)s are equivalent.

When converters is given, it should be a dictionary where each key represents the name of a type converter and each value is a callable implementing the conversion from string to the desired datatype. Every converter gets its own corresponding get*() method on the parser object and section proxies.

*Changed in version 3.1:* The default dict_type is collections.OrderedDict.

*Changed in version 3.2:* allow_no_value, delimiters, comment_prefixes, strict, empty_lines_in_values, default_section and interpolation were added.

*Changed in version 3.5:* The converters argument was added.

**defaults()**

Return a dictionary containing the instance-wide defaults.
sections()

Return a list of the sections available; the *default section* is not included in the list.

add_section(section)

Add a section named `section` to the instance. If a section by the given name already exists, `DuplicateSectionError` is raised. If the *default section* name is passed, `ValueError` is raised. The name of the section must be a string; if not, `TypeError` is raised.

*Changed in version 3.2:* Non-string section names raise `TypeError`.

has_section(section)

Indicates whether the named `section` is present in the configuration. The *default section* is not acknowledged.

options(section)

Return a list of options available in the specified `section`.

has_option(section, option)

If the given `section` exists, and contains the given `option`, return `True`; otherwise return `False`. If the specified `section` is `None` or an empty string, `DEFAULT` is assumed.

read(filenames, encoding=None)

Attempt to read and parse a list of filenames, returning a list of filenames which were successfully parsed. If `filenames` is a string, it is treated as a single filename. If a file named in `filenames` cannot be opened, that file will be ignored. This is designed so that you can specify a list of potential configuration
file locations (for example, the current directory, the user's home directory, and some system-wide directory), and all existing configuration files in the list will be read. If none of the named files exist, the `ConfigParser` instance will contain an empty dataset. An application which requires initial values to be loaded from a file should load the required file or files using `read_file()` before calling `read()` for any optional files:

```python
import configparser, os

config = configparser.ConfigParser()
config.read_file(open('defaults.cfg'))
config.read(["site.cfg", os.path.expanduser('~/myapp.cfg'),
             encoding='cp1250'])
```

*New in version 3.2:* The `encoding` parameter. Previously, all files were read using the default encoding for `open()`.

**read_file**(f, source=None)

Read and parse configuration data from f which must be an iterable yielding Unicode strings (for example files opened in text mode).

Optional argument `source` specifies the name of the file being read. If not given and f has a name attribute, that is used for `source`; the default is '<???>'.

*New in version 3.2:* Replaces `readfp()`.

**read_string**(string, source='<string>')

Parse configuration data from a string.

Optional argument `source` specifies a context-specific name of
the string passed. If not given, '<string>' is used. This should commonly be a filesystem path or a URL.

*New in version 3.2.*

**read_dict**(dictionary, source='<dict>')

Load configuration from any object that provides a dict-like `items()` method. Keys are section names, values are dictionaries with keys and values that should be present in the section. If the used dictionary type preserves order, sections and their keys will be added in order. Values are automatically converted to strings.

Optional argument `source` specifies a context-specific name of the dictionary passed. If not given, `<dict>` is used.

This method can be used to copy state between parsers.

*New in version 3.2.*

**get**(section, option, *, raw=False, vars=None[, fallback])

Get an option value for the named section. If `vars` is provided, it must be a dictionary. The option is looked up in `vars` (if provided), `section`, and in `DEFAULTSECT` in that order. If the key is not found and `fallback` is provided, it is used as a fallback value. None can be provided as a fallback value.

All the '% interpolations are expanded in the return values, unless the `raw` argument is true. Values for interpolation keys are looked up in the same manner as the option.

*Changed in version 3.2: Arguments raw, vars and fallback are keyword only to protect users from trying to use the third*
argument as the *fallback* fallback (especially when using the mapping protocol).

**getint**(section, option, *, raw=False, vars=None[, fallback])

A convenience method which coerces the *option* in the specified *section* to an integer. See *get()* for explanation of *raw*, *vars* and *fallback*.

**getfloat**(section, option, *, raw=False, vars=None[, fallback])

A convenience method which coerces the *option* in the specified *section* to a floating point number. See *get()* for explanation of *raw*, *vars* and *fallback*.

**getboolean**(section, option, *, raw=False, vars=None[, fallback])

A convenience method which coerces the *option* in the specified *section* to a Boolean value. Note that the accepted values for the option are '1', 'yes', 'true', and 'on', which cause this method to return True, and '0', 'no', 'false', and 'off', which cause it to return False. These string values are checked in a case-insensitive manner. Any other value will cause it to raise *ValueError*. See *get()* for explanation of *raw*, *vars* and *fallback*.

**items**(raw=False, vars=None)

**items**(section, raw=False, vars=None)

When *section* is not given, return a list of *section_name*, *section_proxy* pairs, including DEFAULTSECT.

Otherwise, return a list of *name*, *value* pairs for the options in the given *section*. Optional arguments have the same meaning
as for the `get()` method.

*Changed in version 3.2:* Items present in `vars` no longer appear in the result. The previous behaviour mixed actual parser options with variables provided for interpolation.

**set**(section, option, value)

If the given section exists, set the given option to the specified value; otherwise raise `NoSectionError`. `option` and `value` must be strings; if not, `TypeError` is raised.

**write**(fileobject, space_around_delimiters=True)

Write a representation of the configuration to the specified `file object`, which must be opened in text mode (accepting strings). This representation can be parsed by a future `read()` call. If `space_around_delimiters` is true, delimiters between keys and values are surrounded by spaces.

**remove_option**(section, option)

Remove the specified `option` from the specified `section`. If the section does not exist, raise `NoSectionError`. If the option existed to be removed, return `True`; otherwise return `False`.

**remove_section**(section)

Remove the specified `section` from the configuration. If the section in fact existed, return `True`. Otherwise return `False`.

**optionxform**(option)

Transforms the option name `option` as found in an input file or as passed in by client code to the form that should be used in the internal structures. The default implementation returns a lower-case version of `option`; subclasses may override this or
client code can set an attribute of this name on instances to affect this behavior.

You don’t need to subclass the parser to use this method, you can also set it on an instance, to a function that takes a string argument and returns a string. Setting it to \texttt{str}, for example, would make option names case sensitive:

\begin{verbatim}
cfgparser = ConfigParser()
cfgparser.optionxform = str
\end{verbatim}

Note that when reading configuration files, whitespace around the option names is stripped before \texttt{optionxform()} is called.

\texttt{readfp}(fp, filename=None) \quad \textit{Deprecated since version 3.2: Use \texttt{read_file()} instead.}

\textit{Changed in version 3.2: readfp()} now iterates on \texttt{f} instead of calling \texttt{f.readline()}.

For existing code calling \texttt{readfp()} with arguments which don’t support iteration, the following generator may be used as a wrapper around the file-like object:

\begin{verbatim}
def readline_generator(f):
    line = f.readline()
    while line:
        yield line
        line = f.readline()
\end{verbatim}

Instead of \texttt{parser.readfp(f)} use \texttt{parser.read_file(readline_generator(f))}.

\texttt{configparser.MAX\_INTERPOLATION\_DEPTH}
The maximum depth for recursive interpolation for `get()` when the `raw` parameter is false. This is relevant only when the default `interpolation` is used.
14.2.10. RawConfigParser Objects

class configparser.RawConfigParser(defaults=None,
dict_type=collections.OrderedDict, allow_no_value=False, *,
delimiters=('=', ':'), comment_prefixes=('#', ';'),
inline_comment_prefixes=None, strict=True,
empty_lines_in_values=True,
default_section=configparser.DEFAULTSECT,
interpolation)

Legacy variant of the ConfigParser with interpolation disabled by default and unsafe add_section and set methods.

Note: Consider using ConfigParser instead which checks types of the values to be stored internally. If you don’t want interpolation, you can use ConfigParser(interpolation=None).

add_section(section)

Add a section named section to the instance. If a section by the given name already exists, DuplicateSectionError is raised. If the default section name is passed, ValueError is raised.

Type of section is not checked which lets users create non-string named sections. This behaviour is unsupported and may cause internal errors.

set(section, option, value)

If the given section exists, set the given option to the specified value; otherwise raise NoSectionError. While it is possible to use RawConfigParser (or ConfigParser with raw parameters set to true) for internal storage of non-string values,
full functionality (including interpolation and output to files) can only be achieved using string values.

This method lets users assign non-string values to keys internally. This behaviour is unsupported and will cause errors when attempting to write to a file or get it in non-raw mode. **Use the mapping protocol API** which does not allow such assignments to take place.
14.2.11. Exceptions

exception configparser.Error
   Base class for all other configparser exceptions.

exception configparser.NoSectionError
   Exception raised when a specified section is not found.

exception configparser.DuplicateSectionError
   Exception raised if add_section() is called with the name of a section that is already present or in strict parsers when a section if found more than once in a single input file, string or dictionary.

   New in version 3.2: Optional source and lineno attributes and arguments to __init__() were added.

exception configparser.DuplicateOptionError
   Exception raised by strict parsers if a single option appears twice during reading from a single file, string or dictionary. This catches misspellings and case sensitivity-related errors, e.g. a dictionary may have two keys representing the same case-insensitive configuration key.

exception configparser.NoOptionError
   Exception raised when a specified option is not found in the specified section.

exception configparser.InterpolationError
   Base class for exceptions raised when problems occur performing string interpolation.

exception configparser.InterpolationDepthError
Exception raised when string interpolation cannot be completed because the number of iterations exceeds MAX_INTERPOLATION_DEPTH. Subclass of InterpolationError.

```python
exception configparser.InterpolationMissingOptionError
Exception raised when an option referenced from a value does not exist. Subclass of InterpolationError.
```

```python
exception configparser.InterpolationSyntaxError
Exception raised when the source text into which substitutions are made does not conform to the required syntax. Subclass of InterpolationError.
```

```python
exception configparser.MissingSectionHeaderError
Exception raised when attempting to parse a file which has no section headers.
```

```python
exception configparser.ParsingError
Exception raised when errors occur attempting to parse a file.
```

*Changed in version 3.2:* The filename attribute and `__init__()` argument were renamed to `source` for consistency.

---

**Footnotes**

1. Config parsers allow for heavy customization. If you are interested in changing the behaviour outlined by the footnote reference, consult the Customizing Parser Behaviour section.
14.3. netrc — netrc file processing

Source code: Lib/netrc.py

The netrc class parses and encapsulates the netrc file format used by the Unix ftp program and other FTP clients.

```
class netrc.netrc([file])
```

A netrc instance or subclass instance encapsulates data from a netrc file. The initialization argument, if present, specifies the file to parse. If no argument is given, the file .netrc in the user’s home directory will be read. Parse errors will raise NetrcParseError with diagnostic information including the file name, line number, and terminating token. If no argument is specified on a POSIX system, the presence of passwords in the .netrc file will raise a NetrcParseError if the file ownership or permissions are insecure (owned by a user other than the user running the process, or accessible for read or write by any other user). This implements security behavior equivalent to that of ftp and other programs that use .netrc.

*Changed in version 3.4:* Added the POSIX permission check.

```
exception netrc.NetrcParseError
```

Exception raised by the netrc class when syntactical errors are encountered in source text. Instances of this exception provide three interesting attributes: msg is a textual explanation of the error, filename is the name of the source file, and lineno gives the
line number on which the error was found.
14.3.1. netrc Objects

A netrc instance has the following methods:

**netrc.authenticators**(*host*)
Return a 3-tuple (login, account, password) of authenticators for *host*. If the netrc file did not contain an entry for the given host, return the tuple associated with the ‘default’ entry. If neither matching host nor default entry is available, return None.

**netrc.**__repr__**(*)
Dump the class data as a string in the format of a netrc file. (This discards comments and may reorder the entries.)

Instances of netrc have public instance variables:

**netrc.hosts**
Dictionary mapping host names to (login, account, password) tuples. The ‘default’ entry, if any, is represented as a pseudo-host by that name.

**netrc.macros**
Dictionary mapping macro names to string lists.

**Note:** Passwords are limited to a subset of the ASCII character set. All ASCII punctuation is allowed in passwords, however, note that whitespace and non-printable characters are not allowed in passwords. This is a limitation of the way the .netrc file is parsed and may be removed in the future.
14.4. **xdrlib** — Encode and decode XDR data

**Source code:** Lib/xdrlib.py

The `xdrlib` module supports the External Data Representation Standard as described in RFC 1014, written by Sun Microsystems, Inc. June 1987. It supports most of the data types described in the RFC.

The `xdrlib` module defines two classes, one for packing variables into XDR representation, and another for unpacking from XDR representation. There are also two exception classes.

```python
class xdrlib.Packer
    Packer is the class for packing data into XDR representation. The Packer class is instantiated with no arguments.

class xdrlib.Unpacker(data)
    Unpacker is the complementary class which unpacks XDR data values from a string buffer. The input buffer is given as data.
```

**See also:**

**RFC 1014** - XDR: External Data Representation Standard
   This RFC defined the encoding of data which was XDR at the time this module was originally written. It has apparently been obsoleted by RFC 1832.

**RFC 1832** - XDR: External Data Representation Standard
   Newer RFC that provides a revised definition of XDR.
14.4.1. Packer Objects

Packer instances have the following methods:

**Packer.get_buffer()**

Returns the current pack buffer as a string.

**Packer.reset()**

Resets the pack buffer to the empty string.

In general, you can pack any of the most common XDR data types by calling the appropriate pack_type() method. Each method takes a single argument, the value to pack. The following simple data type packing methods are supported: pack_uint(), pack_int(), pack_enum(), pack_bool(), pack_uhyper(), and pack_hyper().

**Packer.pack_float(value)**

Packs the single-precision floating point number value.

**Packer.pack_double(value)**

Packs the double-precision floating point number value.

The following methods support packing strings, bytes, and opaque data:

**Packer.pack_fstring(n, s)**

Packs a fixed length string, s. n is the length of the string but it is not packed into the data buffer. The string is padded with null bytes if necessary to guaranteed 4 byte alignment.

**Packer.pack_fopaque(n, data)**
Packs a fixed length opaque data stream, similarly to `pack_fstring()`.

**Packer.p**ack_string(s)

Packs a variable length string, s. The length of the string is first packed as an unsigned integer, then the string data is packed with `pack_fstring()`.

**Packer.p**ack_opaque(data)

Packs a variable length opaque data string, similarly to `pack_string()`.

**Packer.p**ack_bytes(bytes)

Packs a variable length byte stream, similarly to `pack_string()`.

The following methods support packing arrays and lists:

**Packer.p**ack_list(list, pack_item)

Packs a list of homogeneous items. This method is useful for lists with an indeterminate size; i.e. the size is not available until the entire list has been walked. For each item in the list, an unsigned integer 1 is packed first, followed by the data value from the list. `pack_item` is the function that is called to pack the individual item. At the end of the list, an unsigned integer 0 is packed.

For example, to pack a list of integers, the code might appear like this:

```python
import xdrlib
p = xdrlib.Packer()
p.pack_list([1, 2, 3], p.pack_int)
```

**Packer.p**ack_farray(n, array, pack_item)
Packs a fixed length list \((array)\) of homogeneous items. \(n\) is the length of the list; it is \textit{not} packed into the buffer, but a \texttt{ValueError} exception is raised if \texttt{len(array)} is not equal to \(n\). As above, \texttt{pack_item} is the function used to pack each element.

\texttt{Packer.pack_array(list, pack_item)}

Packs a variable length \texttt{list} of homogeneous items. First, the length of the list is packed as an unsigned integer, then each element is packed as in \texttt{pack_farray()} above.
14.4.2. Unpacker Objects

The Unpacker class offers the following methods:

Unpacker\textttreset(data)\text\reset\text\ resets\ the\ string\ buffer\ with\ the\ given\ data.\n
Unpacker\textttget_position()\text\ get\_position\ returns\ the\ current\ unpack\ position\ in\ the\ data\ buffer.\n
Unpacker\textttset_position(position)\text\ set\_position\ sets\ the\ data\ buffer\ unpack\ position\ to\ position.\ You\ should\ be\ careful\ about\ using\ get\_position()\ and\ set\_position().\n
Unpacker\textttget_buffer()\text\ get\_buffer\ returns\ the\ current\ unpack\ data\ buffer\ as\ a\ string.\n
Unpacker\textttdone()\text\ done\ indicates\ unpack\ completion.\ Raises\ an\ Error\ exception\ if\ all\ of\ the\ data\ has\ not\ been\ unpacked.\n
In addition, every data type that can be packed with a Packer, can be unpacked with an Unpacker. Unpacking methods are of the form unpack\_type(), and take no arguments. They return the unpacked object.

Unpacker\textttunpack\_float()\text\ unpack\_float\ unpacks\ a\ single-precision\ floating\ point\ number.\n
Unpacker\textttunpack\_double()\text\ unpack\_double\ unpacks\ a\ double-precision\ floating\ point\ number,\ similarly\ to\ unpack\_float().
In addition, the following methods unpack strings, bytes, and opaque data:

**Unpacker**.\texttt{unpack\_fstring}(\texttt{n})

Unpacks and returns a fixed length string. \(n\) is the number of characters expected. Padding with null bytes to guaranteed 4 byte alignment is assumed.

**Unpacker**.\texttt{unpack\_fopaque}(\texttt{n})

Unpacks and returns a fixed length opaque data stream, similarly to \texttt{unpack\_fstring()}.

**Unpacker**.\texttt{unpack\_string}()

Unpacks and returns a variable length string. The length of the string is first unpacked as an unsigned integer, then the string data is unpacked with \texttt{unpack\_fstring()}.

**Unpacker**.\texttt{unpack\_opaque}()

Unpacks and returns a variable length opaque data string, similarly to \texttt{unpack\_string()}.

**Unpacker**.\texttt{unpack\_bytes}()

Unpacks and returns a variable length byte stream, similarly to \texttt{unpack\_string()}.

The following methods support unpacking arrays and lists:

**Unpacker**.\texttt{unpack\_list}(\texttt{unpack\_item})

Unpacks and returns a list of homogeneous items. The list is unpacked one element at a time by first unpacking an unsigned integer flag. If the flag is 1, then the item is unpacked and appended to the list. A flag of 0 indicates the end of the list.
unpack_item is the function that is called to unpack the items.

Unpacker. **unpack_farray**\((n, \text{unpack\_item})\)
Unpacks and returns (as a list) a fixed length array of homogeneous items. \(n\) is number of list elements to expect in the buffer. As above, **unpack\_item** is the function used to unpack each element.

Unpacker. **unpack\_array**\((\text{unpack\_item})\)
Unpacks and returns a variable length list of homogeneous items. First, the length of the list is unpacked as an unsigned integer, then each element is unpacked as in **unpack\_farray()** above.
14.4.3. Exceptions

Exceptions in this module are coded as class instances:

```python
import xdrlib
p = xdrlib.Packer()
try:
    p.pack_double(8.01)
except xdrlib.ConversionError as instance:
    print('packing the double failed:', instance.msg)
```

**exception xdrlib.Error**

The base exception class. *Error* has a single public attribute `msg` containing the description of the error.

**exception xdrlib.ConversionError**

Class derived from *Error*. Contains no additional instance variables.

Here is an example of how you would catch one of these exceptions:
14.5. `plistlib` — Generate and parse Mac OS X `.plist` files

**Source code:** `Lib/plistlib.py`

This module provides an interface for reading and writing the “property list” files used mainly by Mac OS X and supports both binary and XML plist files.

The property list (.plist) file format is a simple serialization supporting basic object types, like dictionaries, lists, numbers and strings. Usually the top level object is a dictionary.

To write out and to parse a plist file, use the `dump()` and `load()` functions.

To work with plist data in bytes objects, use `dumps()` and `loads()`.

Values can be strings, integers, floats, booleans, tuples, lists, dictionaries (but only with string keys), `Data`, `bytes`, `bytesarray` or `datetime.datetime` objects.

*Changed in version 3.4:* New API, old API deprecated. Support for binary format plists added.

**See also:**

*PL*ist manual page

Apple’s documentation of the file format.
This module defines the following functions:

```
plistlib.load(fp, *, fmt=None, use_builtin_types=True, dict_type=dict)
```

Read a plist file. `fp` should be a readable and binary file object. Return the unpacked root object (which usually is a dictionary).

The `fmt` is the format of the file and the following values are valid:

- **None**: Autodetect the file format
- **FMT_XML**: XML file format
- **FMT_BINARY**: Binary plist format

If `use_builtin_types` is true (the default) binary data will be returned as instances of `bytes`, otherwise it is returned as instances of `Data`.

The `dict_type` is the type used for dictionaries that are read from the plist file. The exact structure of the plist can be recovered by using `collections.OrderedDict` (although the order of keys shouldn’t be important in plist files).

XML data for the **FMT_XML** format is parsed using the Expat parser from `xml.parsers.expat` – see its documentation for possible exceptions on ill-formed XML. Unknown elements will simply be ignored by the plist parser.

The parser for the binary format raises `InvalidFileException` when the file cannot be parsed.

*New in version 3.4.*

```
plistlib.loads(data, *, fmt=None, use_builtin_types=True, dict_type=dict)
```
Load a plist from a bytes object. See `load()` for an explanation of the keyword arguments.

*New in version 3.4.*

`plistlib.dump(value, fp, *, fmt=FMT_XML, sort_keys=True, skipkeys=False)`

Write `value` to a plist file. `fp` should be a writable, binary file object.

The `fmt` argument specifies the format of the plist file and can be one of the following values:

- `FMT_XML`: XML formatted plist file
- `FMT_BINARY`: Binary formatted plist file

When `sort_keys` is true (the default) the keys for dictionaries will be written to the plist in sorted order, otherwise they will be written in the iteration order of the dictionary.

When `skipkeys` is false (the default) the function raises `TypeError` when a key of a dictionary is not a string, otherwise such keys are skipped.

A `TypeError` will be raised if the object is of an unsupported type or a container that contains objects of unsupported types.

An `OverflowError` will be raised for integer values that cannot be represented in (binary) plist files.

*New in version 3.4.*

`plistlib.dumps(value, *, fmt=FMT_XML, sort_keys=True, skipkeys=False)`

Return `value` as a plist-formatted bytes object. See the
documentation for \texttt{dump()} for an explanation of the keyword arguments of this function.

\textit{New in version 3.4.}

The following functions are deprecated:

\texttt{plistlib.readPlist(pathOrFile)}

Read a plist file. \texttt{pathOrFile} may be either a file name or a (readable and binary) file object. Returns the unpacked root object (which usually is a dictionary).

This function calls \texttt{load()} to do the actual work, see the documentation of that function for an explanation of the keyword arguments.

\begin{quote}
\textbf{Note:} Dict values in the result have a \texttt{\_\_getattr\_\_} method that defers to \texttt{\_\_getitem\_\_}. This means that you can use attribute access to access items of these dictionaries.
\end{quote}

\textit{Deprecated since version 3.4:} Use \texttt{load()} instead.

\texttt{plistlib.writePlist(rootObject, pathOrFile)}

Write \texttt{rootObject} to an XML plist file. \texttt{pathOrFile} may be either a file name or a (writable and binary) file object

\textit{Deprecated since version 3.4:} Use \texttt{dump()} instead.

\texttt{plistlib.readPlistFromBytes(data)}

Read a plist data from a bytes object. Return the root object.

See \texttt{load()} for a description of the keyword arguments.
Note: Dict values in the result have a \_\_getattr\_ method that defers to \_\_getitem\_. This means that you can use attribute access to access items of these dictionaries.

Deprecated since version 3.4: Use \texttt{loads()} instead.

\texttt{plistlib.writePlistToBytes(rootObject)}

Return \texttt{rootObject} as an XML plist-formatted bytes object.

\textit{Deprecated since version 3.4: Use \texttt{dumps()} instead.}

The following classes are available:

\textbf{Dict([dict]):}

Return an extended mapping object with the same value as dictionary \texttt{dict}.

This class is a subclass of \texttt{dict} where attribute access can be used to access items. That is, \texttt{aDict.key} is the same as \texttt{aDict['key']} for getting, setting and deleting items in the mapping.

\textit{Deprecated since version 3.0.}

\textbf{class \texttt{plistlib.Data(data)}}

Return a “data” wrapper object around the bytes object \texttt{data}. This is used in functions converting from/to plists to represent the \texttt{<data>} type available in plists.

It has one attribute, \texttt{data}, that can be used to retrieve the Python bytes object stored in it.

\textit{Deprecated since version 3.4: Use a \texttt{bytes} object instead.}
The following constants are available:

**plistlib.FMT_XML**

The XML format for plist files.

*New in version 3.4.*

**plistlib.FMT_BINARY**

The binary format for plist files

*New in version 3.4.*
14.5.1. Examples

Generating a plist:

```python
pl = dict(
    aString = "Doodah",
    aList = ["A", "B", 12, 32.1, [1, 2, 3]],
    aFloat = 0.1,
    anInt = 728,
    aDict = dict(
        anotherString = "<hello & hi there!>",
        aThirdString = "M\xe4ssig, Ma\xdf",
        aTrueValue = True,
        aFalseValue = False,
    ),
    someData = b"<binary gunk>",
    someMoreData = b"<lots of binary gunk>" * 10,
    aDate = datetime.datetime.fromtimestamp(time.mktime(time.gmtime()))
)
with open(fileName, 'wb') as fp:
    dump(pl, fp)
```

Parsing a plist:

```python
with open(fileName, 'rb') as fp:
    pl = load(fp)
print(pl["aKey"])
```
15. Cryptographic Services

The modules described in this chapter implement various algorithms of a cryptographic nature. They are available at the discretion of the installation. On Unix systems, the crypt module may also be available. Here’s an overview:

- **15.1. hashlib — Secure hashes and message digests**
  - 15.1.1. Hash algorithms
  - 15.1.2. Key derivation
- **15.2. hmac — Keyed-Hashing for Message Authentication**

Hardcore cypherpunks will probably find the cryptographic modules written by A.M. Kuchling of further interest; the package contains modules for various encryption algorithms, most notably AES. These modules are not distributed with Python but available separately. See the URL [http://www.pycrypto.org/](http://www.pycrypto.org/) for more information.
15.1. hashlib — Secure hashes and message digests

Source code: Lib/hashlib.py

This module implements a common interface to many different secure hash and message digest algorithms. Included are the FIPS secure hash algorithms SHA1, SHA224, SHA256, SHA384, and SHA512 (defined in FIPS 180-2) as well as RSA's MD5 algorithm (defined in Internet RFC 1321). The terms “secure hash” and “message digest” are interchangeable. Older algorithms were called message digests. The modern term is secure hash.

**Note:** If you want the adler32 or crc32 hash functions, they are available in the zlib module.

**Warning:** Some algorithms have known hash collision weaknesses, refer to the “See also” section at the end.
15.1.1. Hash algorithms

There is one constructor method named for each type of `hash`. All return a hash object with the same simple interface. For example: use `sha1()` to create a SHA1 hash object. You can now feed this object with `bytes-like objects` (normally `bytes`) using the `update()` method. At any point you can ask it for the `digest` of the concatenation of the data fed to it so far using the `digest()` or `hexdigest()` methods.

**Note:** For better multithreading performance, the Python `GIL` is released for data larger than 2047 bytes at object creation or on `update`.

**Note:** Feeding string objects into `update()` is not supported, as hashes work on bytes, not on characters.

Constructors for hash algorithms that are always present in this module are `md5()`, `sha1()`, `sha224()`, `sha256()`, `sha384()`, and `sha512()`. Additional algorithms may also be available depending upon the OpenSSL library that Python uses on your platform.

For example, to obtain the digest of the byte string `b'Nobody inspects the spammish repetition'`:

```python
>>> import hashlib
>>> m = hashlib.md5()
>>> m.update(b"Nobody inspects")
>>> m.update(b" the spammish repetition")
>>> m.digest()
b'\xbbd\x9c\x83\xdd\xa5\xc9\xdc\xc9\xa1\x8d
>>> m.digest_size
16
```
More condensed:

```python
>>> hashlib.sha224(b"Nobody inspects the spammish repetition"
'a4337bc45a8fc544c03f52dc550cd6e1e87021bc896588bd79e
```

`hashlib.new(name[, data])`

Is a generic constructor that takes the string name of the desired algorithm as its first parameter. It also exists to allow access to the above listed hashes as well as any other algorithms that your OpenSSL library may offer. The named constructors are much faster than `new()` and should be preferred.

Using `new()` with an algorithm provided by OpenSSL:

```python
>>> h = hashlib.new('ripemd160')
>>> h.update(b"Nobody inspects the spammish repetition"
'cc4a5ce1b3df48aec5d22d1f16b894a0b894eccc'
```

Hashlib provides the following constant attributes:

`hashlib.algorithms_guaranteed`

A set containing the names of the hash algorithms guaranteed to be supported by this module on all platforms.

*New in version 3.2.*

`hashlib.algorithms_available`

A set containing the names of the hash algorithms that are
available in the running Python interpreter. These names will be recognized when passed to `new()`. `algorithms_guaranteed` will always be a subset. The same algorithm may appear multiple times in this set under different names (thanks to OpenSSL).

*New in version 3.2.*

The following values are provided as constant attributes of the hash objects returned by the constructors:

`hash.digest_size`

- The size of the resulting hash in bytes.

`hash.block_size`

- The internal block size of the hash algorithm in bytes.

A hash object has the following attributes:

`hash.name`

- The canonical name of this hash, always lowercase and always suitable as a parameter to `new()` to create another hash of this type.

*Changed in version 3.4:* The name attribute has been present in CPython since its inception, but until Python 3.4 was not formally specified, so may not exist on some platforms.

A hash object has the following methods:

`hash.update(arg)`

- Update the hash object with the object `arg`, which must be interpretable as a buffer of bytes. Repeated calls are equivalent to a single call with the concatenation of all the arguments: `m.update(a); m.update(b)` is equivalent to `m.update(a+b).`
Changed in version 3.1: The Python GIL is released to allow other threads to run while hash updates on data larger than 2047 bytes is taking place when using hash algorithms supplied by OpenSSL.

hash.digest()
Return the digest of the data passed to the update() method so far. This is a bytes object of size digest_size which may contain bytes in the whole range from 0 to 255.

hash.hexdigest()
Like digest() except the digest is returned as a string object of double length, containing only hexadecimal digits. This may be used to exchange the value safely in email or other non-binary environments.

hash.copy()
Return a copy (“clone”) of the hash object. This can be used to efficiently compute the digests of data sharing a common initial substring.
15.1.2. Key derivation

Key derivation and key stretching algorithms are designed for secure password hashing. Naive algorithms such as sha1(password) are not resistant against brute-force attacks. A good password hashing function must be tunable, slow, and include a salt.

`hashlib.pbkdf2_hmac(name, password, salt, rounds, dklen=None)`

The function provides PKCS#5 password-based key derivation function 2. It uses HMAC as pseudorandom function.

The string name is the desired name of the hash digest algorithm for HMAC, e.g. ‘sha1’ or ‘sha256’. password and salt are interpreted as buffers of bytes. Applications and libraries should limit password to a sensible value (e.g. 1024). salt should be about 16 or more bytes from a proper source, e.g. os.urandom().

The number of rounds should be chosen based on the hash algorithm and computing power. As of 2013, at least 100,000 rounds of SHA-256 is suggested.

dklen is the length of the derived key. If dklen is None then the digest size of the hash algorithm name is used, e.g. 64 for SHA-512.

```python
>>> import hashlib, binascii
>>> dk = hashlib.pbkdf2_hmac('sha256', b'password', b'0394a2ede332c9a13eb82e9b24631604c31df978b4e2f0f
```

New in version 3.4.
Note: A fast implementation of `pbkdf2_hmac` is available with OpenSSL. The Python implementation uses an inline version of `hmac`. It is about three times slower and doesn’t release the GIL.

See also:

Module **hmac**
A module to generate message authentication codes using hashes.

Module **base64**
Another way to encode binary hashes for non-binary environments.

The FIPS 180-2 publication on Secure Hash Algorithms.

https://en.wikipedia.org/wiki/Cryptographic_hash_function#Crypt
Wikipedia article with information on which algorithms have known issues and what that means regarding their use.

http://www.ietf.org/rfc/rfc2898.txt
PKCS #5: Password-Based Cryptography Specification Version 2.0
15.2. **hmac** — Keyed-Hashing for Message Authentication

**Source code:** Lib/hmac.py

This module implements the HMAC algorithm as described by RFC 2104.

```python
hmac.new(key, msg=None, digestmod=None)
```

Return a new hmac object. `key` is a bytes or bytearray object giving the secret key. If `msg` is present, the method call `update(msg)` is made. `digestmod` is the digest name, digest constructor or module for the HMAC object to use. It supports any name suitable to `hashlib.new()` and defaults to the `hashlib.md5` constructor.

*Changed in version 3.4:* Parameter `key` can be a bytes or bytearray object. Parameter `msg` can be of any type supported by `hashlib`. Parameter `digestmod` can be the name of a hash algorithm.

*Deprecated since version 3.4:* MD5 as implicit default digest for `digestmod` is deprecated.

An HMAC object has the following methods:

**HMAC.update(msg)**

Update the hmac object with `msg`. Repeated calls are equivalent to a single call with the concatenation of all the arguments: `m.update(a); m.update(b)` is equivalent to `m.update(a + b)`. 
Changed in version 3.4: Parameter msg can be of any type supported by hashlib.

**HMAC.digest()**

Return the digest of the bytes passed to the `update()` method so far. This bytes object will be the same length as the `digest_size` of the digest given to the constructor. It may contain non-ASCII bytes, including NUL bytes.

**Warning:** When comparing the output of `digest()` to an externally-supplied digest during a verification routine, it is recommended to use the `compare_digest()` function instead of the `==` operator to reduce the vulnerability to timing attacks.

**HMAC.hexdigest()**

Like `digest()` except the digest is returned as a string twice the length containing only hexadecimal digits. This may be used to exchange the value safely in email or other non-binary environments.

**Warning:** When comparing the output of `hexdigest()` to an externally-supplied digest during a verification routine, it is recommended to use the `compare_digest()` function instead of the `==` operator to reduce the vulnerability to timing attacks.

**HMAC.copy()**

Return a copy (“clone”) of the hmac object. This can be used to efficiently compute the digests of strings that share a common initial substring.

A hash object has the following attributes:
**HMAC.digest_size**

The size of the resulting HMAC digest in bytes.

**HMAC.block_size**

The internal block size of the hash algorithm in bytes.

*New in version 3.4.*

**HMAC.name**

The canonical name of this HMAC, always lowercase, e.g. hmac-md5.

*New in version 3.4.*

This module also provides the following helper function:

**hmac.compare_digest(a, b)**

Return `a == b`. This function uses an approach designed to prevent timing analysis by avoiding content-based short circuiting behaviour, making it appropriate for cryptography. `a` and `b` must both be of the same type: either `str` (ASCII only, as e.g. returned by `HMAC.hexdigest()`), or a bytes-like object.

**Note:** If `a` and `b` are of different lengths, or if an error occurs, a timing attack could theoretically reveal information about the types and lengths of `a` and `b`–but not their values.

*New in version 3.3.*

**See also:**

**Module** `hashlib`

The Python module providing secure hash functions.
16. Generic Operating System Services

The modules described in this chapter provide interfaces to operating system features that are available on (almost) all operating systems, such as files and a clock. The interfaces are generally modeled after the Unix or C interfaces, but they are available on most other systems as well. Here’s an overview:

- **16.1. os — Miscellaneous operating system interfaces**
  - 16.1.1. File Names, Command Line Arguments, and Environment Variables
  - 16.1.2. Process Parameters
  - 16.1.3. File Object Creation
  - 16.1.4. File Descriptor Operations
    - 16.1.4.1. Querying the size of a terminal
    - 16.1.4.2. Inheritance of File Descriptors
  - 16.1.5. Files and Directories
    - 16.1.5.1. Linux extended attributes
  - 16.1.6. Process Management
  - 16.1.7. Interface to the scheduler
  - 16.1.8. Miscellaneous System Information
  - 16.1.9. Miscellaneous Functions

- **16.2. io — Core tools for working with streams**
  - 16.2.1. Overview
    - 16.2.1.1. Text I/O
    - 16.2.1.2. Binary I/O
    - 16.2.1.3. Raw I/O
  - 16.2.2. High-level Module Interface
    - 16.2.2.1. In-memory streams
  - 16.2.3. Class hierarchy
- 16.2.3.1. I/O Base Classes
- 16.2.3.2. Raw File I/O
- 16.2.3.3. Buffered Streams
- 16.2.3.4. Text I/O
- 16.2.4. Performance
  - 16.2.4.1. Binary I/O
  - 16.2.4.2. Text I/O
  - 16.2.4.3. Multi-threading
  - 16.2.4.4. Reentrancy
- 16.3. time — Time access and conversions
- 16.4. argparse — Parser for command-line options, arguments and sub-commands
  - 16.4.1. Example
    - 16.4.1.1. Creating a parser
    - 16.4.1.2. Adding arguments
    - 16.4.1.3. Parsing arguments
  - 16.4.2. ArgumentParser objects
    - 16.4.2.1. prog
    - 16.4.2.2. usage
    - 16.4.2.3. description
    - 16.4.2.4. epilog
    - 16.4.2.5. parents
    - 16.4.2.6. formatter_class
    - 16.4.2.7. prefix_chars
    - 16.4.2.8. fromfile_prefix_chars
    - 16.4.2.9. argument_default
    - 16.4.2.10. allow_abbrev
    - 16.4.2.11. conflict_handler
    - 16.4.2.12. add_help
  - 16.4.3. The add_argument() method
    - 16.4.3.1. name or flags
    - 16.4.3.2. action
    - 16.4.3.3. nargs
    - 16.4.3.4. const
- 16.4.3.5. default
- 16.4.3.6. type
- 16.4.3.7. choices
- 16.4.3.8. required
- 16.4.3.9. help
- 16.4.3.10. metavar
- 16.4.3.11. dest
- 16.4.3.12. Action classes
  - 16.4.4. The parse_args() method
    - 16.4.4.1. Option value syntax
    - 16.4.4.2. Invalid arguments
    - 16.4.4.3. Arguments containing `-`
    - 16.4.4.4. Argument abbreviations (prefix matching)
    - 16.4.4.5. Beyond `sys.argv`
    - 16.4.4.6. The Namespace object
  - 16.4.5. Other utilities
    - 16.4.5.1. Sub-commands
    - 16.4.5.2. FileType objects
    - 16.4.5.3. Argument groups
    - 16.4.5.4. Mutual exclusion
    - 16.4.5.5. Parser defaults
    - 16.4.5.6. Printing help
    - 16.4.5.7. Partial parsing
    - 16.4.5.8. Customizing file parsing
    - 16.4.5.9. Exiting methods
  - 16.4.6. Upgrading optparse code
- 16.5. `getopt` — C-style parser for command line options
- 16.6. `logging` — Logging facility for Python
  - 16.6.1. Logger Objects
  - 16.6.2. Logging Levels
  - 16.6.3. Handler Objects
  - 16.6.4. Formatter Objects
  - 16.6.5. Filter Objects
  - 16.6.6. LogRecord Objects
• 16.6.7. LogRecord attributes
• 16.6.8. LoggerAdapter Objects
• 16.6.9. Thread Safety
• 16.6.10. Module-Level Functions
• 16.6.11. Module-Level Attributes
• 16.6.12. Integration with the warnings module

• 16.7. logging.config — Logging configuration
  • 16.7.1. Configuration functions
  • 16.7.2. Configuration dictionary schema
    ■ 16.7.2.1. Dictionary Schema Details
    ■ 16.7.2.2. Incremental Configuration
    ■ 16.7.2.3. Object connections
    ■ 16.7.2.4. User-defined objects
    ■ 16.7.2.5. Access to external objects
    ■ 16.7.2.6. Access to internal objects
    ■ 16.7.2.7. Import resolution and custom importers
  • 16.7.3. Configuration file format

• 16.8. logging.handlers — Logging handlers
  • 16.8.1. StreamHandler
  • 16.8.2. FileHandler
  • 16.8.3. NullHandler
  • 16.8.4. WatchedFileHandler
  • 16.8.5. BaseRotatingHandler
  • 16.8.6. RotatingFileHandler
  • 16.8.7. TimedRotatingFileHandler
  • 16.8.8. SocketHandler
  • 16.8.9. DatagramHandler
  • 16.8.10. SysLogHandler
  • 16.8.11. NTEventLogHandler
  • 16.8.12. SMTPHandler
  • 16.8.13. MemoryHandler
  • 16.8.14. HTTPHandler
  • 16.8.15. QueueHandler
  • 16.8.16. QueueListener
• 16.9. getpass — Portable password input
• 16.10. curses — Terminal handling for character-cell displays
  o 16.10.1. Functions
  o 16.10.2. Window Objects
  o 16.10.3. Constants
• 16.11. curses.textpad — Text input widget for curses programs
  o 16.11.1. Textbox objects
• 16.12. curses.ascii — Utilities for ASCII characters
• 16.13. curses.panel — A panel stack extension for curses
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16.1. **os** — Miscellaneous operating system interfaces

This module provides a portable way of using operating system dependent functionality. If you just want to read or write a file see `open()`, if you want to manipulate paths, see the `os.path` module, and if you want to read all the lines in all the files on the command line see the `fileinput` module. For creating temporary files and directories see the `tempfile` module, and for high-level file and directory handling see the `shutil` module.

Notes on the availability of these functions:

- The design of all built-in operating system dependent modules of Python is such that as long as the same functionality is available, it uses the same interface; for example, the function `os.stat(path)` returns stat information about `path` in the same format (which happens to have originated with the POSIX interface).
- Extensions peculiar to a particular operating system are also available through the `os` module, but using them is of course a threat to portability.
- All functions accepting path or file names accept both bytes and string objects, and result in an object of the same type, if a path or file name is returned.
- An “Availability: Unix” note means that this function is commonly found on Unix systems. It does not make any claims about its existence on a specific operating system.
- If not separately noted, all functions that claim “Availability: Unix” are supported on Mac OS X, which builds on a Unix core.
**Note:** All functions in this module raise `OSError` in the case of invalid or inaccessible file names and paths, or other arguments that have the correct type, but are not accepted by the operating system.

```python
exception os.error
```

An alias for the built-in `OSError` exception.

```python
os.name
```

The name of the operating system dependent module imported. The following names have currently been registered: 'posix', 'nt', 'ce', 'java'.

**See also:** `sys.platform` has a finer granularity. `os.uname()` gives system-dependent version information. The `platform` module provides detailed checks for the system's identity.
16.1.1. File Names, Command Line Arguments, and Environment Variables

In Python, file names, command line arguments, and environment variables are represented using the string type. On some systems, decoding these strings to and from bytes is necessary before passing them to the operating system. Python uses the file system encoding to perform this conversion (see `sys.getfilesystemencoding()`).

*Changed in version 3.1:* On some systems, conversion using the file system encoding may fail. In this case, Python uses the surrogateescape encoding error handler, which means that undecodable bytes are replaced by a Unicode character U+DCxx on decoding, and these are again translated to the original byte on encoding.

The file system encoding must guarantee to successfully decode all bytes below 128. If the file system encoding fails to provide this guarantee, API functions may raise UnicodeErrors.
16.1.2. Process Parameters

These functions and data items provide information and operate on the current process and user.

**os.ctermid()**

Return the filename corresponding to the controlling terminal of the process.

Availability: Unix.

**os.environ**

A mapping object representing the string environment. For example, environ['HOME'] is the pathname of your home directory (on some platforms), and is equivalent to getenv("HOME") in C.

This mapping is captured the first time the `os` module is imported, typically during Python startup as part of processing site.py. Changes to the environment made after this time are not reflected in `os.environ`, except for changes made by modifying `os.environ` directly.

If the platform supports the `putenv()` function, this mapping may be used to modify the environment as well as query the environment. `putenv()` will be called automatically when the mapping is modified.

On Unix, keys and values use `sys.getfilesystemencoding()` and 'surrogateescape' error handler. Use `environb` if you would like to use a different encoding.
**Note:** Calling `putenv()` directly does not change `os.environ`, so it's better to modify `os.environ`.

**Note:** On some platforms, including FreeBSD and Mac OS X, setting `environ` may cause memory leaks. Refer to the system documentation for `putenv()`.

If `putenv()` is not provided, a modified copy of this mapping may be passed to the appropriate process-creation functions to cause child processes to use a modified environment.

If the platform supports the `unsetenv()` function, you can delete items in this mapping to unset environment variables. `unsetenv()` will be called automatically when an item is deleted from `os.environ`, and when one of the `pop()` or `clear()` methods is called.

**os.environb**

Bytes version of `environ`: a `mapping` object representing the environment as byte strings. `environ` and `environb` are synchronized (modify `environb` updates `environ`, and vice versa).

`environb` is only available if `supports_bytes_environ` is `True`.

*New in version 3.2.*

**os.chdir(path)**

**os.fchdir(fd)**

**os.getcwd()**

These functions are described in *Files and Directories.*
os.\texttt{fsencode(filename)}
Encode \texttt{filename} to the filesystem encoding with 'surrogateescape' error handler, or 'strict' on Windows; return \texttt{bytes} unchanged.

\texttt{fsdecode()} is the reverse function.

New in version 3.2.

os.\texttt{fsdecode(filename)}
Decode \texttt{filename} from the filesystem encoding with 'surrogateescape' error handler, or 'strict' on Windows; return \texttt{str} unchanged.

\texttt{fsencode()} is the reverse function.

New in version 3.2.

os.\texttt{getenv(key, default=None)}
Return the value of the environment variable \texttt{key} if it exists, or \texttt{default} if it doesn't. \texttt{key, default} and the result are \texttt{str}.

On Unix, keys and values are decoded with \texttt{sys.getfilesystemencoding()} and 'surrogateescape' error handler. Use \texttt{os.getenvb()} if you would like to use a different encoding.

Availability: most flavors of Unix, Windows.

os.\texttt{getenvb(key, default=None)}
Return the value of the environment variable \texttt{key} if it exists, or \texttt{default} if it doesn't. \texttt{key, default} and the result are \texttt{bytes}. 
Availability: most flavors of Unix.

*New in version 3.2.*

**os.get_exec_path(env=None)**

Returns the list of directories that will be searched for a named executable, similar to a shell, when launching a process. `env`, when specified, should be an environment variable dictionary to lookup the PATH in. By default, when `env` is None, `environ` is used.

*New in version 3.2.*

**os.getegid()**

Return the effective group id of the current process. This corresponds to the “set id” bit on the file being executed in the current process.

Availability: Unix.

**os.geteuid()**

Return the current process’s effective user id.

Availability: Unix.

**os.getgid()**

Return the real group id of the current process.

Availability: Unix.

**os.getgrouplist(user, group)**

Return list of group ids that `user` belongs to. If `group` is not in the list, it is included; typically, `group` is specified as the group ID field from the password record for `user`.
Availability: Unix.

New in version 3.3.

**os.getgroups()**

Return list of supplemental group ids associated with the current process.

Availability: Unix.

**Note:** On Mac OS X, `getgroups()` behavior differs somewhat from other Unix platforms. If the Python interpreter was built with a deployment target of 10.5 or earlier, `getgroups()` returns the list of effective group ids associated with the current user process; this list is limited to a system-defined number of entries, typically 16, and may be modified by calls to `setgroups()` if suitably privileged. If built with a deployment target greater than 10.5, `getgroups()` returns the current group access list for the user associated with the effective user id of the process; the group access list may change over the lifetime of the process, it is not affected by calls to `setgroups()`, and its length is not limited to 16. The deployment target value, MACOSX_DEPLOYMENT_TARGET, can be obtained with `sysconfig.get_config_var()`.

**os.getlogin()**

Return the name of the user logged in on the controlling terminal of the process. For most purposes, it is more useful to use the environment variables LOGNAME or USERNAME to find out who the user is, or `pwd.getpwuid(os.getuid())[0]` to get the login name of the current real user id.
Availability: Unix, Windows.

**os.getpgid(pid)**

Return the process group id of the process with process id `pid`. If `pid` is 0, the process group id of the current process is returned.

Availability: Unix.

**os.getpgrp()**

Return the id of the current process group.

Availability: Unix.

**os.getpid()**

Return the current process id.

**os.getppid()**

Return the parent's process id. When the parent process has exited, on Unix the id returned is the one of the init process (1), on Windows it is still the same id, which may be already reused by another process.

Availability: Unix, Windows.

*Changed in version 3.2:* Added support for Windows.

**os.getpriority(which, who)**

Get program scheduling priority. The value `which` is one of `PRI0_PROCESS`, `PRI0_PGRP`, or `PRI0_USER`, and `who` is interpreted relative to `which` (a process identifier for `PRI0_PROCESS`, process group identifier for `PRI0_PGRP`, and a user ID for `PRI0_USER`). A zero value for `who` denotes (respectively) the calling process, the process group of the calling
process, or the real user ID of the calling process.

Availability: Unix.

*New in version 3.3.*

**os.PRI0_PROCESS**
**os.PRI0_PGRP**
**os.PRI0_USER**
Parameters for the `getpriority()` and `setpriority()` functions.

Availability: Unix.

*New in version 3.3.*

**os.getresuid()**
Return a tuple (ruid, euid, suid) denoting the current process’s real, effective, and saved user ids.

Availability: Unix.

*New in version 3.2.*

**os.getresgid()**
Return a tuple (rgid, egid, sgid) denoting the current process’s real, effective, and saved group ids.

Availability: Unix.

*New in version 3.2.*

**os.getuid()**
Return the current process’s real user id.
Availability: Unix.

**os.initgroups(username, gid)**
Call the system initgroups() to initialize the group access list with all of the groups of which the specified username is a member, plus the specified group id.

Availability: Unix.

*New in version 3.2.*

**os.putenv(key, value)**
Set the environment variable named key to the string value. Such changes to the environment affect subprocesses started with `os.system()`, `popen()` or `fork()` and `execv()`.

Availability: most flavors of Unix, Windows.

**Note:** On some platforms, including FreeBSD and Mac OS X, setting `environ` may cause memory leaks. Refer to the system documentation for `putenv`.

When `putenv()` is supported, assignments to items in `os.environ` are automatically translated into corresponding calls to `putenv()`; however, calls to `putenv()` don’t update `os.environ`, so it is actually preferable to assign to items of `os.environ`.

**os.setegid(egid)**
Set the current process’s effective group id.

Availability: Unix.
**os.seteuid(euid)**
Set the current process's effective user id.

Availability: Unix.

**os.setgid(gid)**
Set the current process' group id.

Availability: Unix.

**os.setgroups(groups)**
Set the list of supplemental group ids associated with the current process to groups. groups must be a sequence, and each element must be an integer identifying a group. This operation is typically available only to the superuser.

Availability: Unix.

**Note:** On Mac OS X, the length of groups may not exceed the system-defined maximum number of effective group ids, typically 16. See the documentation for getgroups() for cases where it may not return the same group list set by calling setgroups().

**os.setpgrp()**
Call the system call setpgrp() or setpgrp(0, 0) depending on which version is implemented (if any). See the Unix manual for the semantics.

Availability: Unix.

**os.setpgid(pid, pgrp)**
Call the system call setpgid() to set the process group id of the process with id pid to the process group with id pgrp. See the Unix
manual for the semantics.

Availability: Unix.

**os**. `setpriority(which, who, priority)`

Set program scheduling priority. The value `which` is one of `PRI0_PROCESS`, `PRI0_PGRP`, or `PRI0_USER`, and `who` is interpreted relative to `which` (a process identifier for `PRI0_PROCESS`, process group identifier for `PRI0_PGRP`, and a user ID for `PRI0_USER`). A zero value for `who` denotes (respectively) the calling process, the process group of the calling process, or the real user ID of the calling process. `priority` is a value in the range -20 to 19. The default priority is 0; lower priorities cause more favorable scheduling.

Availability: Unix  
*New in version 3.3.*

**os**. `setregid(rgid, egid)`

Set the current process’s real and effective group ids.

Availability: Unix.

**os**. `setresgid(rgid, egid, sgid)`

Set the current process’s real, effective, and saved group ids.

Availability: Unix  
*New in version 3.2.*

**os**. `setresuid(ruid, euid, suid)`

Set the current process’s real, effective, and saved user ids.
Availability: Unix.

New in version 3.2.

**os.setreuid(ruid, euid)**
Set the current process's real and effective user ids.

Availability: Unix.

**os.getsid(pid)**
Call the system call getsid(). See the Unix manual for the semantics.

Availability: Unix.

**os.setsid()**
Call the system call setsid(). See the Unix manual for the semantics.

Availability: Unix.

**os.setuid(uid)**
Set the current process's user id.

Availability: Unix.

**os.strerror(code)**
Return the error message corresponding to the error code in code. On platforms where strerror() returns NULL when given an unknown error number, ValueError is raised.

**os.supports_bytes_environ**
True if the native OS type of the environment is bytes (eg. False on Windows).
New in version 3.2.

**os.umask(mask)**
Set the current numeric umask and return the previous umask.

**os.uname()**
Returns information identifying the current operating system. The return value is an object with five attributes:

- sysname - operating system name
- nodename - name of machine on network (implementation-defined)
- release - operating system release
- version - operating system version
- machine - hardware identifier

For backwards compatibility, this object is also iterable, behaving like a five-tuple containing sysname, nodename, release, version, and machine in that order.

Some systems truncate nodename to 8 characters or to the leading component; a better way to get the hostname is socket.gethostname() or even socket.gethostbyaddr(socket.gethostname()).

Availability: recent flavors of Unix.

*Changed in version 3.3*: Return type changed from a tuple to a tuple-like object with named attributes.

**os.unsetenv(key)**
Unset (delete) the environment variable named key. Such changes to the environment affect subprocesses started with os.system(), popen() or fork() and execv().
When `unsetenv()` is supported, deletion of items in `os.environ` is automatically translated into a corresponding call to `unsetenv()`; however, calls to `unsetenv()` don’t update `os.environ`, so it is actually preferable to delete items of `os.environ`.

Availability: most flavors of Unix, Windows.
16.1.3. File Object Creation

This function creates new file objects. (See also open() for opening file descriptors.)

```
fdopen(fd, *args, **kwargs)
```

Return an open file object connected to the file descriptor `fd`. This is an alias of the `open()` built-in function and accepts the same arguments. The only difference is that the first argument of `fdopen()` must always be an integer.
16.1.4. File Descriptor Operations

These functions operate on I/O streams referenced using file descriptors.

File descriptors are small integers corresponding to a file that has been opened by the current process. For example, standard input is usually file descriptor 0, standard output is 1, and standard error is 2. Further files opened by a process will then be assigned 3, 4, 5, and so forth. The name “file descriptor” is slightly deceptive; on Unix platforms, sockets and pipes are also referenced by file descriptors.

The `fileno()` method can be used to obtain the file descriptor associated with a file object when required. Note that using the file descriptor directly will bypass the file object methods, ignoring aspects such as internal buffering of data.

`os.close(fd)`

Close file descriptor `fd`.

**Note:** This function is intended for low-level I/O and must be applied to a file descriptor as returned by `os.open()` or `pipe()`. To close a “file object” returned by the built-in function `open()` or by `popen()` or `fdopen()`, use its `close()` method.

`os.closerange(fd_low, fd_high)`

Close all file descriptors from `fd_low` (inclusive) to `fd_high` (exclusive), ignoring errors. Equivalent to (but much faster than):

```python
for fd in range(fd_low, fd_high):
    try:
        os.close(fd)
```
except OSError:
    pass

os.device_encoding(fd)
    Return a string describing the encoding of the device associated
    with fd if it is connected to a terminal; else return None.

os.dup(fd)
    Return a duplicate of file descriptor fd. The new file descriptor is
    non-inheritable.

    On Windows, when duplicating a standard stream (0: stdin, 1:
    stdout, 2: stderr), the new file descriptor is inheritable.

    Changed in version 3.4: The new file descriptor is now non-
    inheritable.

os.dup2(fd, fd2, inheritable=True)
    Duplicate file descriptor fd to fd2, closing the latter first if necessary.
    The file descriptor fd2 is inheritable by default, or non-inheritable if
    inheritable is False.

    Changed in version 3.4: Add the optional inheritable parameter.

os.fchmod(fd, mode)
    Change the mode of the file given by fd to the numeric mode. See
    the docs for chmod() for possible values of mode. As of Python
    3.3, this is equivalent to os.chmod(fd, mode).

    Availability: Unix.

os.fchown(fd, uid, gid)
    Change the owner and group id of the file given by fd to the
numeric *uid* and *gid*. To leave one of the ids unchanged, set it to -1. See *chown()*). As of Python 3.3, this is equivalent to *os.chown*(fd, uid, gid).

Availability: Unix.

**os.fdatasync**(fd)

Force write of file with file descriptor *fd* to disk. Does not force update of metadata.

Availability: Unix.

**Note:** This function is not available on MacOS.

**os.fpathconf**(fd, name)

Return system configuration information relevant to an open file. *name* specifies the configuration value to retrieve; it may be a string which is the name of a defined system value; these names are specified in a number of standards (POSIX.1, Unix 95, Unix 98, and others). Some platforms define additional names as well. The names known to the host operating system are given in the *pathconf_names* dictionary. For configuration variables not included in that mapping, passing an integer for *name* is also accepted.

If *name* is a string and is not known, *ValueError* is raised. If a specific value for *name* is not supported by the host system, even if it is included in *pathconf_names*, an *OSError* is raised with *errno.EINVAL* for the error number.

As of Python 3.3, this is equivalent to *os.pathconf*(fd, name).

Availability: Unix.
**os.fstat(fd)**

Get the status of the file descriptor `fd`. Return a `stat_result` object.

As of Python 3.3, this is equivalent to `os.stat(fd)`.

**See also:** The `stat()` function.

**os.fstatvfs(fd)**

Return information about the filesystem containing the file associated with file descriptor `fd`, like `statvfs()`. As of Python 3.3, this is equivalent to `os.statvfs(fd)`.

Availability: Unix.

**os.fsync(fd)**

Force write of file with filedescriptor `fd` to disk. On Unix, this calls the native `fsync()` function; on Windows, the MS _commit() function.

If you're starting with a buffered Python file object `f`, first do `f.flush()`, and then do `os.fsync(f.fileno())`, to ensure that all internal buffers associated with `f` are written to disk.

Availability: Unix, Windows.

**os.ftruncate(fd, length)**

Truncate the file corresponding to file descriptor `fd`, so that it is at most `length` bytes in size. As of Python 3.3, this is equivalent to `os.truncate(fd, length)`.

Availability: Unix, Windows.
Changed in version 3.5: Added support for Windows

**os.get_blocking(fd)**

Get the blocking mode of the file descriptor: False if the 0_NONBLOCK flag is set, True if the flag is cleared.

See also `set_blocking()` and `socket.socket.setblocking()`.

Availability: Unix.

*New in version 3.5.*

**os.isatty(fd)**

Return True if the file descriptor `fd` is open and connected to a tty(-like) device, else False.

**os.lockf(fd, cmd, len)**

Apply, test or remove a POSIX lock on an open file descriptor. `fd` is an open file descriptor. `cmd` specifies the command to use - one of `F_LOCK`, `F_TLOCK`, `F_ULOCK` or `F_TEST`. `len` specifies the section of the file to lock.

Availability: Unix.

*New in version 3.3.*

**os.F_LOCK**

**os.F_TLOCK**

**os.F_ULOCK**

**os.F_TEST**

Flags that specify what action `lockf()` will take.

Availability: Unix.
New in version 3.3.

**os.lseek(fd, pos, how)**

Set the current position of file descriptor `fd` to position `pos`, modified by `how`: `SEEK_SET` or 0 to set the position relative to the beginning of the file; `SEEK_CUR` or 1 to set it relative to the current position; `SEEK_END` or 2 to set it relative to the end of the file. Return the new cursor position in bytes, starting from the beginning.

**os.SEEK_SET**
**os.SEEK_CUR**
**os.SEEK_END**

Parameters to the `lseek()` function. Their values are 0, 1, and 2, respectively.

New in version 3.3: Some operating systems could support additional values, like `os.SEEK_HOLE` or `os.SEEK_DATA`.

**os.open(path, flags, mode=0o777, *, dir_fd=None)**

Open the file `path` and set various flags according to `flags` and possibly its mode according to `mode`. When computing `mode`, the current umask value is first masked out. Return the file descriptor for the newly opened file. The new file descriptor is non-inheritable.

For a description of the flag and mode values, see the C run-time documentation; flag constants (like `O_RDONLY` and `O_WRONLY`) are defined in the `os` module. In particular, on Windows adding `O_BINARY` is needed to open files in binary mode.

This function can support paths relative to directory descriptors with the `dir_fd` parameter.

Changed in version 3.4: The new file descriptor is now non-
inheritable.

**Note:** This function is intended for low-level I/O. For normal usage, use the built-in function `open()`, which returns a file object with `read()` and `write()` methods (and many more). To wrap a file descriptor in a file object, use `fdopen()`.

*New in version 3.3:* The `dir_fd` argument.

*Changed in version 3.5:* If the system call is interrupted and the signal handler does not raise an exception, the function now retries the system call instead of raising an `InterruptedError` exception (see PEP 475 for the rationale).

The following constants are options for the `flags` parameter to the `open()` function. They can be combined using the bitwise OR operator `|`. Some of them are not available on all platforms. For descriptions of their availability and use, consult the `open(2)` manual page on Unix or the MSDN on Windows.

```python
os.O_RDONLY
os.O_WRONLY
os.O_RDWR
os.O_APPEND
os.O_CREAT
os.O_EXCL
os.O_TRUNC
```

These constants are available on Unix and Windows.

```python
os.O_DSYNC
os.O_RSYNC
os.O_SYNC
os.O_NDELAY
```
os._NONBLOCK
os._NOCTTY
os._SHLOCK
os._EXLOCK
os._CLOEXEC

These constants are only available on Unix.

*Changed in version 3.3:* Add 0_CLOEXEC constant.

os.__BINARY
os._NOINHERIT
os._SHORT_LIVED
os._TEMPORARY
os._RANDOM
os._SEQUENTIAL
os._TEXT

These constants are only available on Windows.

os._ASYNC
os._DIRECT
os._DIRECTORY
os._NOFOLLOW
os._NOATIME
os._PATH
os._TMPFILE

These constants are GNU extensions and not present if they are not defined by the C library.

*Changed in version 3.4:* Add 0_PATH on systems that support it. Add 0_TMPFILE, only available on Linux Kernel 3.11 or newer.

os.openpty()

Open a new pseudo-terminal pair. Return a pair of file descriptors.
(master, slave) for the pty and the tty, respectively. The new file descriptors are non-inheritable. For a (slightly) more portable approach, use the pty module.

Availability: some flavors of Unix.

*Changed in version 3.4:* The new file descriptors are now non-inheritable.

**os.pipe()**
Create a pipe. Return a pair of file descriptors \((r, w)\) usable for reading and writing, respectively. The new file descriptor is non-inheritable.

Availability: Unix, Windows.

*Changed in version 3.4:* The new file descriptors are now non-inheritable.

**os.pipe2(flags)**
Create a pipe with flags set atomically. flags can be constructed by ORing together one or more of these values: 0_NONBLOCK, 0_CLOEXEC. Return a pair of file descriptors \((r, w)\) usable for reading and writing, respectively.

Availability: some flavors of Unix.

*New in version 3.3.*

**os.posix_fallocate(fd, offset, len)**
Ensures that enough disk space is allocated for the file specified by \(fd\) starting from \(offset\) and continuing for \(len\) bytes.

Availability: Unix.
New in version 3.3.

```python
os.posix_fadvise(fd, offset, len, advice)
```
Announces an intention to access data in a specific pattern thus allowing the kernel to make optimizations. The advice applies to the region of the file specified by `fd` starting at `offset` and continuing for `len` bytes. `advice` is one of `POSIX_FADV_NORMAL`, `POSIX_FADV_SEQUENTIAL`, `POSIX_FADV_RANDOM`, `POSIX_FADV_NOREUSE`, `POSIX_FADV_WILLNEED` or `POSIX_FADV_DONTNEED`.

Availability: Unix.

New in version 3.3.

```python
os.POSIX_FADV_NORMAL
os.POSIX_FADV_SEQUENTIAL
os.POSIX_FADV_RANDOM
os.POSIX_FADV_NOREUSE
os.POSIX_FADV_WILLNEED
os.POSIX_FADV_DONTNEED
```
Flags that can be used in `advice` in `posix_fadvise()` that specify the access pattern that is likely to be used.

Availability: Unix.

New in version 3.3.

```python
os.pread(fd, buffersize, offset)
```
Read from a file descriptor, `fd`, at a position of `offset`. It will read up to `buffersize` number of bytes. The file offset remains unchanged.

Availability: Unix.
**New in version 3.3.**

**os.pwrite(fd, str, offset)**

Write bytestring to a file descriptor, *fd*, from offset, leaving the file offset unchanged.

*Availability: Unix.*

**New in version 3.3.**

**os.read(fd, n)**

Read at most *n* bytes from file descriptor *fd*. Return a bytestring containing the bytes read. If the end of the file referred to by *fd* has been reached, an empty bytes object is returned.

**Note:** This function is intended for low-level I/O and must be applied to a file descriptor as returned by *os.open()* or *pipe().* To read a “file object” returned by the built-in function *open()* or by *popen()* or *fdopen(),* or *sys.stdin,* use its *read()* or *readline()* methods.

*Changed in version 3.5:* If the system call is interrupted and the signal handler does not raise an exception, the function now retries the system call instead of raising an *InterruptedError* exception (see *PEP 475* for the rationale).

**os.sendfile(out, in, offset, count)**

**os.sendfile(out, in, offset, count, [headers, ]trailers, )flags=0)**

Copy *count* bytes from file descriptor *in* to file descriptor *out* starting at *offset*. Return the number of bytes sent. When EOF is reached return 0.

The first function notation is supported by all platforms that define
sendfile().

On Linux, if offset is given as None, the bytes are read from the current position of in and the position of in is updated.

The second case may be used on Mac OS X and FreeBSD where headers and trailers are arbitrary sequences of buffers that are written before and after the data from in is written. It returns the same as the first case.

On Mac OS X and FreeBSD, a value of 0 for count specifies to send until the end of in is reached.

All platforms support sockets as out file descriptor, and some platforms allow other types (e.g. regular file, pipe) as well.

Cross-platform applications should not use headers, trailers and flags arguments.

Availability: Unix.

Note: For a higher-level wrapper of sendfile(), see socket.socket.sendfile().

New in version 3.3.

os.set_blocking(fd, blocking)

Set the blocking mode of the specified file descriptor. Set the O_NONBLOCK flag if blocking is False, clear the flag otherwise.

See also get_blocking() and socket.socket.setblocking().

Availability: Unix.
New in version 3.5.

**os.SF_NODISKIO**
**os.SF_MNOWAIT**
**os.SF_SYNC**
Parameters to the `sendfile()` function, if the implementation supports them.

Availability: Unix.

New in version 3.3.

**os.readv(fd, buffers)**
Read from a file descriptor `fd` into a number of mutable `bytes-like objects` `buffers`. `readv()` will transfer data into each buffer until it is full and then move on to the next buffer in the sequence to hold the rest of the data. `readv()` returns the total number of bytes read (which may be less than the total capacity of all the objects).

Availability: Unix.

New in version 3.3.

**os.tcgetpgrp(fd)**
Return the process group associated with the terminal given by `fd` (an open file descriptor as returned by `os.open()`).

Availability: Unix.

**os.tcsetpgrp(fd, pg)**
Set the process group associated with the terminal given by `fd` (an open file descriptor as returned by `os.open()`) to `pg`.

Availability: Unix.
**os.TTYNAME(fd)**

Return a string which specifies the terminal device associated with file descriptor *fd*. If *fd* is not associated with a terminal device, an exception is raised.

Availability: Unix.

**os.WRITE(fd, str)**

Write the bytestring in *str* to file descriptor *fd*. Return the number of bytes actually written.

**Note:** This function is intended for low-level I/O and must be applied to a file descriptor as returned by os.open() or pipe(). To write a “file object” returned by the built-in function open() or by popen() or fdopen(), or sys.stdout or sys.stderr, use its write() method.

*Changed in version 3.5:* If the system call is interrupted and the signal handler does not raise an exception, the function now retries the system call instead of raising an InterruptedError exception (see PEP 475 for the rationale).

**os.WRITEV(fd, buffers)**

Write the contents of *buffers* to file descriptor *fd*. *buffers* must be a sequence of bytes-like objects. writev() writes the contents of each object to the file descriptor and returns the total number of bytes written.

Availability: Unix.

*New in version 3.3.*
16.1.4.1. Querying the size of a terminal

*New in version 3.3.*

**os.get_terminal_size(fd=STDOUT_FILENO)**

Return the size of the terminal window as (columns, lines),
tuple of type `terminal_size`.

The optional argument `fd` (default STDOUT_FILENO, or standard output) specifies which file descriptor should be queried.

If the file descriptor is not connected to a terminal, an `OSError` is raised.

`shutil.get_terminal_size()` is the high-level function which
should normally be used, `os.get_terminal_size` is the low-level implementation.

Availability: Unix, Windows.

**class os.terminal_size**

A subclass of tuple, holding (columns, lines) of the terminal
window size.

**columns**

Width of the terminal window in characters.

**lines**

Height of the terminal window in characters.

16.1.4.2. Inheritance of File Descriptors
New in version 3.4.

A file descriptor has an “inheritable” flag which indicates if the file descriptor can be inherited by child processes. Since Python 3.4, file descriptors created by Python are non-inheritable by default.

On UNIX, non-inheritable file descriptors are closed in child processes at the execution of a new program, other file descriptors are inherited.

On Windows, non-inheritable handles and file descriptors are closed in child processes, except for standard streams (file descriptors 0, 1 and 2: stdin, stdout and stderr), which are always inherited. Using spawn* functions, all inheritable handles and all inheritable file descriptors are inherited. Using the subprocess module, all file descriptors except standard streams are closed, and inheritable handles are only inherited if the close_fds parameter is False.

\[\text{os.} \text{get\_inheritable}(\text{fd})\]  
Get the “inheritable” flag of the specified file descriptor (a boolean).

\[\text{os.} \text{set\_inheritable}(\text{fd}, \text{inheritable})\]  
Set the “inheritable” flag of the specified file descriptor.

\[\text{os.} \text{get\_handle\_inheritable}(\text{handle})\]  
Get the “inheritable” flag of the specified handle (a boolean).

Availability: Windows.

\[\text{os.} \text{set\_handle\_inheritable}(\text{handle}, \text{inheritable})\]  
Set the “inheritable” flag of the specified handle.

Availability: Windows.
16.1.5. Files and Directories

On some Unix platforms, many of these functions support one or more of these features:

- **specifying a file descriptor:** For some functions, the *path* argument can be not only a string giving a path name, but also a file descriptor. The function will then operate on the file referred to by the descriptor. (For POSIX systems, Python will call the f... version of the function.)

  You can check whether or not *path* can be specified as a file descriptor on your platform using `os.supports_fd`. If it is unavailable, using it will raise a `NotImplementedError`.

  If the function also supports `dir_fd` or `follow_symlinks` arguments, it is an error to specify one of those when supplying *path* as a file descriptor.

- **paths relative to directory descriptors:** If `dir_fd` is not None, it should be a file descriptor referring to a directory, and the path to operate on should be relative; path will then be relative to that directory. If the path is absolute, `dir_fd` is ignored. (For POSIX systems, Python will call the ...at or f...at version of the function.)

  You can check whether or not `dir_fd` is supported on your platform using `os.supports_dir_fd`. If it is unavailable, using it will raise a `NotImplementedError`.

- **not following symlinks:** If `follow_symlinks` is False, and the last element of the path to operate on is a symbolic link, the function
will operate on the symbolic link itself instead of the file the link points to. (For POSIX systems, Python will call the 1... version of the function.)

You can check whether or not follow_symlinks is supported on your platform using `os.supports_follow_symlinks`. If it is unavailable, using it will raise a `NotImplementedError`.

```python
os.access(path, mode, *, dir_fd=None, effective_ids=False, follow_symlinks=True)
```

Use the real uid/gid to test for access to `path`. Note that most operations will use the effective uid/gid, therefore this routine can be used in a suid/sgid environment to test if the invoking user has the specified access to `path`. `mode` should be `F_OK` to test the existence of `path`, or it can be the inclusive OR of one or more of `R_OK`, `W_OK`, and `X_OK` to test permissions. Return `True` if access is allowed, `False` if not. See the Unix man page `access(2)` for more information.

This function can support specifying paths relative to directory descriptors and not following symlinks.

If `effective_ids` is True, `access()` will perform its access checks using the effective uid/gid instead of the real uid/gid. `effective_ids` may not be supported on your platform; you can check whether or not it is available using `os.supports_effective_ids`. If it is unavailable, using it will raise a `NotImplementedError`.

**Note:** Using `access()` to check if a user is authorized to e.g. open a file before actually doing so using `open()` creates a security hole, because the user might exploit the short time interval between checking and opening the file to manipulate it.
It's preferable to use EAFP techniques. For example:

```python
if os.access("myfile", os.R_OK):
    with open("myfile") as fp:
        return fp.read()
return "some default data"
```

is better written as:

```python
try:
    fp = open("myfile")
except PermissionError:
    return "some default data"
else:
    with fp:
        return fp.read()
```

**Note:** I/O operations may fail even when `access()` indicates that they would succeed, particularly for operations on network filesystems which may have permissions semantics beyond the usual POSIX permission-bit model.

*Changed in version 3.3:* Added the `dir_fd`, `effective_ids`, and `follow_symlinks` parameters.

```python
os.F_OK
os.R_OK
os.W_OK
os.X_OK
```

Values to pass as the `mode` parameter of `access()` to test the existence, readability, writability and executability of `path`, respectively.

```python
os.chdir(path)
```
Change the current working directory to *path*.

This function can support specifying a file descriptor. The descriptor must refer to an opened directory, not an open file.

*New in version 3.3:* Added support for specifying *path* as a file descriptor on some platforms.

```
import os

os.chflags(path, flags, *, follow_symlinks=True)
```

Set the flags of *path* to the numeric *flags*. *flags* may take a combination (bitwise OR) of the following values (as defined in the *stat* module):

- `stat.UF_NODUMP`
- `stat.UF_IMMUTABLE`
- `stat.UF_APPEND`
- `stat.UF_OPAQUE`
- `stat.UF_NOUNLINK`
- `stat.UF_COMPRESSED`
- `stat.UF_HIDDEN`
- `stat.SF_ARCHIVED`
- `stat.SF_IMMUTABLE`
- `stat.SF_APPEND`
- `stat.SF_NOUNLINK`
- `stat.SF_SNAPSHOT`

This function can support not following symlinks.

Availability: Unix.

*New in version 3.3:* The *follow_symlinks* argument.

```
import os

os.chmod(path, mode, *, dir_fd=None, follow_symlinks=True)
```

Change the mode of *path* to the numeric *mode*. *mode* may take
one of the following values (as defined in the `stat` module) or bitwise ORed combinations of them:

- `stat.S_ISUID`
- `stat.S_ISGID`
- `stat.S_ENFMT`
- `stat.S_ISVTX`
- `stat.S_IREAD`
- `stat.S_IWRITE`
- `stat.S_IEXEC`
- `stat.S_IRWXU`
- `stat.S_IRUSR`
- `stat.S_IWUSR`
- `stat.S_IXUSR`
- `stat.S_IRWXG`
- `stat.S_IRGRP`
- `stat.S_IWGRP`
- `stat.S_IXGRP`
- `stat.S_IRWXO`
- `stat.S_IROTH`
- `stat.S_IWOTH`
- `stat.S_IXOTH`

This function can support specifying a file descriptor, paths relative to directory descriptors and not following symlinks.

**Note:** Although Windows supports `chmod()`, you can only set the file’s read-only flag with it (via the `stat.S_IWRITE` and `stat.S_IREAD` constants or a corresponding integer value). All other bits are ignored.

*New in version 3.3:* Added support for specifying `path` as an open file descriptor, and the `dir_fd` and `follow_symlinks` arguments.
os.chown(path, uid, gid, *, dir_fd=None, follow_symlinks=True)
Change the owner and group id of path to the numeric uid and gid. To leave one of the ids unchanged, set it to -1.

This function can support specifying a file descriptor, paths relative to directory descriptors and not following symlinks.

See shutil.chown() for a higher-level function that accepts names in addition to numeric ids.

Availability: Unix.

New in version 3.3: Added support for specifying an open file descriptor for path, and the dir_fd and follow_symlinks arguments.

os.chroot(path)
Change the root directory of the current process to path.

Availability: Unix.

os.fchdir(fd)
Change the current working directory to the directory represented by the file descriptor fd. The descriptor must refer to an opened directory, not an open file. As of Python 3.3, this is equivalent to os.chdir(fd).

Availability: Unix.

os.getcwd()
Return a string representing the current working directory.

os.getcwdb()
Return a bytestring representing the current working directory.
os.lchflags(path, flags)
Set the flags of path to the numeric flags, like chflags(), but do not follow symbolic links. As of Python 3.3, this is equivalent to os.chflags(path, flags, follow_symlinks=False).

Availability: Unix.

os.lchmod(path, mode)
Change the mode of path to the numeric mode. If path is a symlink, this affects the symlink rather than the target. See the docs for chmod() for possible values of mode. As of Python 3.3, this is equivalent to os.chmod(path, mode, follow_symlinks=False).

Availability: Unix.

os.lchown(path, uid, gid)
Change the owner and group id of path to the numeric uid and gid. This function will not follow symbolic links. As of Python 3.3, this is equivalent to os.chown(path, uid, gid, follow_symlinks=False).

Availability: Unix.

os.link(src, dst, *, src_dir_fd=None, dst_dir_fd=None, follow_symlinks=True)
Create a hard link pointing to src named dst.

This function can support specifying src_dir_fd and/or dst_dir_fd to supply paths relative to directory descriptors, and not following symlinks.

Availability: Unix, Windows.
**Changed in version 3.2:** Added Windows support.

**New in version 3.3:** Added the `src_dir_fd`, `dst_dir_fd`, and `follow_symlinks` arguments.

os.`listdir(path=':')`

Return a list containing the names of the entries in the directory given by `path`. The list is in arbitrary order, and does not include the special entries ' .' and '..' even if they are present in the directory.

`path` may be either of type `str` or of type `bytes`. If `path` is of type `bytes`, the filenames returned will also be of type `bytes`; in all other circumstances, they will be of type `str`.

This function can also support specifying a file descriptor; the file descriptor must refer to a directory.

**Note:** To encode `str` filenames to `bytes`, use `fsencode()`.

**See also:** The `scandir()` function returns directory entries along with file attribute information, giving better performance for many common use cases.

**Changed in version 3.2:** The `path` parameter became optional.

**New in version 3.3:** Added support for specifying an open file descriptor for `path`.

os.`lstat(path, *, dir_fd=None)`

Perform the equivalent of an `lstat()` system call on the given path. Similar to `stat()`, but does not follow symbolic links. Return a `stat_result` object.
On platforms that do not support symbolic links, this is an alias for `stat()`.

As of Python 3.3, this is equivalent to `os.stat(path, dir_fd=dir_fd, follow_symlinks=False)`.

This function can also support paths relative to directory descriptors.

**See also:** The `stat()` function.

*Changed in version 3.2:* Added support for Windows 6.0 (Vista) symbolic links.

*Changed in version 3.3:* Added the `dir_fd` parameter.

```python
os.mkdir(path, mode=0o777, *, dir_fd=None)
```

Create a directory named `path` with numeric mode `mode`.

On some systems, `mode` is ignored. Where it is used, the current umask value is first masked out. If the directory already exists, `OSError` is raised.

This function can also support paths relative to directory descriptors.

It is also possible to create temporary directories; see the `tempfile` module's `tempfile.mkdtemp()` function.

*New in version 3.3:* The `dir_fd` argument.

```python
os.makedirs(name, mode=0o777, exist_ok=False)
```

Recursive directory creation function. Like `mkdir()`, but makes all intermediate-level directories needed to contain the leaf directory.
The default mode is 0o777 (octal). On some systems, mode is ignored. Where it is used, the current umask value is first masked out.

If exist_ok is False (the default), an OSError is raised if the target directory already exists.

**Note:** makedirs() will become confused if the path elements to create include pardir (eg. ".." on UNIX systems).

This function handles UNC paths correctly.

*Ninew in version 3.2:* The exist_ok parameter.

*Changed in version 3.4.1:* Before Python 3.4.1, if exist_ok was True and the directory existed, makedirs() would still raise an error if mode did not match the mode of the existing directory. Since this behavior was impossible to implement safely, it was removed in Python 3.4.1. See issue 21082.

**os.mkfifo(path, mode=0o666, *, dir_fd=None)**

Create a FIFO (a named pipe) named path with numeric mode mode. The current umask value is first masked out from the mode.

This function can also support paths relative to directory descriptors.

FIFOs are pipes that can be accessed like regular files. FIFOs exist until they are deleted (for example with os.unlink()). Generally, FIFOs are used as rendezvous between “client” and “server” type processes: the server opens the FIFO for reading, and the client opens it for writing. Note that mkfifo() doesn’t open the FIFO — it just creates the rendezvous point.
Availability: Unix.

*New in version 3.3:* The `dir_fd` argument.

```python
os.mknod(path, mode=0o600, device=0, *, dir_fd=None)
```

Create a filesystem node (file, device special file or named pipe) named `path`. `mode` specifies both the permissions to use and the type of node to be created, being combined (bitwise OR) with one of `stat.S_IFREG`, `stat.S_IFCHR`, `stat.S_IFBLK`, and `stat.S_IFIFO` (those constants are available in `stat`). For `stat.S_IFCHR` and `stat.S_IFBLK`, `device` defines the newly created device special file (probably using `os.makedev()`), otherwise it is ignored.

This function can also support paths relative to directory descriptors.

*New in version 3.3:* The `dir_fd` argument.

```python
os.major(device)
```

Extract the device major number from a raw device number (usually the `st_dev` or `st_rdev` field from `stat`).

```python
os.minor(device)
```

Extract the device minor number from a raw device number (usually the `st_dev` or `st_rdev` field from `stat`).

```python
os.makedev(major, minor)
```

Compose a raw device number from the major and minor device numbers.

```python
os.pathconf(path, name)
```

Return system configuration information relevant to a named file.
name specifies the configuration value to retrieve; it may be a string which is the name of a defined system value; these names are specified in a number of standards (POSIX.1, Unix 95, Unix 98, and others). Some platforms define additional names as well. The names known to the host operating system are given in the pathconf_names dictionary. For configuration variables not included in that mapping, passing an integer for name is also accepted.

If name is a string and is not known, ValueError is raised. If a specific value for name is not supported by the host system, even if it is included in pathconf_names, an OSError is raised with errno.EINVAL for the error number.

This function can support specifying a file descriptor.

Availability: Unix.

os.pathconf_names
Dictionary mapping names accepted by pathconf() and fpathconf() to the integer values defined for those names by the host operating system. This can be used to determine the set of names known to the system.

Availability: Unix.

os.readlink(path, *, dir_fd=None)
Return a string representing the path to which the symbolic link points. The result may be either an absolute or relative pathname; if it is relative, it may be converted to an absolute pathname using os.path.join(os.path.dirname(path), result).

If the path is a string object, the result will also be a string object,
and the call may raise an UnicodeDecodeError. If the path is a bytes object, the result will be a bytes object.

This function can also support paths relative to directory descriptors.

Availability: Unix, Windows

*Changed in version 3.2:* Added support for Windows 6.0 (Vista) symbolic links.

*New in version 3.3:* The dir_fd argument.

```python
os.remove(path, *, dir_fd=None)
```
Remove (delete) the file path. If path is a directory, OSError is raised. Use rmdir() to remove directories.

This function can support paths relative to directory descriptors.

On Windows, attempting to remove a file that is in use causes an exception to be raised; on Unix, the directory entry is removed but the storage allocated to the file is not made available until the original file is no longer in use.

This function is identical to unlink().

*New in version 3.3:* The dir_fd argument.

```python
os.removedirs(name)
```
Remove directories recursively. Works like rmdir() except that, if the leaf directory is successfully removed, removedirs() tries to successively remove every parent directory mentioned in path until an error is raised (which is ignored, because it generally means that a parent directory is not empty). For example,
os.removedirs('foo/bar/baz') will first remove the directory 'foo/bar/baz', and then remove 'foo/bar' and 'foo' if they are empty. Raises **OSError** if the leaf directory could not be successfully removed.

```py
os.rename(src, dst, *, src_dir_fd=None, dst_dir_fd=None)
```

Rename the file or directory `src` to `dst`. If `dst` is a directory, **OSError** will be raised. On Unix, if `dst` exists and is a file, it will be replaced silently if the user has permission. The operation may fail on some Unix flavors if `src` and `dst` are on different filesystems. If successful, the renaming will be an atomic operation (this is a POSIX requirement). On Windows, if `dst` already exists, **OSError** will be raised even if it is a file.

This function can support specifying `src_dir_fd` and/or `dst_dir_fd` to supply paths relative to directory descriptors.

If you want cross-platform overwriting of the destination, use `replace()`.

**New in version 3.3:** The `src_dir_fd` and `dst_dir_fd` arguments.

```py
os.renames(old, new)
```

Recursive directory or file renaming function. Works like `rename()`, except creation of any intermediate directories needed to make the new pathname good is attempted first. After the rename, directories corresponding to rightmost path segments of the old name will be pruned away using `removedirs()`.

**Note:** This function can fail with the new directory structure made if you lack permissions needed to remove the leaf directory or file.
os.replace(src, dst, *, src_dir_fd=None, dst_dir_fd=None)

Renew the file or directory src to dst. If dst is a directory, OSError will be raised. If dst exists and is a file, it will be replaced silently if the user has permission. The operation may fail if src and dst are on different filesystems. If successful, the renaming will be an atomic operation (this is a POSIX requirement).

This function can support specifying src_dir_fd and/or dst_dir_fd to supply paths relative to directory descriptors.

New in version 3.3.

os.rmdir(path, *, dir_fd=None)

Remove (delete) the directory path. Only works when the directory is empty, otherwise, OSError is raised. In order to remove whole directory trees, shutil.rmtree() can be used.

This function can support paths relative to directory descriptors.

New in version 3.3: The dir_fd parameter.

os.scandir(path='.')

Return an iterator of DirEntry objects corresponding to the entries in the directory given by path. The entries are yielded in arbitrary order, and the special entries '.' and '..' are not included.

Using scandir() instead of listdir() can significantly increase the performance of code that also needs file type or file attribute information, because DirEntry objects expose this information if the operating system provides it when scanning a directory. All DirEntry methods may perform a system call, but is_dir() and is_file() usually only require a system call for
symbolic links; `DirEntry.stat()` always requires a system call on Unix but only requires one for symbolic links on Windows.

On Unix, `path` can be of type `str` or `bytes` (use `fsencode()` and `fsdecode()` to encode and decode `bytes` paths). On Windows, `path` must be of type `str`. On both systems, the type of the `name` and `path` attributes of each `DirEntry` will be of the same type as `path`.

The following example shows a simple use of `scandir()` to display all the files (excluding directories) in the given `path` that don't start with '.'. The `entry.is_file()` call will generally not make an additional system call:

```python
for entry in os.scandir(path):
    if not entry.name.startswith('.') and entry.is_file():
        print(entry.name)
```

**Note:** On Unix-based systems, `scandir()` uses the system's `opendir()` and `readdir()` functions. On Windows, it uses the Win32 `FindFirstFileW` and `FindNextFileW` functions.

*New in version 3.5.*

class os.DirEntry

Object yielded by `scandir()` to expose the file path and other file attributes of a directory entry.

`scandir()` will provide as much of this information as possible without making additional system calls. When a `stat()` or `lstat()` system call is made, the `DirEntry` object will cache the result.
DirEntry instances are not intended to be stored in long-lived data structures; if you know the file metadata has changed or if a long time has elapsed since calling `scandir()`, call `os.stat(entry.path)` to fetch up-to-date information.

Because the DirEntry methods can make operating system calls, they may also raise `OSError`. If you need very fine-grained control over errors, you can catch `OSError` when calling one of the DirEntry methods and handle as appropriate.

Attributes and methods on a DirEntry instance are as follows:

**name**

The entry's base filename, relative to the `scandir()` path argument.

The `name` attribute will be of the same type (`str` or `bytes`) as the `scandir()` path argument. Use `fsdecode()` to decode byte filenames.

**path**

The entry's full path name: equivalent to `os.path.join(scandir_path, entry.name)` where `scandir_path` is the `scandir()` path argument. The path is only absolute if the `scandir()` path argument was absolute.

The `path` attribute will be of the same type (`str` or `bytes`) as the `scandir()` path argument. Use `fsdecode()` to decode byte filenames.

**inode()**

Return the inode number of the entry.
The result is cached on the DirEntry object, use `os.stat(entry.path, follow_symlinks=False).st_ino` to fetch up-to-date information.

On Unix, no system call is required.

**is_dir( *, follow_symlinks=True)**

If `follow_symlinks` is True (the default), return True if the entry is a directory or a symbolic link pointing to a directory; return False if it is or points to any other kind of file, or if it doesn’t exist anymore.

If `follow_symlinks` is False, return True only if this entry is a directory; return False if it is any other kind of file or if it doesn't exist anymore.

The result is cached on the DirEntry object. Call `os.stat()` along with `stat.S_ISDIR()` to fetch up-to-date information.

This method can raise `OSError`, such as `PermissionError`, but `FileNotFoundError` is caught and not raised.

In most cases, no system call is required.

**is_file( *, follow_symlinks=True)**

If `follow_symlinks` is True (the default), return True if the entry is a file or a symbolic link pointing to a file; return False if it is or points to a directory or other non-file entry, or if it doesn’t exist anymore.

If `follow_symlinks` is False, return True only if this entry is a file; return False if it is a directory or other non-file entry, or if it
doesn't exist anymore.

The result is cached on the DirEntry object. Call `os.stat()` along with `stat.S_ISREG()` to fetch up-to-date information.

This method can raise `OSError`, such as `PermissionError`, but `FileNotFoundError` is caught and not raised.

In most cases, no system call is required.

**is_symlink()**

Return True if this entry is a symbolic link (even if broken); return False if it points to a directory or any kind of file, or if it doesn’t exist anymore.

The result is cached on the DirEntry object. Call `os.path.islink()` to fetch up-to-date information.

The method can raise `OSError`, such as `PermissionError`, but `FileNotFoundError` is caught and not raised.

In most cases, no system call is required.

**stat(**, follow_symlinks=True)**

Return a `stat_result` object for this entry. This method follows symbolic links by default; to stat a symbolic link add the `follow_symlinks=False` argument.

On Unix, this method always requires a system call. On Windows, `DirEntry.stat()` requires a system call only if the entry is a symbolic link, and `DirEntry.stat(follow_symlinks=False)` never requires a system call.
On Windows, the st_ino, st_dev and st_nlink attributes of the stat_result are always set to zero. Call os.stat() to get these attributes.

The result is cached on the DirEntry object. Call os.stat() to fetch up-to-date information.

New in version 3.5.

os.stat(path, *, dir_fd=None, follow_symlinks=True)

Get the status of a file or a file descriptor. Perform the equivalent of a stat() system call on the given path. path may be specified as either a string or as an open file descriptor. Return a stat_result object.

This function normally follows symlinks; to stat a symlink add the argument follow_symlinks=False, or use lstat().

This function can support specifying a file descriptor and not following symlinks.

Example:

```python
>>> import os
>>> statinfo = os.stat('somefile.txt')
>>> statinfo
os.stat_result(st_mode=33188, st_ino=7876932, st_dev=234881026, st_nlink=1, st_uid=501, st_gid=501, st_size=264, st_atime=1297230295, st_mtime=1297230027, st_ctime=1297230027)
>>> statinfo.st_size
264
```

See also: fstat() and lstat() functions.
New in version 3.3: Added the dir_fd and follow_symlinks arguments, specifying a file descriptor instead of a path.

class os.stat_result
Object whose attributes correspond roughly to the members of the stat structure. It is used for the result of os.stat(), os.fstat() and os.lstat().

Attributes:

st_mode
File mode: file type and file mode bits (permissions).

st_ino
Inode number.

st_dev
Identifier of the device on which this file resides.

st_nlink
Number of hard links.

st_uid
User identifier of the file owner.

st_gid
Group identifier of the file owner.

st_size
Size of the file in bytes, if it is a regular file or a symbolic link. The size of a symbolic link is the length of the pathname it contains, without a terminating null byte.

Timestamps:
**st_atime**  
Time of most recent access expressed in seconds.

**st_mtime**  
Time of most recent content modification expressed in seconds.

**st_ctime**  
Platform dependent:

- the time of most recent metadata change on Unix,
- the time of creation on Windows, expressed in seconds.

**st_atime_ns**  
Time of most recent access expressed in nanoseconds as an integer.

**st_mtime_ns**  
Time of most recent content modification expressed in nanoseconds as an integer.

**st_ctime_ns**  
Platform dependent:

- the time of most recent metadata change on Unix,
- the time of creation on Windows, expressed in nanoseconds as an integer.

See also the `stat_float_times()` function.

**Note:** The exact meaning and resolution of the `st_atime`, `st_mtime`, and `st_ctime` attributes depend on the operating system and the file system. For example, on Windows systems using the FAT or FAT32 file systems, `st_mtime` has 2-second resolution, and `st_atime` has only 1-day resolution. See your
Similarly, although `st_atime_ns`, `st_mtime_ns`, and `st_ctime_ns` are always expressed in nanoseconds, many systems do not provide nanosecond precision. On systems that do provide nanosecond precision, the floating-point object used to store `st_atime`, `st_mtime`, and `st_ctime` cannot preserve all of it, and as such will be slightly inexact. If you need the exact timestamps you should always use `st_atime_ns`, `st_mtime_ns`, and `st_ctime_ns`.

On some Unix systems (such as Linux), the following attributes may also be available:

**st_blocks**

Number of 512-byte blocks allocated for file. This may be smaller than `st_size/512` when the file has holes.

**st_blksize**

"Preferred" blocksize for efficient file system I/O. Writing to a file in smaller chunks may cause an inefficient read-modify-rewrite.

**st_rdev**

Type of device if an inode device.

**st_flags**

User defined flags for file.

On other Unix systems (such as FreeBSD), the following attributes may be available (but may be only filled out if root tries to use them):

**st_gen**

File generation number.
**st_birthtime**
Time of file creation.

On Mac OS systems, the following attributes may also be available:

**st_rsize**
Real size of the file.

**st_creator**
Creator of the file.

**st_type**
File type.

On Windows systems, the following attribute is also available:

**st_file_attributes**
Windows file attributes: dwFileAttributes member of the BY_HANDLE_FILE_INFORMATION structure returned by GetFileInformationByHandle(). See the FILE_ATTRIBUTE_* constants in the stat module.

The standard module `stat` defines functions and constants that are useful for extracting information from a stat structure. (On Windows, some items are filled with dummy values.)

For backward compatibility, a `stat_result` instance is also accessible as a tuple of at least 10 integers giving the most important (and portable) members of the stat structure, in the order `st_mode`, `st_ino`, `st_dev`, `st_nlink`, `st_uid`, `st_gid`, `st_size`, `st_atime`, `st_mtime`, `st_ctime`. More items may be added at the end by some implementations. For compatibility with
older Python versions, accessing \texttt{stat\_result} as a tuple always returns integers.

\textit{New in version 3.3}: Added the \texttt{st\_atime\_ns}, \texttt{st\_mtime\_ns}, and \texttt{st\_ctime\_ns} members.

\textit{New in version 3.5}: Added the \texttt{st\_file\_attributes} member on Windows.

\texttt{os.stat\_float\_times([newvalue])}

Determine whether \texttt{stat\_result} represents time stamps as float objects. If \texttt{newvalue} is True, future calls to \texttt{stat()} return floats, if it is False, future calls return ints. If \texttt{newvalue} is omitted, return the current setting.

For compatibility with older Python versions, accessing \texttt{stat\_result} as a tuple always returns integers.

Python now returns float values by default. Applications which do not work correctly with floating point time stamps can use this function to restore the old behaviour.

The resolution of the timestamps (that is the smallest possible fraction) depends on the system. Some systems only support second resolution; on these systems, the fraction will always be zero.

It is recommended that this setting is only changed at program startup time in the \texttt{__main__} module; libraries should never change this setting. If an application uses a library that works incorrectly if floating point time stamps are processed, this application should turn the feature off until the library has been corrected.
*Deprecation*

```

Deprecated since version 3.3.
```

**os.statvfs(path)**

Perform a statvfs() system call on the given path. The return value is an object whose attributes describe the filesystem on the given path, and correspond to the members of the statvfs structure, namely: `f_bsize`, `f_frsize`, `f_blocks`, `f_bfree`, `f_bavail`, `f_files`, `f_ffree`, `f_favail`, `f_flag`, `f_namemax`.

Two module-level constants are defined for the `f_flag` attribute's bit-flags: if `ST_RDONLY` is set, the filesystem is mounted read-only, and if `ST_NOSUID` is set, the semantics of setuid/setgid bits are disabled or not supported.

Additional module-level constants are defined for GNU/glibc based systems. These are `ST_NODEV` (disallow access to device special files), `ST_NOEXEC` (disallow program execution), `ST_SYNCHRONOUS` (writes are synced at once), `ST_MANDLOCK` (allow mandatory locks on an FS), `ST_WRITE` (write on file/directory/symlink), `ST_APPEND` (append-only file), `ST_IMMUTABLE` (immutable file), `ST_NOATIME` (do not update access times), `ST_NODIRATIME` (do not update directory access times), `ST_RELATIME` (update atime relative to mtimes/ctime).

This function can support specifying a file descriptor.

*Changed in version 3.2:* The `ST_RDONLY` and `ST_NOSUID` constants were added.

*Changed in version 3.4:* The `ST_NODEV`, `ST_NOEXEC`, `ST_SYNCHRONOUS`, `ST_MANDLOCK`, `ST_WRITE`, `ST_APPEND`,
ST_IMMUTABLE, ST_NOATIME, ST_NODIRATIME, and ST_RELATIME constants were added.

Availability: Unix.

*New in version 3.3:* Added support for specifying an open file descriptor for *path*.

**os.supports_dir_fd**

A *Set* object indicating which functions in the *os* module permit use of their *dir_fd* parameter. Different platforms provide different functionality, and an option that might work on one might be unsupported on another. For consistency’s sakes, functions that support *dir_fd* always allow specifying the parameter, but will raise an exception if the functionality is not actually available.

To check whether a particular function permits use of its *dir_fd* parameter, use the in operator on `supports_dir_fd`. As an example, this expression determines whether the *dir_fd* parameter of `os.stat()` is locally available:

```python
os.stat in os.supports_dir_fd
```

Currently *dir_fd* parameters only work on Unix platforms; none of them work on Windows.

*New in version 3.3.*

**os.supports_effective_ids**

A *Set* object indicating which functions in the *os* module permit use of the *effective_ids* parameter for `os.access()`. If the local platform supports it, the collection will contain `os.access()`, otherwise it will be empty.
To check whether you can use the `effective_ids` parameter for `os.access()`, use the `in` operator on `supports_effective_ids`, like so:

```
os.access in os.supports_effective_ids
```

Currently `effective_ids` only works on Unix platforms; it does not work on Windows.

*New in version 3.3.*

**os.supports_fd**

A `Set` object indicating which functions in the `os` module permit specifying their `path` parameter as an open file descriptor. Different platforms provide different functionality, and an option that might work on one might be unsupported on another. For consistency's sakes, functions that support `fd` always allow specifying the parameter, but will raise an exception if the functionality is not actually available.

To check whether a particular function permits specifying an open file descriptor for its `path` parameter, use the `in` operator on `supports_fd`. As an example, this expression determines whether `os.chdir()` accepts open file descriptors when called on your local platform:

```
os.chdir in os.supports_fd
```

*New in version 3.3.*

**os.supports_follow_symlinks**

A `Set` object indicating which functions in the `os` module permit use of their `follow_symlinks` parameter. Different platforms provide
different functionality, and an option that might work on one might be unsupported on another. For consistency's sakes, functions that support follow_symlinks always allow specifying the parameter, but will raise an exception if the functionality is not actually available.

To check whether a particular function permits use of its follow_symlinks parameter, use the in operator on supports_follow_symlinks. As an example, this expression determines whether the follow_symlinks parameter of os.stat() is locally available:

```
    os.stat in os.supports_follow_symlinks
```

*New in version 3.3.*

```
    os.symlink(src, dst, target_is_directory=False, *, dir_fd=None)
```

Create a symbolic link pointing to src named dst.

On Windows, a symlink represents either a file or a directory, and does not morph to the target dynamically. If the target is present, the type of the symlink will be created to match. Otherwise, the symlink will be created as a directory if target_is_directory is True or a file symlink (the default) otherwise. On non-Window platforms, target_is_directory is ignored.

Symbolic link support was introduced in Windows 6.0 (Vista). symlink() will raise a `NotImplementedError` on Windows versions earlier than 6.0.

This function can support paths relative to directory descriptors.

**Note:** On Windows, the `SeCreateSymbolicLinkPrivilege` is required in order to successfully create symlinks. This privilege is
not typically granted to regular users but is available to accounts which can escalate privileges to the administrator level. Either obtaining the privilege or running your application as an administrator are ways to successfully create symlinks. \texttt{OSError} is raised when the function is called by an unprivileged user.

Availability: Unix, Windows.

\textit{Changed in version 3.2}: Added support for Windows 6.0 (Vista) symbolic links.

\textit{New in version 3.3}: Added the \texttt{dir\_fd} argument, and now allow \texttt{target\_is\_directory} on non-Windows platforms.

\texttt{os.sync()}

Force write of everything to disk.

Availability: Unix.

\textit{New in version 3.3}.

\texttt{os.truncate(path, length)}

Truncate the file corresponding to \texttt{path}, so that it is at most \texttt{length} bytes in size.

This function can support specifying a file descriptor.

Availability: Unix, Windows.

\textit{New in version 3.3}.

\textit{Changed in version 3.5}: Added support for Windows

\texttt{os.unlink(path, \*, dir\_fd=None)}
Remove (delete) the file *path*. This function is identical to `remove()`; the unlink name is its traditional Unix name. Please see the documentation for `remove()` for further information.

*New in version 3.3:* The `dir_fd` parameter.

```python
os.utime(path, times=None, *, [ns, ]dir_fd=None, follow_symlinks=True)
```

Set the access and modified times of the file specified by *path*.

`utime()` takes two optional parameters, *times* and *ns*. These specify the times set on *path* and are used as follows:

- If *ns* is specified, it must be a 2-tuple of the form \((\text{atime}\_\text{ns}, \text{mtime}\_\text{ns})\) where each member is an int expressing nanoseconds.
- If *times* is not None, it must be a 2-tuple of the form \((\text{atime}, \text{mtime})\) where each member is an int or float expressing seconds.
- If *times* is None and *ns* is unspecified, this is equivalent to specifying \(\text{ns}=(\text{atime}\_\text{ns}, \text{mtime}\_\text{ns})\) where both times are the current time.

It is an error to specify tuples for both *times* and *ns*.

Whether a directory can be given for *path* depends on whether the operating system implements directories as files (for example, Windows does not). Note that the exact times you set here may not be returned by a subsequent `stat()` call, depending on the resolution with which your operating system records access and modification times; see `stat()`. The best way to preserve exact times is to use the `st_atime_ns` and `st_mtime_ns` fields from the `os.stat()` result object with the *ns* parameter to `utime`. 
This function can support specifying a file descriptor, paths relative to directory descriptors and not following symlinks.

New in version 3.3: Added support for specifying an open file descriptor for path, and the dir_fd, follow_symlinks, and ns parameters.

```
import os

os.walk(top, topdown=True, onerror=None, followlinks=False)
```

Generate the file names in a directory tree by walking the tree either top-down or bottom-up. For each directory in the tree rooted at directory top (including top itself), it yields a 3-tuple (dirpath, dirnames, filenames).

- `dirpath` is a string, the path to the directory. `dirnames` is a list of the names of the subdirectories in `dirpath` (excluding '.' and '..').
- `filenames` is a list of the names of the non-directory files in `dirpath`.

Note that the names in the lists contain no path components. To get a full path (which begins with top) to a file or directory in `dirpath`, do `os.path.join(dirpath, name)`.

If optional argument `topdown` is True or not specified, the triple for a directory is generated before the triples for any of its subdirectories (directories are generated top-down). If `topdown` is False, the triple for a directory is generated after the triples for all of its subdirectories (directories are generated bottom-up). No matter the value of `topdown`, the list of subdirectories is retrieved before the tuples for the directory and its subdirectories are generated.

When `topdown` is True, the caller can modify the `dirnames` list in-place (perhaps using `del` or slice assignment), and `walk()` will only recurse into the subdirectories whose names remain in
dirnames; this can be used to prune the search, impose a specific order of visiting, or even to inform walk() about directories the caller creates or renames before it resumes walk() again. Modifying dirnames when topdown is False has no effect on the behavior of the walk, because in bottom-up mode the directories in dirnames are generated before dirpath itself is generated.

By default, errors from the listdir() call are ignored. If optional argument onerror is specified, it should be a function; it will be called with one argument, an OSError instance. It can report the error to continue with the walk, or raise the exception to abort the walk. Note that the filename is available as the filename attribute of the exception object.

By default, walk() will not walk down into symbolic links that resolve to directories. Set followlinks to True to visit directories pointed to by symlinks, on systems that support them.

Note: Be aware that setting followlinks to True can lead to infinite recursion if a link points to a parent directory of itself. walk() does not keep track of the directories it visited already.

Note: If you pass a relative pathname, don’t change the current working directory between resumptions of walk(). walk() never changes the current directory, and assumes that its caller doesn’t either.

This example displays the number of bytes taken by non-directory files in each directory under the starting directory, except that it doesn’t look under any CVS subdirectory:

```python
import os
```
from os.path import join, getsize
for root, dirs, files in os.walk('python/Lib/email'):
    print(root, "consumes")
print(sum(getsize(join(root, name)) for name in files))
if 'CVS' in dirs:
    dirs.remove('CVS')  # don't visit CVS dir

In the next example (simple implementation of shutil.rmtree()), walking the tree bottom-up is essential, rmdir() doesn’t allow deleting a directory before the directory is empty:

```python
# Delete everything reachable from the directory
# assuming there are no symbolic links.
# CAUTION: This is dangerous! For example, if top
# could delete all your disk files.
import os
for root, dirs, files in os.walk(top, topdown=False):
    for name in files:
        os.remove(os.path.join(root, name))
    for name in dirs:
        os.rmdir(os.path.join(root, name))
```

*Changed in version 3.5:* This function now calls os.scandir() instead of os.listdir(), making it faster by reducing the number of calls to os.stat().

```python
os.fwalk(top='.', topdown=True, onerror=None, *,
          follow_symlinks=False, dir_fd=None)
```

This behaves exactly like walk(), except that it yields a 4-tuple (dirpath, dirnames, filenames, dirfd), and it supports dir_fd.
dirpath, dirnames and filenames are identical to walk() output, and dirfd is a file descriptor referring to the directory dirpath.

This function always supports paths relative to directory descriptors and not following symlinks. Note however that, unlike other functions, the fwalk() default value for follow_symlinks is False.

**Note:** Since fwalk() yields file descriptors, those are only valid until the next iteration step, so you should duplicate them (e.g. with dup()) if you want to keep them longer.

This example displays the number of bytes taken by non-directory files in each directory under the starting directory, except that it doesn't look under any CVS subdirectory:

```python
import os
for root, dirs, files, rootfd in os.fwalk('python/Lib/email'
print(root, "consumes", end="")
print(sum([os.stat(name, dir_fd=rootfd).st_size
end=""),
print("bytes in", len(files), "non-directory")
if 'CVS' in dirs:
dirs.remove('CVS')  # don't visit CVS dirs
```

In the next example, walking the tree bottom-up is essential: rmdir() doesn't allow deleting a directory before the directory is empty:

```python
# Delete everything reachable from the directory top,
# assuming there are no symbolic links.
# CAUTION: This is dangerous! For example, if top == 
# could delete all your disk files.
import os
for root, dirs, files, rootfd in os.fwalk(top, to
for name in files:
    os.unlink(name, dir_fd=rootfd)

for name in dirs:
    os.rmdir(name, dir_fd=root_fd)

Availability: Unix.

New in version 3.3.

16.1.5.1. Linux extended attributes

New in version 3.3.

These functions are all available on Linux only.

`os.getxattr(path, attribute, *, follow_symlinks=True)`

Return the value of the extended filesystem attribute `attribute` for `path`. `attribute` can be bytes or str. If it is str, it is encoded with the filesystem encoding.

This function can support specifying a file descriptor and not following symlinks.

`os.listxattr(path=None, *, follow_symlinks=True)`

Return a list of the extended filesystem attributes on `path`. The attributes in the list are represented as strings decoded with the filesystem encoding. If `path` is None, `listxattr()` will examine the current directory.

This function can support specifying a file descriptor and not following symlinks.

`os.removexattr(path, attribute, *, follow_symlinks=True)`
Removes the extended filesystem attribute `attribute` from `path`. `attribute` should be bytes or str. If it is a string, it is encoded with the filesystem encoding.

This function can support specifying a file descriptor and not following symlinks.

```python
os.setxattr(path, attribute, value, flags=0, *, follow_symlinks=True)
```

Set the extended filesystem attribute `attribute` on `path` to `value`. `attribute` must be a bytes or str with no embedded NULs. If it is a str, it is encoded with the filesystem encoding. `flags` may be `XATTR_REPLACE` or `XATTR_CREATE`. If `XATTR_REPLACE` is given and the attribute does not exist, `EEXISTS` will be raised. If `XATTR_CREATE` is given and the attribute already exists, the attribute will not be created and `ENODATA` will be raised.

This function can support specifying a file descriptor and not following symlinks.

**Note:** A bug in Linux kernel versions less than 2.6.39 caused the flags argument to be ignored on some filesystems.

```python
os.XATTR_SIZE_MAX
```

The maximum size the value of an extended attribute can be. Currently, this is 64 KiB on Linux.

```python
os.XATTR_CREATE
```

This is a possible value for the flags argument in `setxattr()`. It indicates the operation must create an attribute.

```python
os.XATTR_REPLACE
```
This is a possible value for the flags argument in `setxattr()`. It indicates the operation must replace an existing attribute.
16.1.6. Process Management

These functions may be used to create and manage processes.

The various exec* functions take a list of arguments for the new program loaded into the process. In each case, the first of these arguments is passed to the new program as its own name rather than as an argument a user may have typed on a command line. For the C programmer, this is the argv[0] passed to a program's main(). For example, os.execv('/bin/echo', ['foo', 'bar']) will only print bar on standard output; foo will seem to be ignored.

**os.abort()**

Generate a SIGABRT signal to the current process. On Unix, the default behavior is to produce a core dump; on Windows, the process immediately returns an exit code of 3. Be aware that calling this function will not call the Python signal handler registered for SIGABRT with signal.signal().

**os.exec**

These functions all execute a new program, replacing the current process; they do not return. On Unix, the new executable is loaded into the current process, and will have the same process id as the caller. Errors will be reported as OSError exceptions.
The current process is replaced immediately. Open file objects and descriptors are not flushed, so if there may be data buffered on these open files, you should flush them using `sys.stdout.flush()` or `os.fsync()` before calling an `exec*` function.

The “l” and “v” variants of the `exec*` functions differ in how command-line arguments are passed. The “l” variants are perhaps the easiest to work with if the number of parameters is fixed when the code is written; the individual parameters simply become additional parameters to the `execl*()` functions. The “v” variants are good when the number of parameters is variable, with the arguments being passed in a list or tuple as the `args` parameter. In either case, the arguments to the child process should start with the name of the command being run, but this is not enforced.

The variants which include a “p” near the end (`execlp()`, `execlpe()`, `execvp()`, and `execvpe()`) will use the PATH environment variable to locate the program file. When the environment is being replaced (using one of the `exec*e` variants, discussed in the next paragraph), the new environment is used as the source of the PATH variable. The other variants, `execl()`, `execle()`, `execv()`, and `execve()`, will not use the PATH variable to locate the executable; `path` must contain an appropriate absolute or relative path.

For `execle()`, `execlpe()`, `execve()`, and `execvpe()` (note that these all end in “e”), the `env` parameter must be a mapping which is used to define the environment variables for the new process (these are used instead of the current process’ environment); the functions `execl()`, `execlp()`, `execv()`, and `execvp()` all cause the new process to inherit the environment of
the current process.

For `execve()` on some platforms, `path` may also be specified as an open file descriptor. This functionality may not be supported on your platform; you can check whether or not it is available using `os.supports_fd`. If it is unavailable, using it will raise a `NotImplementedError`.

Availability: Unix, Windows.

*New in version 3.3:* Added support for specifying an open file descriptor for `path` for `execve()`.

**os._exit(n)**

Exit the process with status `n`, without calling cleanup handlers, flushing stdio buffers, etc.

**Note:** The standard way to exit is `sys.exit(n)`. `_exit()` should normally only be used in the child process after a `fork()`.

The following exit codes are defined and can be used with `_exit()`, although they are not required. These are typically used for system programs written in Python, such as a mail server’s external command delivery program.

**Note:** Some of these may not be available on all Unix platforms, since there is some variation. These constants are defined where they are defined by the underlying platform.

**os.EX_OK**

Exit code that means no error occurred.
Availability: Unix.

\texttt{os.EX\_USAGE}
Exit code that means the command was used incorrectly, such as when the wrong number of arguments are given.
Availability: Unix.

\texttt{os.EX\_DATAERR}
Exit code that means the input data was incorrect.
Availability: Unix.

\texttt{os.EX\_NOINPUT}
Exit code that means an input file did not exist or was not readable.
Availability: Unix.

\texttt{os.EX\_NOUSER}
Exit code that means a specified user did not exist.
Availability: Unix.

\texttt{os.EX\_NOHOST}
Exit code that means a specified host did not exist.
Availability: Unix.

\texttt{os.EX\_UNAVAILABLE}
Exit code that means that a required service is unavailable.
Availability: Unix.

\texttt{os.EX\_SOFTWARE}
Exit code that means an internal software error was detected.
Availability: Unix.

**os.EX_OSERR**
Exit code that means an operating system error was detected, such as the inability to fork or create a pipe.

Availability: Unix.

**os.EX_OSFILE**
Exit code that means some system file did not exist, could not be opened, or had some other kind of error.

Availability: Unix.

**os.EX_CANTCREAT**
Exit code that means a user specified output file could not be created.

Availability: Unix.

**os.EX_IOERR**
Exit code that means that an error occurred while doing I/O on some file.

Availability: Unix.

**os.EX_TEMPFAIL**
Exit code that means a temporary failure occurred. This indicates something that may not really be an error, such as a network connection that couldn’t be made during a retryable operation.

Availability: Unix.

**os.EX_PROTOCOL**
Exit code that means that a protocol exchange was illegal, invalid, or not understood.

Availability: Unix.

**os.EX_NOPERM**

Exit code that means that there were insufficient permissions to perform the operation (but not intended for file system problems).

Availability: Unix.

**os.EX_CONFIG**

Exit code that means that some kind of configuration error occurred.

Availability: Unix.

**os.EX_NOTFOUND**

Exit code that means something like “an entry was not found”.

Availability: Unix.

**os.fork()**

Fork a child process. Return 0 in the child and the child’s process id in the parent. If an error occurs **OSError** is raised.

Note that some platforms including FreeBSD <= 6.3 and Cygwin have known issues when using fork() from a thread.

**Warning:** See **ssl** for applications that use the SSL module with fork().

Availability: Unix.
os.**forkpty()**

Fork a child process, using a new pseudo-terminal as the child's controlling terminal. Return a pair of (pid, fd), where `pid` is 0 in the child, the new child's process id in the parent, and `fd` is the file descriptor of the master end of the pseudo-terminal. For a more portable approach, use the `pty` module. If an error occurs `OSError` is raised.

Availability: some flavors of Unix.

os.**kill(pid, sig)**

Send signal `sig` to the process `pid`. Constants for the specific signals available on the host platform are defined in the `signal` module.

Windows: The `signal.CTRL_C_EVENT` and `signal.CTRL_BREAK_EVENT` signals are special signals which can only be sent to console processes which share a common console window, e.g., some subprocesses. Any other value for `sig` will cause the process to be unconditionally killed by the TerminateProcess API, and the exit code will be set to `sig`. The Windows version of `kill()` additionally takes process handles to be killed.

See also `signal.pthread_kill()`.

*New in version 3.2*: Windows support.

os.**killpg(pgid, sig)**

Send the signal `sig` to the process group `pgid`.

Availability: Unix.
os.nice(increment)

Add increment to the process’s “niceness”. Return the new niceness.

Availability: Unix.

os.plock(op)

Lock program segments into memory. The value of op (defined in <sys/lock.h>) determines which segments are locked.

Availability: Unix.

os.popen(cmd, mode='r', buffering=-1)

Open a pipe to or from command cmd. The return value is an open file object connected to the pipe, which can be read or written depending on whether mode is 'r' (default) or 'w'. The buffering argument has the same meaning as the corresponding argument to the built-in open() function. The returned file object reads or writes text strings rather than bytes.

The close method returns None if the subprocess exited successfully, or the subprocess's return code if there was an error. On POSIX systems, if the return code is positive it represents the return value of the process left-shifted by one byte. If the return code is negative, the process was terminated by the signal given by the negated value of the return code. (For example, the return value might be - signal.SIGKILL if the subprocess was killed.) On Windows systems, the return value contains the signed integer return code from the child process.

This is implemented using subprocess.Popen; see that class's documentation for more powerful ways to manage and communicate with subprocesses.
os.spawnl(mode, path, ...)
os.spawnle(mode, path, ..., env)
os.spawnlp(mode, file, ...)
os.spawnlpe(mode, file, ..., env)
os.spawnv(mode, path, args)
os.spawnve(mode, path, args, env)
os.spawnvp(mode, file, args)
os.spawnvpe(mode, file, args, env)

Execute the program path in a new process.

(Note that the subprocess module provides more powerful facilities for spawning new processes and retrieving their results; using that module is preferable to using these functions. Check especially the Replacing Older Functions with the subprocess Module section.)

If mode is P_NOWAIT, this function returns the process id of the new process; if mode is P_WAIT, returns the process's exit code if it exits normally, or -signal, where signal is the signal that killed the process. On Windows, the process id will actually be the process handle, so can be used with the waitpid() function.

The “l” and “v” variants of the spawn* functions differ in how command-line arguments are passed. The “l” variants are perhaps the easiest to work with if the number of parameters is fixed when the code is written; the individual parameters simply become additional parameters to the spawnl*() functions. The “v” variants are good when the number of parameters is variable, with the arguments being passed in a list or tuple as the args parameter. In either case, the arguments to the child process must start with the name of the command being run.
The variants which include a second “p” near the end (spawnlp(), spawnlpe(), spawnvp(), and spawnvpe()) will use the PATH environment variable to locate the program file. When the environment is being replaced (using one of the spawn*e variants, discussed in the next paragraph), the new environment is used as the source of the PATH variable. The other variants, spawnl(), spawnle(), spawnv(), and spawnve(), will not use the PATH variable to locate the executable; path must contain an appropriate absolute or relative path.

For spawnle(), spawnlpe(), spawnve(), and spawnvpe() (note that these all end in “e”), the env parameter must be a mapping which is used to define the environment variables for the new process (they are used instead of the current process’ environment); the functions spawnl(), spawnlp(), spawnv(), and spawnvp() all cause the new process to inherit the environment of the current process. Note that keys and values in the env dictionary must be strings; invalid keys or values will cause the function to fail, with a return value of 127.

As an example, the following calls to spawnlp() and spawnvpe() are equivalent:

```python
import os
os.spawnlp(os.P_WAIT, 'cp', 'cp', 'index.html', '
L = ['cp', 'index.html', '/dev/null']
os.spawnvpe(os.P_WAIT, 'cp', L, os.environ)
```

Availability: Unix, Windows. spawnlp(), spawnlpe(), spawnvp() and spawnvpe() are not available on Windows. spawnle() and spawnve() are not thread-safe on Windows; we
advise you to use the subprocess module instead.

`os.P_NOWAIT`
`os.P_NOWAITO`
Possible values for the *mode* parameter to the *spawn* family of functions. If either of these values is given, the *spawn*() functions will return as soon as the new process has been created, with the process id as the return value.

Availability: Unix, Windows.

`os.P_WAIT`
Possible value for the *mode* parameter to the *spawn* family of functions. If this is given as *mode*, the *spawn*() functions will not return until the new process has run to completion and will return the exit code of the process the run is successful, or -signal if a signal kills the process.

Availability: Unix, Windows.

`os.P_DETACH`
`os.P_OVERLAY`
Possible values for the *mode* parameter to the *spawn* family of functions. These are less portable than those listed above. *P_DETACH* is similar to *P_NOWAIT*, but the new process is detached from the console of the calling process. If *P_OVERLAY* is used, the current process will be replaced; the *spawn* function will not return.

Availability: Windows.

`os.startfile(path[, operation])`
Start a file with its associated application.

When *operation* is not specified or 'open', this acts like double-clicking the file in Windows Explorer, or giving the file name as an argument to the `start` command from the interactive command shell: the file is opened with whatever application (if any) its extension is associated.

When another *operation* is given, it must be a “command verb” that specifies what should be done with the file. Common verbs documented by Microsoft are 'print' and 'edit' (to be used on files) as well as 'explore' and 'find' (to be used on directories).

`startfile()` returns as soon as the associated application is launched. There is no option to wait for the application to close, and no way to retrieve the application’s exit status. The *path* parameter is relative to the current directory. If you want to use an absolute path, make sure the first character is not a slash (`/`); the underlying Win32 `ShellExecute()` function doesn't work if it is. Use the `os.path.normpath()` function to ensure that the path is properly encoded for Win32.

To reduce interpreter startup overhead, the Win32 `ShellExecute()` function is not resolved until this function is first called. If the function cannot be resolved, `NotImplementedError` will be raised.

Availability: Windows.

`os.system(command)`

Execute the command (a string) in a subshell. This is implemented by calling the Standard C function `system()`, and has the same
limitations. Changes to `sys.stdin`, etc. are not reflected in the environment of the executed command. If `command` generates any output, it will be sent to the interpreter standard output stream.

On Unix, the return value is the exit status of the process encoded in the format specified for `wait()`. Note that POSIX does not specify the meaning of the return value of the C `system()` function, so the return value of the Python function is system-dependent.

On Windows, the return value is that returned by the system shell after running `command`. The shell is given by the Windows environment variable `COMSPEC`: it is usually `cmd.exe`, which returns the exit status of the command run; on systems using a non-native shell, consult your shell documentation.

The `subprocess` module provides more powerful facilities for spawning new processes and retrieving their results; using that module is preferable to using this function. See the Replacing Older Functions with the subprocess Module section in the subprocess documentation for some helpful recipes.

Availability: Unix, Windows.

`os.times()`
Returns the current global process times. The return value is an object with five attributes:

- `user` - user time
- `system` - system time
- `children_user` - user time of all child processes
- `children_system` - system time of all child processes
- `elapsed` - elapsed real time since a fixed point in the past
For backwards compatibility, this object also behaves like a five-tuple containing user, system, children_user, children_system, and elapsed in that order.

See the Unix manual page times(2) or the corresponding Windows Platform API documentation. On Windows, only user and system are known; the other attributes are zero.

Availability: Unix, Windows.

Changed in version 3.3: Return type changed from a tuple to a tuple-like object with named attributes.

os.wait()  
Wait for completion of a child process, and return a tuple containing its pid and exit status indication: a 16-bit number, whose low byte is the signal number that killed the process, and whose high byte is the exit status (if the signal number is zero); the high bit of the low byte is set if a core file was produced.

Availability: Unix.

os.waitid(idtype, id, options)  
Wait for the completion of one or more child processes. idtype can be P_PID, P_PGID or P_ALL. id specifies the pid to wait on. options is constructed from the ORing of one or more of WEXITED, WSTOPPED or WCONTINUED and additionally may be ORed with WNOHANG or WNOWAIT. The return value is an object representing the data contained in the siginfo_t structure, namely: si_pid, si_uid, si_signo, si_status, si_code or None if WNOHANG is specified and there are no children in a waitable state.

Availability: Unix.
New in version 3.3.

```

os.P_PID
os.P_PGID
os.P_ALL
These are the possible values for idtype in `waitid()`. They affect how `id` is interpreted.

Availability: Unix.

New in version 3.3.

os.WEXITED
os.WSTOPPED
os.WNOWAIT
Flags that can be used in options in `waitid()` that specify what child signal to wait for.

Availability: Unix.

New in version 3.3.

os.CLD_EXITED
os.CLD_DUMPED
os.CLD_TRAPPED
os.CLD_CONTINUED
These are the possible values for si_code in the result returned by `waitid()`.

Availability: Unix.

New in version 3.3.

os.waitpid(pid, options)
The details of this function differ on Unix and Windows.

On Unix: Wait for completion of a child process given by process id `pid`, and return a tuple containing its process id and exit status indication (encoded as for `wait()`). The semantics of the call are affected by the value of the integer `options`, which should be 0 for normal operation.

If `pid` is greater than 0, `waitpid()` requests status information for that specific process. If `pid` is 0, the request is for the status of any child in the process group of the current process. If `pid` is -1, the request pertains to any child of the current process. If `pid` is less than -1, status is requested for any process in the process group - `pid` (the absolute value of `pid`).

An `OSError` is raised with the value of `errno` when the syscall returns -1.

On Windows: Wait for completion of a process given by process handle `pid`, and return a tuple containing `pid`, and its exit status shifted left by 8 bits (shifting makes cross-platform use of the function easier). A `pid` less than or equal to 0 has no special meaning on Windows, and raises an exception. The value of integer `options` has no effect. `pid` can refer to any process whose id is known, not necessarily a child process. The `spawn*` functions called with `P_NOWAIT` return suitable process handles.

*Changed in version 3.5:* If the system call is interrupted and the signal handler does not raise an exception, the function now retries the system call instead of raising an `InterruptedError` exception (see `PEP 475` for the rationale).
os.wait3(*options*)

Similar to `waitpid()`, except no process id argument is given and a 3-element tuple containing the child's process id, exit status indication, and resource usage information is returned. Refer to `resource.getrusage()` for details on resource usage information. The option argument is the same as that provided to `waitpid()` and `wait4()`.

Availability: Unix.

os.wait4(*pid, options*)

Similar to `waitpid()`, except a 3-element tuple, containing the child's process id, exit status indication, and resource usage information is returned. Refer to `resource.getrusage()` for details on resource usage information. The arguments to `wait4()` are the same as those provided to `waitpid()`.

Availability: Unix.

os.WNOHANG

The option for `waitpid()` to return immediately if no child process status is available immediately. The function returns `(0, 0)` in this case.

Availability: Unix.

os.WCONTINUED

This option causes child processes to be reported if they have been continued from a job control stop since their status was last reported.

Availability: some Unix systems.
This option causes child processes to be reported if they have been stopped but their current state has not been reported since they were stopped.

Availability: Unix.

The following functions take a process status code as returned by `system()`, `wait()`, or `waitpid()` as a parameter. They may be used to determine the disposition of a process.

**os.WUNCOREDUMP**(status)
Return True if a core dump was generated for the process, otherwise return False.

Availability: Unix.

**os.WIFCONTINUED**(status)
Return True if the process has been continued from a job control stop, otherwise return False.

Availability: Unix.

**os.WIFSTOPPED**(status)
Return True if the process has been stopped, otherwise return False.

Availability: Unix.

**os.WIFSIGNALED**(status)
Return True if the process exited due to a signal, otherwise return False.
Availability: Unix.

**os.WIFEXITED**(status)

Return True if the process exited using the `exit(2)` system call, otherwise return False.

Availability: Unix.

**os.WEXITSTATUS**(status)

If WIFEXITED(status) is true, return the integer parameter to the `exit(2)` system call. Otherwise, the return value is meaningless.

Availability: Unix.

**os.WSTOPSIG**(status)

Return the signal which caused the process to stop.

Availability: Unix.

**os.WTERMSIG**(status)

Return the signal which caused the process to exit.

Availability: Unix.
16.1.7. Interface to the scheduler

These functions control how a process is allocated CPU time by the operating system. They are only available on some Unix platforms. For more detailed information, consult your Unix manpages.

*New in version 3.3.*

The following scheduling policies are exposed if they are supported by the operating system.

- **os.SCHED_OTHER**
  - The default scheduling policy.

- **os.SCHED_BATCH**
  - Scheduling policy for CPU-intensive processes that tries to preserve interactivity on the rest of the computer.

- **os.SCHED_IDLE**
  - Scheduling policy for extremely low priority background tasks.

- **os.SCHED_SPORADIC**
  - Scheduling policy for sporadic server programs.

- **os.SCHED_FIFO**
  - A First In First Out scheduling policy.

- **os.SCHED_RR**
  - A round-robin scheduling policy.

- **os.SCHED_RESET_ON_FORK**
  - This flag can OR'ed with any other scheduling policy. When a process with this flag set forks, its child’s scheduling policy and
priority are reset to the default.

\texttt{class os\texttt{.}sched\_param(sched\_priority)}

This class represents tunable scheduling parameters used in \texttt{sched\_setparam()}, \texttt{sched\_setscheduler()}, and \texttt{sched\_getparam()}. It is immutable.

At the moment, there is only one possible parameter:

\texttt{sched\_priority}

The scheduling priority for a scheduling policy.

\texttt{os\texttt{.}sched\_get\_priority\_min(policy)}

Get the minimum priority value for \texttt{policy}. \texttt{policy} is one of the scheduling policy constants above.

\texttt{os\texttt{.}sched\_get\_priority\_max(policy)}

Get the maximum priority value for \texttt{policy}. \texttt{policy} is one of the scheduling policy constants above.

\texttt{os\texttt{.}sched\_setscheduler(pid, policy, param)}

Set the scheduling policy for the process with PID \texttt{pid}. A \texttt{pid} of 0 means the calling process. \texttt{policy} is one of the scheduling policy constants above. \texttt{param} is a \texttt{sched\_param} instance.

\texttt{os\texttt{.}sched\_getscheduler(pid)}

Return the scheduling policy for the process with PID \texttt{pid}. A \texttt{pid} of 0 means the calling process. The result is one of the scheduling policy constants above.

\texttt{os\texttt{.}sched\_setparam(pid, param)}

Set a scheduling parameters for the process with PID \texttt{pid}. A \texttt{pid} of 0 means the calling process. \texttt{param} is a \texttt{sched\_param} instance.
os.\texttt{sched\_getparam}(\textit{pid})

Return the scheduling parameters as a \texttt{sched\_param} instance for the process with PID \textit{pid}. A \textit{pid} of 0 means the calling process.

os.\texttt{sched\_rr\_get\_interval}(\textit{pid})

Return the round-robin quantum in seconds for the process with PID \textit{pid}. A \textit{pid} of 0 means the calling process.

os.\texttt{sched\_yield}()

Voluntarily relinquish the CPU.

os.\texttt{sched\_setaffinity}(\textit{pid}, \textit{mask})

Restrict the process with PID \textit{pid} (or the current process if zero) to a set of CPUs. \textit{mask} is an iterable of integers representing the set of CPUs to which the process should be restricted.

os.\texttt{sched\_getaffinity}(\textit{pid})

Return the set of CPUs the process with PID \textit{pid} (or the current process if zero) is restricted to.
16.1.8. Miscellaneous System Information

**os.confstr(name)**

Return string-valued system configuration values. *name* specifies the configuration value to retrieve; it may be a string which is the name of a defined system value; these names are specified in a number of standards (POSIX, Unix 95, Unix 98, and others). Some platforms define additional names as well. The names known to the host operating system are given as the keys of the `confstr_names` dictionary. For configuration variables not included in that mapping, passing an integer for *name* is also accepted.

If the configuration value specified by *name* isn’t defined, None is returned.

If *name* is a string and is not known, `ValueError` is raised. If a specific value for *name* is not supported by the host system, even if it is included in `confstr_names`, an `OSError` is raised with `errno.EINVAL` for the error number.

Availability: Unix.

**os.confstr_names**

Dictionary mapping names accepted by `confstr()` to the integer values defined for those names by the host operating system. This can be used to determine the set of names known to the system.

Availability: Unix.

**os.cpu_count()**

Return the number of CPUs in the system. Returns None if
undetermined.

*New in version 3.4.*

**os.getloadavg()**

Return the number of processes in the system run queue averaged over the last 1, 5, and 15 minutes or raises **OSError** if the load average was unobtainable.

Availability: Unix.

**os.sysconf(name)**

Return integer-valued system configuration values. If the configuration value specified by name isn’t defined, -1 is returned. The comments regarding the name parameter for **confstr()** apply here as well; the dictionary that provides information on the known names is given by sysconf_names.

Availability: Unix.

**os.sysconf_names**

Dictionary mapping names accepted by **sysconf()** to the integer values defined for those names by the host operating system. This can be used to determine the set of names known to the system.

Availability: Unix.

The following data values are used to support path manipulation operations. These are defined for all platforms.

Higher-level operations on pathnames are defined in the **os.path** module.

**os.getcwd**
The constant string used by the operating system to refer to the current directory. This is '.' for Windows and POSIX. Also available via os.path.

**os.pardir**
The constant string used by the operating system to refer to the parent directory. This is '..' for Windows and POSIX. Also available via os.path.

**os.sep**
The character used by the operating system to separate pathname components. This is '/' for POSIX and '\\' for Windows. Note that knowing this is not sufficient to be able to parse or concatenate pathnames — use os.path.split() and os.path.join() — but it is occasionally useful. Also available via os.path.

**os.altsep**
An alternative character used by the operating system to separate pathname components, or None if only one separator character exists. This is set to '/' on Windows systems where sep is a backslash. Also available via os.path.

**os.extsep**
The character which separates the base filename from the extension; for example, the '.' in os.py. Also available via os.path.

**os.pathsep**
The character conventionally used by the operating system to separate search path components (as in PATH), such as ':' for POSIX or ';' for Windows. Also available via os.path.
**os.defpath**
The default search path used by `exec*p*` and `spawn*p*` if the environment doesn't have a 'PATH' key. Also available via `os.path`.

**os.linesep**
The string used to separate (or, rather, terminate) lines on the current platform. This may be a single character, such as '\n' for POSIX, or multiple characters, for example, '\r\n' for Windows. Do not use `os.linesep` as a line terminator when writing files opened in text mode (the default); use a single '\n' instead, on all platforms.

**os.devnull**
The file path of the null device. For example: '/dev/null' for POSIX, 'nul' for Windows. Also available via `os.path`.

**os.RTLD_LAZY**
**os.RTLD_NOW**
**os.RTLD_GLOBAL**
**os.RTLD_LOCAL**
**os.RTLD_NODELETE**
**os.RTLD_NOLOAD**
**os.RTLD_DEEPBIND**
Flags for use with the `setdlopenflags()` and `getdlopenflags()` functions. See the Unix manual page `dlopen(3)` for what the different flags mean.

*New in version 3.3.*
16.1.9. Miscellaneous Functions

```
16.1.9.	Miscellaneous	Functions

os.urandom(n)

Return a string of n random bytes suitable for cryptographic use.

This function returns random bytes from an OS-specific randomness source. The returned data should be unpredictable enough for cryptographic applications, though its exact quality depends on the OS implementation. On a Unix-like system this will query /dev/urandom, and on Windows it will use CryptGenRandom(). If a randomness source is not found, NotImplementedError will be raised.

For an easy-to-use interface to the random number generator provided by your platform, please see random.SystemRandom.

Changed in version 3.5: On Linux 3.17 and newer, the getrandom() syscall is now used when available. On OpenBSD 5.6 and newer, the C getentropy() function is now used. These functions avoid the usage of an internal file descriptor.
```
16.2. **io** — Core tools for working with streams
16.2.1. Overview

The `io` module provides Python’s main facilities for dealing with various types of I/O. There are three main types of I/O: text I/O, binary I/O and raw I/O. These are generic categories, and various backing stores can be used for each of them. A concrete object belonging to any of these categories is called a file object. Other common terms are stream and file-like object.

Independently of its category, each concrete stream object will also have various capabilities: it can be read-only, write-only, or read-write. It can also allow arbitrary random access (seeking forwards or backwards to any location), or only sequential access (for example in the case of a socket or pipe).

All streams are careful about the type of data you give to them. For example giving a `str` object to the `write()` method of a binary stream will raise a TypeError. So will giving a `bytes` object to the `write()` method of a text stream.

*Changed in version 3.3:* Operations that used to raise IOError now raise OSError, since IOError is now an alias of OSError.

16.2.1.1. Text I/O

Text I/O expects and produces `str` objects. This means that whenever the backing store is natively made of bytes (such as in the case of a file), encoding and decoding of data is made transparently as well as optional translation of platform-specific newline characters.

The easiest way to create a text stream is with `open()`, optionally
specifying an encoding:

```python
f = open("myfile.txt", "r", encoding="utf-8")
```

In-memory text streams are also available as `StringIO` objects:

```python
f = io.StringIO("some initial text data")
```

The text stream API is described in detail in the documentation of `TextIOWrapper`.

### 16.2.1.2. Binary I/O

Binary I/O (also called *buffered I/O*) expects and produces `bytes` objects. No encoding, decoding, or newline translation is performed. This category of streams can be used for all kinds of non-text data, and also when manual control over the handling of text data is desired.

The easiest way to create a binary stream is with `open()` with 'b' in the mode string:

```python
f = open("myfile.jpg", "rb")
```

In-memory binary streams are also available as `BytesIO` objects:

```python
f = io.BytesIO(b"some initial binary data: \x00\x01")
```

The binary stream API is described in detail in the docs of `BufferedIOWrapper`.

Other library modules may provide additional ways to create text or binary streams. See `socket.socket.makefile()` for example.
16.2.1.3. Raw I/O

Raw I/O (also called unbuffered I/O) is generally used as a low-level building-block for binary and text streams; it is rarely useful to directly manipulate a raw stream from user code. Nevertheless, you can create a raw stream by opening a file in binary mode with buffering disabled:

```python
f = open("myfile.jpg", "rb", buffering=0)
```

The raw stream API is described in detail in the docs of `RawIOBase`.
16.2.2. High-level Module Interface

**io.DEFAULT_BUFFER_SIZE**

An int containing the default buffer size used by the module's buffered I/O classes. `open()` uses the file's blksize (as obtained by `os.stat()`) if possible.

**io.open(file, mode='r', buffering=-1, encoding=None, errors=None, newline=None, closefd=True, opener=None)**

This is an alias for the builtin `open()` function.

**exception io.BlockingIOError**

This is a compatibility alias for the builtin `BlockingIOError` exception.

**exception io.UnsupportedOperation**

An exception inheriting `OSError` and `ValueError` that is raised when an unsupported operation is called on a stream.

16.2.2.1. In-memory streams

It is also possible to use a `str` or `bytes`-like object as a file for both reading and writing. For strings `StringIO` can be used like a file opened in text mode. `BytesIO` can be used like a file opened in binary mode. Both provide full read-write capabilities with random access.

**See also:**

- `sys`
  - contains the standard IO streams: `sys.stdin`, `sys.stdout`,
and \texttt{sys.stderr}.
16.2.3. Class hierarchy

The implementation of I/O streams is organized as a hierarchy of classes. First abstract base classes (ABCs), which are used to specify the various categories of streams, then concrete classes providing the standard stream implementations.

**Note:** The abstract base classes also provide default implementations of some methods in order to help implementation of concrete stream classes. For example, `BufferedIOBase` provides unoptimized implementations of `readinto()` and `readline()`.

At the top of the I/O hierarchy is the abstract base class `I0Base`. It defines the basic interface to a stream. Note, however, that there is no separation between reading and writing to streams; implementations are allowed to raise `UnsupportedOperation` if they do not support a given operation.

The `RawI0Base` ABC extends `I0Base`. It deals with the reading and writing of bytes to a stream. `FileI0` subclasses `RawI0Base` to provide an interface to files in the machine’s file system.

The `BufferedI0Base` ABC deals with buffering on a raw byte stream (`RawI0Base`). Its subclasses, `BufferedReader`, `BufferedWriter`, and `BufferedRWPair` buffer streams that are readable, writable, and both readable and writable. `BufferedRandom` provides a buffered interface to random access streams. Another `BufferedI0Base` subclass, `BytesI0`, is a stream of in-memory bytes.

The `TextI0Base` ABC, another subclass of `I0Base`, deals with
streams whose bytes represent text, and handles encoding and decoding to and from strings. **TextIOWrapper**, which extends it, is a buffered text interface to a buffered raw stream (**BufferedIOBase**). Finally, **StringI0** is an in-memory stream for text.

Argument names are not part of the specification, and only the arguments of *open()* are intended to be used as keyword arguments.

The following table summarizes the ABCs provided by the **io** module:

<table>
<thead>
<tr>
<th>ABC</th>
<th>Inherits</th>
<th>Stub Methods</th>
<th>Mixin Methods and Properties</th>
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</thead>
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<td></td>
<td>fileno, seek, and truncate</td>
<td>close, closed, <strong>enter</strong>, <strong>exit</strong>, flush, isatty, <strong>iter</strong>, <strong>next</strong>, readable, readline, readlines, seekable, tell, writable, and writelines</td>
</tr>
<tr>
<td>RawIOBase</td>
<td>IOBase</td>
<td>readinto and write</td>
<td>Inherited <strong>IOBase</strong> methods, read, and readall</td>
</tr>
<tr>
<td>BufferedIOBase</td>
<td>IOBase</td>
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<td>Inherited <strong>IOBase</strong> methods, readinto</td>
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<tr>
<td>TextIOBase</td>
<td>IOBase</td>
<td>detach, read, readline, and write</td>
<td>Inherited <strong>IOBase</strong> methods, encoding, errors, and</td>
</tr>
</tbody>
</table>
16.2.3.1. I/O Base Classes

`class io.IOBase`

The abstract base class for all I/O classes, acting on streams of bytes. There is no public constructor.

This class provides empty abstract implementations for many methods that derived classes can override selectively; the default implementations represent a file that cannot be read, written or seeked.

Even though `IOBase` does not declare `read()`, `readinto()`, or `write()` because their signatures will vary, implementations and clients should consider those methods part of the interface. Also, implementations may raise a `ValueError` (or `UnsupportedOperation`) when operations they do not support are called.

The basic type used for binary data read from or written to a file is `bytes`. `bytearrays` are accepted too, and in some cases (such as `readinto()`) required. Text I/O classes work with `str` data.

Note that calling any method (even inquiries) on a closed stream is undefined. Implementations may raise `ValueError` in this case.

`IOBase` (and its subclasses) supports the iterator protocol, meaning that an `IOBase` object can be iterated over yielding the lines in a stream. Lines are defined slightly differently depending on whether the stream is a binary stream (yielding bytes), or a text stream (yielding character strings). See `readline()` below.
**IOBase** is also a context manager and therefore supports the ```with``` statement. In this example, ```file``` is closed after the ```with``` statement’s suite is finished—even if an exception occurs:

```python
with open('spam.txt', 'w') as file:
    file.write('Spam and eggs!')
```

**IOBase** provides these data attributes and methods:

- **close()**
  
  Flush and close this stream. This method has no effect if the file is already closed. Once the file is closed, any operation on the file (e.g. reading or writing) will raise a **ValueError**.

  As a convenience, it is allowed to call this method more than once; only the first call, however, will have an effect.

- **closed**
  
  True if the stream is closed.

- **fileno()**
  
  Return the underlying file descriptor (an integer) of the stream if it exists. An **OSError** is raised if the IO object does not use a file descriptor.

- **flush()**
  
  Flush the write buffers of the stream if applicable. This does nothing for read-only and non-blocking streams.

- **isatty()**
  
  Return True if the stream is interactive (i.e., connected to a terminal/tty device).
**readable()**
Return True if the stream can be read from. If False, read() will raise OSError.

**readline(size=-1)**
Read and return one line from the stream. If size is specified, at most size bytes will be read.

The line terminator is always b'\n' for binary files; for text files, the newline argument to open() can be used to select the line terminator(s) recognized.

**readlines(hint=-1)**
Read and return a list of lines from the stream. hint can be specified to control the number of lines read: no more lines will be read if the total size (in bytes/characters) of all lines so far exceeds hint.

Note that it's already possible to iterate on file objects using for line in file: ... without calling file.readlines().

**seek(offset[, whence])**
Change the stream position to the given byte offset. offset is interpreted relative to the position indicated by whence. The default value for whence is SEEK_SET. Values for whence are:

- SEEK_SET or 0 – start of the stream (the default); offset should be zero or positive
- SEEK_CUR or 1 – current stream position; offset may be negative
- SEEK_END or 2 – end of the stream; offset is usually
negative

Return the new absolute position.

*New in version 3.1:* The SEEK_* constants.

*New in version 3.3:* Some operating systems could support additional values, like os.SEEK_HOLE or os.SEEK_DATA. The valid values for a file could depend on it being open in text or binary mode.

**seekable()**

Return True if the stream supports random access. If False, *seek(), tell() and truncate() will raise OSError.*

**tell()**

Return the current stream position.

**truncate(size=None)**

Resize the stream to the given size in bytes (or the current position if size is not specified). The current stream position isn't changed. This resizing can extend or reduce the current file size. In case of extension, the contents of the new file area depend on the platform (on most systems, additional bytes are zero-filled). The new file size is returned.

*Changed in version 3.5:* Windows will now zero-fill files when extending.

**writable()**

Return True if the stream supports writing. If False, *write() and truncate() will raise OSError.*

**writelines(lines)**
Write a list of lines to the stream. Line separators are not added, so it is usual for each of the lines provided to have a line separator at the end.

```python
__del__()
```

Prepare for object destruction. `IOBase` provides a default implementation of this method that calls the instance's `close()` method.

```python
class io.RawIOBase
```

Base class for raw binary I/O. It inherits `IOBase`. There is no public constructor.

Raw binary I/O typically provides low-level access to an underlying OS device or API, and does not try to encapsulate it in high-level primitives (this is left to Buffered I/O and Text I/O, described later in this page).

In addition to the attributes and methods from `IOBase`, `RawIOBase` provides the following methods:

```python
read(size=-1)
```

Read up to `size` bytes from the object and return them. As a convenience, if `size` is unspecified or -1, `readall()` is called. Otherwise, only one system call is ever made. Fewer than `size` bytes may be returned if the operating system call returns fewer than `size` bytes.

If 0 bytes are returned, and `size` was not 0, this indicates end of file. If the object is in non-blocking mode and no bytes are available, `None` is returned.

```python
readall()
```
Read and return all the bytes from the stream until EOF, using multiple calls to the stream if necessary.

**readinto**(b)
Read up to \( \text{len}(b) \) bytes into `bytearray b` and return the number of bytes read. If the object is in non-blocking mode and no bytes are available, `None` is returned.

**write**(b)
Write the given `bytes` or `bytearray` object, \( b \), to the underlying raw stream and return the number of bytes written. This can be less than \( \text{len}(b) \), depending on specifics of the underlying raw stream, and especially if it is in non-blocking mode. `None` is returned if the raw stream is set not to block and no single byte could be readily written to it.

**class** `io.BufferedIOBase`
Base class for binary streams that support some kind of buffering. It inherits `IOBase`. There is no public constructor.

The main difference with `RawIOBase` is that methods `read()`, `readinto()` and `write()` will try (respectively) to read as much input as requested or to consume all given output, at the expense of making perhaps more than one system call.

In addition, those methods can raise `BlockingIOError` if the underlying raw stream is in non-blocking mode and cannot take or give enough data; unlike their `RawIOBase` counterparts, they will never return `None`.

Besides, the `read()` method does not have a default implementation that defers to `readinto()`.
A typical `BufferedIOBase` implementation should not inherit from a `RawIOBase` implementation, but wrap one, like `BufferedWriter` and `BufferedReader` do.

`BufferedIOBase` provides or overrides these methods and attribute in addition to those from `IOBase`:

**raw**

The underlying raw stream (a `RawIOBase` instance) that `BufferedIOBase` deals with. This is not part of the `BufferedIOBase` API and may not exist on some implementations.

**detach()**

Separate the underlying raw stream from the buffer and return it.

After the raw stream has been detached, the buffer is in an unusable state.

Some buffers, like `BytesIO`, do not have the concept of a single raw stream to return from this method. They raise `UnsupportedOperation`.

*New in version 3.1.*

**read(size=-1)**

Read and return up to size bytes. If the argument is omitted, None, or negative, data is read and returned until EOF is reached. An empty `bytes` object is returned if the stream is already at EOF.

If the argument is positive, and the underlying raw stream is not
interactive, multiple raw reads may be issued to satisfy the byte count (unless EOF is reached first). But for interactive raw streams, at most one raw read will be issued, and a short result does not imply that EOF is imminent.

A **BlockingIOError** is raised if the underlying raw stream is in non blocking-mode, and has no data available at the moment.

**read1(size=-1)**
Read and return up to size bytes, with at most one call to the underlying raw stream’s `read()` (or `readinto()`) method. This can be useful if you are implementing your own buffering on top of a `BufferedIOBase` object.

**readinto(b)**
Read up to `len(b)` bytes into bytearray `b` and return the number of bytes read.

Like `read()`, multiple reads may be issued to the underlying raw stream, unless the latter is interactive.

A **BlockingIOError** is raised if the underlying raw stream is in non blocking-mode, and has no data available at the moment.

**readinto1(b)**
Read up to `len(b)` bytes into bytearray `b`, using at most one call to the underlying raw stream’s `read()` (or `readinto()`) method. Return the number of bytes read.

A **BlockingIOError** is raised if the underlying raw stream is in non blocking-mode, and has no data available at the
write(b)
Write the given bytes or bytearray object, b and return the number of bytes written (never less than len(b), since if the write fails an OSError will be raised). Depending on the actual implementation, these bytes may be readily written to the underlying stream, or held in a buffer for performance and latency reasons.

When in non-blocking mode, a BlockingIOError is raised if the data needed to be written to the raw stream but it couldn’t accept all the data without blocking.

16.2.3.2. Raw File I/O

class io.FileIO(name, mode='r', closefd=True, opener=None)

FileIO represents an OS-level file containing bytes data. It implements the RawIOBase interface (and therefore the IOBase interface, too).

The name can be one of two things:

- a character string or bytes object representing the path to the file which will be opened. In this case closefd must be True (the default) otherwise an error will be raised.
- an integer representing the number of an existing OS-level file descriptor to which the resulting FileIO object will give access. When the FileIO object is closed this fd will be closed as well, unless closefd is set to False.
The *mode* can be 'r', 'w', 'x' or 'a' for reading (default), writing, exclusive creation or appending. The file will be created if it doesn't exist when opened for writing or appending; it will be truncated when opened for writing. *FileExistsError* will be raised if it already exists when opened for creating. Opening a file for creating implies writing, so this mode behaves in a similar way to 'w'. Add a '+' to the mode to allow simultaneous reading and writing.

The read() (when called with a positive argument), readinto() and write() methods on this class will only make one system call.

A custom opener can be used by passing a callable as *opener*. The underlying file descriptor for the file object is then obtained by calling *opener* with (name, flags). *opener* must return an open file descriptor (passing *os.open* as *opener* results in functionality similar to passing None).

The newly created file is non-inheritable.

See the *open()* built-in function for examples on using the *opener* parameter.

*Changed in version 3.3:* The *opener* parameter was added. The 'x' mode was added.

*Changed in version 3.4:* The file is now non-inheritable.

In addition to the attributes and methods from *IOBase* and *RawIOBase*, *FileIO* provides the following data attributes:

*mode*
The mode as given in the constructor.

name
The file name. This is the file descriptor of the file when no name is given in the constructor.

16.2.3.3. Buffered Streams

Buffered I/O streams provide a higher-level interface to an I/O device than raw I/O does.

class io.BytesIO([initial_bytes])
A stream implementation using an in-memory bytes buffer. It inherits BufferedIOBase. The buffer is discarded when the close() method is called.

The argument initial_bytes contains optional initial bytes data.

BytesIO provides or overrides these methods in addition to those from BufferedIOBase and IOBase:

getbuffer()
Return a readable and writable view over the contents of the buffer without copying them. Also, mutating the view will transparently update the contents of the buffer:

```python
>>> b = io.BytesIO(b"abcdef")
>>> view = b.getbuffer()
>>> view[2:4] = b"56"
>>> b.getvalue()
b'ab56ef'
```
Note: As long as the view exists, the BytesIO object cannot be resized or closed.

New in version 3.2.

getvalue()
Return bytes containing the entire contents of the buffer.

read1()
In BytesIO, this is the same as read().

readinto1()
In BytesIO, this is the same as readinto().

New in version 3.5.

class io.BufferedReader(raw,
buffer_size=DEFAULT_BUFFER_SIZE)
A buffer providing higher-level access to a readable, sequential RawIOBase object. It inherits BufferedReader. When reading data from this object, a larger amount of data may be requested from the underlying raw stream, and kept in an internal buffer. The buffered data can then be returned directly on subsequent reads.

The constructor creates a BufferedReader for the given readable raw stream and buffer_size. If buffer_size is omitted, DEFAULT_BUFFER_SIZE is used.

BufferedReader provides or overrides these methods in addition to those from BufferedReader and IOBase:

peek([size])
Return bytes from the stream without advancing the position. At
most one single read on the raw stream is done to satisfy the call. The number of bytes returned may be less or more than requested.

`read([size])`
Read and return size bytes, or if size is not given or negative, until EOF or if the read call would block in non-blocking mode.

`read1(size)`
Read and return up to size bytes with only one call on the raw stream. If at least one byte is buffered, only buffered bytes are returned. Otherwise, one raw stream read call is made.

```python
class io.BufferedWriter(raw,
buffer_size=DEFAULT_BUFFER_SIZE)
```
A buffer providing higher-level access to a writeable, sequential `RawIOBase` object. It inherits `BufferedIOBase`. When writing to this object, data is normally placed into an internal buffer. The buffer will be written out to the underlying `RawIOBase` object under various conditions, including:

- when the buffer gets too small for all pending data;
- when `flush()` is called;
- when a `seek()` is requested (for `BufferedRandom` objects);
- when the `BufferedWriter` object is closed or destroyed.

The constructor creates a `BufferedWriter` for the given writeable `raw` stream. If the `buffer_size` is not given, it defaults to `DEFAULT_BUFFER_SIZE`.

`BufferedWriter` provides or overrides these methods in addition to those from `BufferedIOBase` and `I0Base`:
flush()
Force bytes held in the buffer into the raw stream. A BlockingIOError should be raised if the raw stream blocks.

write(b)
Write the bytes or bytearray object, b and return the number of bytes written. When in non-blocking mode, a BlockingIOError is raised if the buffer needs to be written out but the raw stream blocks.

class io.BufferedRandom(raw,
buffer_size=DEFAULT_BUFFER_SIZE)
A buffered interface to random access streams. It inherits BufferedReader and BufferedWriter, and further supports seek() and tell() functionality.

The constructor creates a reader and writer for a seekable raw stream, given in the first argument. If the buffer_size is omitted it defaults to DEFAULT_BUFFER_SIZE.

BufferedRandom is capable of anything BufferedReader or BufferedWriter can do.

class io.BufferedRWPair(reader, writer,
buffer_size=DEFAULT_BUFFER_SIZE)
A buffered I/O object combining two unidirectional RawIOBase objects – one readable, the other writeable – into a single bidirectional endpoint. It inherits BufferedIOBase.

reader and writer are RawIOBase objects that are readable and writeable respectively. If the buffer_size is omitted it defaults to DEFAULT_BUFFER_SIZE.
BufferedRWPair implements all of BufferedIOBase's methods except for detach(), which raises UnsupportedOperation.

**Warning:** BufferedRWPair does not attempt to synchronize accesses to its underlying raw streams. You should not pass it the same object as reader and writer; use BufferedRandom instead.

16.2.3.4. Text I/O

class io.TextIOBase
Base class for text streams. This class provides a character and line based interface to stream I/O. There is no readinto() method because Python’s character strings are immutable. It inherits IOBase. There is no public constructor.

TextIOBase provides or overrides these data attributes and methods in addition to those from IOBase:

**encoding**
The name of the encoding used to decode the stream’s bytes into strings, and to encode strings into bytes.

**errors**
The error setting of the decoder or encoder.

**newlines**
A string, a tuple of strings, or None, indicating the newlines translated so far. Depending on the implementation and the initial constructor flags, this may not be available.

**buffer**
The underlying binary buffer (a `BufferedIOBase` instance) that `TextIOBase` deals with. This is not part of the `TextIOBase` API and may not exist in some implementations.

**detach()**

Separate the underlying binary buffer from the `TextIOBase` and return it.

After the underlying buffer has been detached, the `TextIOBase` is in an unusable state.

Some `TextIOBase` implementations, like `StringIO`, may not have the concept of an underlying buffer and calling this method will raise `UnsupportedOperation`.

*New in version 3.1.*

**read(size)**

Read and return at most `size` characters from the stream as a single `str`. If `size` is negative or `None`, reads until EOF.

**readline(size=-1)**

Read until newline or EOF and return a single `str`. If the stream is already at EOF, an empty string is returned.

If `size` is specified, at most `size` characters will be read.

**seek(offset[, whence])**

Change the stream position to the given `offset`. Behaviour depends on the `whence` parameter. The default value for `whence` is `SEEK_SET`.

- `SEEK_SET` or 0: seek from the start of the stream (the
offset} must either be a number returned by \texttt{TextIOBase.tell()}, or zero. Any other \texttt{offset} value produces undefined behaviour.

- \texttt{SEEK\_CUR} or 1: “seek” to the current position; \texttt{offset} must be zero, which is a no-operation (all other values are unsupported).

- \texttt{SEEK\_END} or 2: seek to the end of the stream; \texttt{offset} must be zero (all other values are unsupported).

Return the new absolute position as an opaque number.

\textit{New in version 3.1}: The \texttt{SEEK\_\*} constants.

\texttt{tell()}

Return the current stream position as an opaque number. The number does not usually represent a number of bytes in the underlying binary storage.

\texttt{write(s)}

Write the string \texttt{s} to the stream and return the number of characters written.

\texttt{class io.TextIOWrapper(buffer, encoding=None, errors=None, newline=None, line_buffering=False, write_through=False)}

A buffered text stream over a \texttt{BufferedIOBase} binary stream. It inherits \texttt{TextIOBase}.

\textit{encoding} gives the name of the encoding that the stream will be decoded or encoded with. It defaults to \texttt{locale.getpreferredencoding(False)}.

\textit{errors} is an optional string that specifies how encoding and decoding errors are to be handled. Pass 'strict' to raise a \texttt{ValueError} exception if there is an encoding error (the default of
None has the same effect), or pass 'ignore' to ignore errors.
(Note that ignoring encoding errors can lead to data loss.)
'replace' causes a replacement marker (such as '?') to be
inserted where there is malformed data. 'backslashreplace'
causes malformed data to be replaced by a backslashed escape
sequence. When writing, 'xmlcharrefreplace' (replace with
the appropriate XML character reference) or 'namereplace'
(replace with \N{...} escape sequences) can be used. Any other
error handling name that has been registered with
codecs.register_error() is also valid.

newline controls how line endings are handled. It can be None, '',
'\n', '\r', and '\r\n'. It works as follows:

- When reading input from the stream, if newline is None,
universal newlines mode is enabled. Lines in the input can end
in '\n', '\r', or '\r\n', and these are translated into '\n'
before being returned to the caller. If it is '', universal
newlines mode is enabled, but line endings are returned to
the caller untranslated. If it has any of the other legal values,
input lines are only terminated by the given string, and the line
ending is returned to the caller untranslated.
- When writing output to the stream, if newline is None, any
'\n' characters written are translated to the system default
line separator, os.linesep. If newline is '' or '\n', no
translation takes place. If newline is any of the other legal
values, any '\n' characters written are translated to the given
string.

If line_buffering is True, flush() is implied when a call to write
contains a newline character.

If write_through is True, calls to write() are guaranteed not to
be buffered: any data written on the `TextIOWrapper` object is immediately handled to its underlying binary buffer.

*Changed in version 3.3:* The `write_through` argument has been added.

*Changed in version 3.3:* The default encoding is now `locale.getpreferredencoding(False)` instead of `locale.getpreferredencoding()`. Don't change temporary the locale encoding using `locale.setlocale()`, use the current locale encoding instead of the user preferred encoding.

`TextIOWrapper` provides one attribute in addition to those of `TextIOWrapper` and its parents:

`line_buffering`

Whether line buffering is enabled.

```
class io.StringIO(initial_value='', newline=None)
```

An in-memory stream for text I/O. The text buffer is discarded when the `close()` method is called.

The initial value of the buffer can be set by providing `initial_value`. If newline translation is enabled, newlines will be encoded as if by `write()`. The stream is positioned at the start of the buffer.

The `newline` argument works like that of `TextIOWrapper`. The default is to consider only `\n` characters as ends of lines and to do no newline translation. If `newline` is set to `None`, newlines are written as `\n` on all platforms, but universal newline decoding is still performed when reading.

`StringIO` provides this method in addition to those from
**TextIOWrapper** and its parents:

`getvalue()`

Return a str containing the entire contents of the buffer. Newlines are decoded as if by `read()`, although the stream position is not changed.

Example usage:

```python
import io

output = io.StringIO()
output.write('First line.
')
print('Second line.', file=output)

# Retrieve file contents -- this will be
# 'First line.
Second line.
'
contents = output.getvalue()

# Close object and discard memory buffer --
# .getvalue() will now raise an exception.
output.close()
```

class `io.IncrementalNewlineDecoder`

A helper codec that decodes newlines for **universal newlines** mode. It inherits `codecs.IncrementalDecoder`. 
16.2.4. Performance

This section discusses the performance of the provided concrete I/O implementations.

16.2.4.1. Binary I/O

By reading and writing only large chunks of data even when the user asks for a single byte, buffered I/O hides any inefficiency in calling and executing the operating system's unbuffered I/O routines. The gain depends on the OS and the kind of I/O which is performed. For example, on some modern OSes such as Linux, unbuffered disk I/O can be as fast as buffered I/O. The bottom line, however, is that buffered I/O offers predictable performance regardless of the platform and the backing device. Therefore, it is almost always preferable to use buffered I/O rather than unbuffered I/O for binary data.

16.2.4.2. Text I/O

Text I/O over a binary storage (such as a file) is significantly slower than binary I/O over the same storage, because it requires conversions between unicode and binary data using a character codec. This can become noticeable handling huge amounts of text data like large log files. Also, TextIOWrapper.tell() and TextIOWrapper.seek() are both quite slow due to the reconstruction algorithm used.

StringIO, however, is a native in-memory unicode container and will exhibit similar speed to BytesIO.
16.2.4.3. Multi-threading

FileIO objects are thread-safe to the extent that the operating system calls (such as read(2) under Unix) they wrap are thread-safe too.

Binary buffered objects (instances of BufferedReader, BufferedWriter, BufferedRandom and BufferedRWPair) protect their internal structures using a lock; it is therefore safe to call them from multiple threads at once.

TextIOWrapper objects are not thread-safe.

16.2.4.4. Reentrancy

Binary buffered objects (instances of BufferedReader, BufferedWriter, BufferedRandom and BufferedRWPair) are not reentrant. While reentrant calls will not happen in normal situations, they can arise from doing I/O in a signal handler. If a thread tries to re-enter a buffered object which it is already accessing, a RuntimeError is raised. Note this doesn’t prohibit a different thread from entering the buffered object.

The above implicitly extends to text files, since the open() function will wrap a buffered object inside a TextIOWrapper. This includes standard streams and therefore affects the built-in function print() as well.
The Python Software Foundation is a non-profit corporation. Please donate.

Last updated on Dec 06, 2015. Found a bug?

Created using Sphinx 1.3.1.
16.3. time — Time access and conversions

This module provides various time-related functions. For related functionality, see also the datetime and calendar modules.

Although this module is always available, not all functions are available on all platforms. Most of the functions defined in this module call platform C library functions with the same name. It may sometimes be helpful to consult the platform documentation, because the semantics of these functions varies among platforms.

An explanation of some terminology and conventions is in order.

- The epoch is the point where the time starts. On January 1st of that year, at 0 hours, the “time since the epoch” is zero. For Unix, the epoch is 1970. To find out what the epoch is, look at gmtime(0).

- The functions in this module may not handle dates and times before the epoch or far in the future. The cut-off point in the future is determined by the C library; for 32-bit systems, it is typically in 2038.

- Year 2000 (Y2K) issues: Python depends on the platform’s C library, which generally doesn’t have year 2000 issues, since all dates and times are represented internally as seconds since the epoch. Function strptime() can parse 2-digit years when given %y format code. When 2-digit years are parsed, they are converted according to the POSIX and ISO C standards: values 69–99 are mapped to 1969–1999, and values 0–68 are mapped to 2000–2068.
UTC is Coordinated Universal Time (formerly known as Greenwich Mean Time, or GMT). The acronym UTC is not a mistake but a compromise between English and French.

DST is Daylight Saving Time, an adjustment of the timezone by (usually) one hour during part of the year. DST rules are magic (determined by local law) and can change from year to year. The C library has a table containing the local rules (often it is read from a system file for flexibility) and is the only source of True Wisdom in this respect.

The precision of the various real-time functions may be less than suggested by the units in which their value or argument is expressed. E.g. on most Unix systems, the clock “ticks” only 50 or 100 times a second.

On the other hand, the precision of `time()` and `sleep()` is better than their Unix equivalents: times are expressed as floating point numbers, `time()` returns the most accurate time available (using Unix `gettimeofday()` where available), and `sleep()` will accept a time with a nonzero fraction (Unix `select()` is used to implement this, where available).

The time value as returned by `gmtime()`, `localtime()`, and `strptime()`, and accepted by `asctime()`, `mktime()` and `strftime()`, is a sequence of 9 integers. The return values of `gmtime()`, `localtime()`, and `strptime()` also offer attribute names for individual fields.

See `struct_time` for a description of these objects.

*Changed in version 3.3:* The `struct_time` type was extended to provide the `tm_gmtoff` and `tm_zone` attributes when platform
supports corresponding struct tm members.

- Use the following functions to convert between time representations:

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>seconds since the epoch</td>
<td>struct_time in UTC</td>
<td>gmtime()</td>
</tr>
<tr>
<td>seconds since the epoch</td>
<td>struct_time in local time</td>
<td>localtime()</td>
</tr>
<tr>
<td>struct_time in UTC</td>
<td>seconds since the epoch</td>
<td>calendar.timegm()</td>
</tr>
<tr>
<td>struct_time in local time</td>
<td>seconds since the epoch</td>
<td>mktime()</td>
</tr>
</tbody>
</table>

The module defines the following functions and data items:

time.altzone

The offset of the local DST timezone, in seconds west of UTC, if one is defined. This is negative if the local DST timezone is east of UTC (as in Western Europe, including the UK). Only use this if daylight is nonzero.

time.asctime([t])

Convert a tuple or struct_time representing a time as returned by gmtime() or localtime() to a string of the following form: 'Sun Jun 20 23:21:05 1993'. If t is not provided, the current time as returned by localtime() is used. Locale information is not used by asctime().

Note: Unlike the C function of the same name, asctime()
**time.**clock()
On Unix, return the current processor time as a floating point number expressed in seconds. The precision, and in fact the very definition of the meaning of “processor time”, depends on that of the C function of the same name.

On Windows, this function returns wall-clock seconds elapsed since the first call to this function, as a floating point number, based on the Win32 function QueryPerformanceCounter(). The resolution is typically better than one microsecond.

*Deprecated since version 3.3:* The behaviour of this function depends on the platform: use perf_counter() or process_time() instead, depending on your requirements, to have a well defined behaviour.

**time.**clock_getres(clk_id)
Return the resolution (precision) of the specified clock clk_id.

Availability: Unix.

*New in version 3.3.*

**time.**clock_gettime(clk_id)
Return the time of the specified clock clk_id.

Availability: Unix.

*New in version 3.3.*

**time.**clock_settime(clk_id, time)
Set the time of the specified clock `clk_id`.

Availability: Unix.

*New in version 3.3.*

**time.CLOCK_HIGHRES**

The Solaris OS has a CLOCK_HIGHRES timer that attempts to use an optimal hardware source, and may give close to nanosecond resolution. CLOCK_HIGHRES is the nonadjustable, high-resolution clock.

Availability: Solaris.

*New in version 3.3.*

**time.CLOCK_MONOTONIC**

Clock that cannot be set and represents monotonic time since some unspecified starting point.

Availability: Unix.

*New in version 3.3.*

**time.CLOCK_MONOTONIC_RAW**

Similar to `CLOCK_MONOTONIC`, but provides access to a raw hardware-based time that is not subject to NTP adjustments.

Availability: Linux 2.6.28 or later.

*New in version 3.3.*

**time.CLOCK_PROCESS_CPUTIME_ID**

High-resolution per-process timer from the CPU.
Availability: Unix.

*New in version 3.3.*

time.`CLOCK_REALTIME`

System-wide real-time clock. Setting this clock requires appropriate privileges.

Availability: Unix.

*New in version 3.3.*

time.`CLOCK_THREAD_CPUTIME_ID`

Thread-specific CPU-time clock.

Availability: Unix.

*New in version 3.3.*

time.`ctime([secs])`

Convert a time expressed in seconds since the epoch to a string representing local time. If secs is not provided or `None`, the current time as returned by `time()` is used. `ctime(secs)` is equivalent to `asctime(localtime(secs))`. Locale information is not used by `ctime()`.

time.`daylight`

Nonzero if a DST timezone is defined.

time.`get_clock_info(name)`

Get information on the specified clock as a namespace object. Supported clock names and the corresponding functions to read their value are:
- 'clock': `time.clock()`
- 'monotonic': `time.monotonic()`
- 'perf_counter': `time.perf_counter()`
- 'process_time': `time.process_time()`
- 'time': `time.time()`

The result has the following attributes:

- **adjustable**: True if the clock can be changed automatically (e.g. by a NTP daemon) or manually by the system administrator, False otherwise
- **implementation**: The name of the underlying C function used to get the clock value
- **monotonic**: True if the clock cannot go backward, False otherwise
- **resolution**: The resolution of the clock in seconds (**float**)

*New in version 3.3.*

`time.gmtime([secs])`

Convert a time expressed in seconds since the epoch to a **struct_time** in UTC in which the dst flag is always zero. If **secs** is not provided or **None**, the current time as returned by **time()** is used. Fractions of a second are ignored. See above for a description of the **struct_time** object. See **calendar.timegm()** for the inverse of this function.

`time.localtime([secs])`

Like **gmtime()** but converts to local time. If **secs** is not provided or **None**, the current time as returned by **time()** is used. The dst flag is set to 1 when DST applies to the given time.

`time.mktime(t)`
This is the inverse function of \texttt{localtime()}. Its argument is the \texttt{struct\_time} or full 9-tuple (since the dst flag is needed; use -1 as the dst flag if it is unknown) which expresses the time in \textit{local} time, not UTC. It returns a floating point number, for compatibility with \texttt{time()}. If the input value cannot be represented as a valid time, either \texttt{OverflowError} or \texttt{ValueError} will be raised (which depends on whether the invalid value is caught by Python or the underlying C libraries). The earliest date for which it can generate a time is platform-dependent.

\texttt{time.monotonic()}

Return the value (in fractional seconds) of a monotonic clock, i.e. a clock that cannot go backwards. The clock is not affected by system clock updates. The reference point of the returned value is undefined, so that only the difference between the results of consecutive calls is valid.

On Windows versions older than Vista, \texttt{monotonic()} detects \texttt{GetTickCount()} integer overflow (32 bits, roll-over after 49.7 days). It increases an internal epoch (reference time) by $2^{32}$ each time that an overflow is detected. The epoch is stored in the process-local state and so the value of \texttt{monotonic()} may be different in two Python processes running for more than 49 days. On more recent versions of Windows and on other operating systems, \texttt{monotonic()} is system-wide.

\textit{New in version 3.3.}

\textit{Changed in version 3.5:} The function is now always available.

\texttt{time.perf\_counter()}

Return the value (in fractional seconds) of a performance counter,
i.e. a clock with the highest available resolution to measure a short duration. It does include time elapsed during sleep and is system-wide. The reference point of the returned value is undefined, so that only the difference between the results of consecutive calls is valid.

*New in version 3.3.*

**time.process_time()**
Return the value (in fractional seconds) of the sum of the system and user CPU time of the current process. It does not include time elapsed during sleep. It is process-wide by definition. The reference point of the returned value is undefined, so that only the difference between the results of consecutive calls is valid.

*New in version 3.3.*

**time.sleep(secs)**
Suspend execution of the calling thread for the given number of seconds. The argument may be a floating point number to indicate a more precise sleep time. The actual suspension time may be less than that requested because any caught signal will terminate the sleep() following execution of that signal's catching routine. Also, the suspension time may be longer than requested by an arbitrary amount because of the scheduling of other activity in the system.

*Changed in version 3.5:* The function now sleeps at least secs even if the sleep is interrupted by a signal, except if the signal handler raises an exception (see PEP 475 for the rationale).

**time.strftime(format[, t])**
Convert a tuple or struct_time representing a time as returned by gmtime() or localtime() to a string as specified by the
format argument. If t is not provided, the current time as returned by \texttt{localtime()} is used. \texttt{format} must be a string. \texttt{ValueError} is raised if any field in \( t \) is outside of the allowed range.

0 is a legal argument for any position in the time tuple; if it is normally illegal the value is forced to a correct one.

The following directives can be embedded in the \texttt{format} string. They are shown without the optional field width and precision specification, and are replaced by the indicated characters in the \texttt{strftime()} result:

<table>
<thead>
<tr>
<th>Directive</th>
<th>Meaning</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>%a</td>
<td>Locale’s abbreviated weekday name.</td>
<td></td>
</tr>
<tr>
<td>%A</td>
<td>Locale’s full weekday name.</td>
<td></td>
</tr>
<tr>
<td>%b</td>
<td>Locale’s abbreviated month name.</td>
<td></td>
</tr>
<tr>
<td>%B</td>
<td>Locale’s full month name.</td>
<td></td>
</tr>
<tr>
<td>%c</td>
<td>Locale’s appropriate date and time representation.</td>
<td></td>
</tr>
<tr>
<td>%d</td>
<td>Day of the month as a decimal number [01,31].</td>
<td></td>
</tr>
<tr>
<td>%H</td>
<td>Hour (24-hour clock) as a decimal number [00,23].</td>
<td></td>
</tr>
<tr>
<td>%I</td>
<td>Hour (12-hour clock) as a decimal number [01,12].</td>
<td></td>
</tr>
<tr>
<td>%j</td>
<td>Day of the year as a decimal number [001,366].</td>
<td></td>
</tr>
<tr>
<td>%m</td>
<td>Month as a decimal number [01,12].</td>
<td></td>
</tr>
<tr>
<td>%M</td>
<td>Minute as a decimal number [00,59].</td>
<td></td>
</tr>
<tr>
<td>%p</td>
<td>Locale’s equivalent of either AM or PM.</td>
<td>(1)</td>
</tr>
<tr>
<td>%S</td>
<td>Second as a decimal number [00,61].</td>
<td>(2)</td>
</tr>
<tr>
<td>----</td>
<td>----------------------------------</td>
<td>----</td>
</tr>
<tr>
<td>%U</td>
<td>Week number of the year (Sunday as the first day of the week) as a decimal number [00,53]. All days in a new year preceding the first Sunday are considered to be in week 0.</td>
<td>(3)</td>
</tr>
<tr>
<td>%W</td>
<td>Weekday as a decimal number [0(Sunday),6].</td>
<td></td>
</tr>
<tr>
<td>%W</td>
<td>Week number of the year (Monday as the first day of the week) as a decimal number [00,53]. All days in a new year preceding the first Monday are considered to be in week 0.</td>
<td>(3)</td>
</tr>
<tr>
<td>%x</td>
<td>Locale's appropriate date representation.</td>
<td></td>
</tr>
<tr>
<td>%X</td>
<td>Locale's appropriate time representation.</td>
<td></td>
</tr>
<tr>
<td>%y</td>
<td>Year without century as a decimal number [00,99].</td>
<td></td>
</tr>
<tr>
<td>%Y</td>
<td>Year with century as a decimal number.</td>
<td></td>
</tr>
<tr>
<td>%z</td>
<td>Time zone offset indicating a positive or negative time difference from UTC/GMT of the form +HHMM or -HHMM, where H represents decimal hour digits and M represents decimal minute digits [-23:59, +23:59].</td>
<td></td>
</tr>
<tr>
<td>%Z</td>
<td>Time zone name (no characters if no time zone exists).</td>
<td></td>
</tr>
<tr>
<td>%%</td>
<td>A literal '%' character.</td>
<td></td>
</tr>
</tbody>
</table>

Notes:

1. When used with the `strptime()` function, the %p directive only affects the output hour field if the %I directive is used to
parse the hour.  

2. The range really is 0 to 61; value 60 is valid in timestamps representing leap seconds and value 61 is supported for historical reasons.

3. When used with the `strptime()` function, `%U` and `%W` are only used in calculations when the day of the week and the year are specified.

Here is an example, a format for dates compatible with that specified in the RFC 2822 Internet email standard. [1]

```python
>>> from time import gmtime, strftime
>>> strftime("%a, %d %b %Y %H:%M:%S +0000", gmtime)
'Thu, 28 Jun 2001 14:17:15 +0000'
```

Additional directives may be supported on certain platforms, but only the ones listed here have a meaning standardized by ANSI C. To see the full set of format codes supported on your platform, consult the `strftime(3)` documentation.

On some platforms, an optional field width and precision specification can immediately follow the initial '%' of a directive in the following order; this is also not portable. The field width is normally 2 except for %j where it is 3.

```python
time.strptime(string[, format])
```

Parse a string representing a time according to a format. The return value is a `struct_time` as returned by `gmtime()` or `localtime()`.

The `format` parameter uses the same directives as those used by `strftime()`; it defaults to "%a %b %d %H:%M:%S %Y" which matches the formatting returned by `ctime()`. If `string` cannot be
parsed according to format, or if it has excess data after parsing, ValueError is raised. The default values used to fill in any missing data when more accurate values cannot be inferred are (1900, 1, 1, 0, 0, 0, 0, 1, -1). Both string and format must be strings.

For example:

```python
>>> import time
>>> time.strptime("30 Nov 00", "%d %b %y")
time.struct_time(tm_year=2000, tm_mon=11, tm_mday=30,
    tm_sec=0, tm_wday=3, tm_yday=335)
```

Support for the %Z directive is based on the values contained in tzname and whether daylight is true. Because of this, it is platform-specific except for recognizing UTC and GMT which are always known (and are considered to be non-daylight savings timezones).

Only the directives specified in the documentation are supported. Because strftime() is implemented per platform it can sometimes offer more directives than those listed. But strptime() is independent of any platform and thus does not necessarily support all directives available that are not documented as supported.

class time.struct_time

The type of the time value sequence returned by gmtime(), localtime(), and strptime(). It is an object with a named tuple interface: values can be accessed by index and by attribute name. The following values are present:
<table>
<thead>
<tr>
<th>Index</th>
<th>Attribute</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>tm_year</td>
<td>(for example, 1993)</td>
</tr>
<tr>
<td>1</td>
<td>tm_mon</td>
<td>range [1, 12]</td>
</tr>
<tr>
<td>2</td>
<td>tm_mday</td>
<td>range [1, 31]</td>
</tr>
<tr>
<td>3</td>
<td>tm_hour</td>
<td>range [0, 23]</td>
</tr>
<tr>
<td>4</td>
<td>tm_min</td>
<td>range [0, 59]</td>
</tr>
<tr>
<td>5</td>
<td>tm_sec</td>
<td>range [0, 61]; see (2) in strftime() description</td>
</tr>
<tr>
<td>6</td>
<td>tm_wday</td>
<td>range [0, 6], Monday is 0</td>
</tr>
<tr>
<td>7</td>
<td>tm_yday</td>
<td>range [1, 366]</td>
</tr>
<tr>
<td>8</td>
<td>tm_isdst</td>
<td>0, 1 or -1; see below</td>
</tr>
<tr>
<td>N/A</td>
<td>tm_zone</td>
<td>abbreviation of timezone name</td>
</tr>
<tr>
<td>N/A</td>
<td>tm_gmtoff</td>
<td>offset east of UTC in seconds</td>
</tr>
</tbody>
</table>

Note that unlike the C structure, the month value is a range of [1, 12], not [0, 11]. A -1 argument as the daylight savings flag, passed to mktime() will usually result in the correct daylight savings state to be filled in.

When a tuple with an incorrect length is passed to a function expecting a struct_time, or having elements of the wrong type, a TypeError is raised.

*Changed in version 3.3:* tm_gmtoff and tm_zone attributes are available on platforms with C library supporting the corresponding fields in struct tm.

time.time()

Return the time in seconds since the epoch as a floating point
number. Note that even though the time is always returned as a floating point number, not all systems provide time with a better precision than 1 second. While this function normally returns non-decreasing values, it can return a lower value than a previous call if the system clock has been set back between the two calls.

**time.timezone**

The offset of the local (non-DST) timezone, in seconds west of UTC (negative in most of Western Europe, positive in the US, zero in the UK).

**time.tzname**

A tuple of two strings: the first is the name of the local non-DST timezone, the second is the name of the local DST timezone. If no DST timezone is defined, the second string should not be used.

**time.tzset()**

Resets the time conversion rules used by the library routines. The environment variable TZ specifies how this is done.

**Availability**: Unix.

**Note**: Although in many cases, changing the TZ environment variable may affect the output of functions like `localtime()` without calling `tzset()`, this behavior should not be relied on. The TZ environment variable should contain no whitespace.

The standard format of the TZ environment variable is (whitespace added for clarity):

```
std offset [dst [offset [,start[/time], end[/time] [,endtime]]] [,...]]
```
Where the components are:

std and dst

Three or more alphanumerics giving the timezone abbreviations. These will be propagated into time.tzname

offset

The offset has the form: ± hh[:mm[:ss]]. This indicates the value added the local time to arrive at UTC. If preceded by a ‘-‘, the timezone is east of the Prime Meridian; otherwise, it is west. If no offset follows dst, summer time is assumed to be one hour ahead of standard time.

start[/time], end[/time]

Indicates when to change to and back from DST. The format of the start and end dates are one of the following:

\[ Jn \]

The Julian day \( n \) (\( 1 <= n <= 365 \)). Leap days are not counted, so in all years February 28 is day 59 and March 1 is day 60.

\[ n \]

The zero-based Julian day (\( 0 <= n <= 365 \)). Leap days are counted, and it is possible to refer to February 29.

\[ Mm.n.d \]

The \( d \)'th day (\( 0 <= d <= 6 \)) or week \( n \) of month \( m \) of the year (\( 1 <= n <= 5, 1 <= m <= 12 \), where week 5 means “the last \( d \) day in month \( m \)” which may occur in either the fourth or the fifth week). Week 1 is the first week in which the \( d \)'th day occurs. Day zero is Sunday.

time has the same format as offset except that no leading sign (‘-‘ or ‘+’) is allowed. The default, if time is not given, is 02:00:00.
On many Unix systems (including *BSD, Linux, Solaris, and Darwin), it is more convenient to use the system’s zoneinfo (tzfile(5)) database to specify the timezone rules. To do this, set the TZ environment variable to the path of the required timezone datafile, relative to the root of the systems ‘zoneinfo’ timezone database, usually located at /usr/share/zoneinfo. For example, 'US/Eastern', 'Australia/Melbourne', 'Egypt' or 'Europe/Amsterdam'.

See also:

Module datetime
More object-oriented interface to dates and times.

Module locale
Internationalization services. The locale setting affects the
interpretation of many format specifiers in `strftime()` and `strptime()`.

**Module** calendar

General calendar-related functions. `timegm()` is the inverse of `gmtime()` from this module.

**Footnotes**

[1] The use of `%Z` is now deprecated, but the `%z` escape that expands to the preferred hour/minute offset is not supported by all ANSI C libraries. Also, a strict reading of the original 1982 RFC 822 standard calls for a two-digit year (%y rather than %Y), but practice moved to 4-digit years long before the year 2000. After that, RFC 822 became obsolete and the 4-digit year has been first recommended by RFC 1123 and then mandated by RFC 2822.
16.4. `argparse` — Parser for command-line options, arguments and sub-commands

New in version 3.2.

**Source code:** Lib/argparse.py

The `argparse` module makes it easy to write user-friendly command-line interfaces. The program defines what arguments it requires, and `argparse` will figure out how to parse those out of `sys.argv`. The `argparse` module also automatically generates help and usage messages and issues errors when users give the program invalid arguments.

**Tutorial**

This page contains the API reference information. For a more gentle introduction to Python command-line parsing, have a look at the [argparse tutorial](#).
16.4.1. Example

The following code is a Python program that takes a list of integers and produces either the sum or the max:

```python
import argparse

parser = argparse.ArgumentParser(description='Process some integers.

parser.add_argument('integers', metavar='N', type=int, help='an integer for the accumulator

parser.add_argument('--sum', dest='accumulate', const=sum, default=max, help='sum the integers (default: find the max)

args = parser.parse_args()
print(args.accumulate(args.integers))
```

Assuming the Python code above is saved into a file called `prog.py`, it can be run at the command line and provides useful help messages:

```
$ python prog.py -h
usage: prog.py [-h] [--sum] N [N ...]

Process some integers.

positional arguments:
  N an integer for the accumulator

optional arguments:
  -h, --help    show this help message and exit
  --sum         sum the integers (default: find the max
```

When run with the appropriate arguments, it prints either the sum or
the max of the command-line integers:

```
$ python prog.py 1 2 3 4
4
$ python prog.py 1 2 3 4 --sum
10
```

If invalid arguments are passed in, it will issue an error:

```
$ python prog.py a b c
usage: prog.py [-h] [--sum] N [N ...]
prog.py: error: argument N: invalid int value: 'a'
```

The following sections walk you through this example.

### 16.4.1.1. Creating a parser

The first step in using the argparse is creating an ArgumentParser object:

```
>>> parser = argparse.ArgumentParser(description='Process some integers.

The ArgumentParser object will hold all the information necessary to parse the command line into Python data types.

### 16.4.1.2. Adding arguments

Filling an ArgumentParser with information about program arguments is done by making calls to the add_argument() method. Generally, these calls tell the ArgumentParser how to take the strings on the command line and turn them into objects. This
information is stored and used when `parse_args()` is called. For example:

```python
>>> parser.add_argument('integers', metavar='N', type=int,
                        help='an integer for the accumulator')
>>> parser.add_argument('--sum', dest='accumulate',
                        const=sum, default=max,
                        help='sum the integers (default: find the max)')
```

Later, calling `parse_args()` will return an object with two attributes, `integers` and `accumulate`. The `integers` attribute will be a list of one or more ints, and the `accumulate` attribute will be either the `sum()` function, if `--sum` was specified at the command line, or the `max()` function if it was not.

16.4.1.3. Parsing arguments

`ArgumentParser` parses arguments through the `parse_args()` method. This will inspect the command line, convert each argument to the appropriate type and then invoke the appropriate action. In most cases, this means a simple `Namespace` object will be built up from attributes parsed out of the command line:

```python
>>> parser.parse_args(['--sum', '7', '-1', '42'])
Namespace(accumulate=<built-in function sum>, integers=[7, -1, 42])
```

In a script, `parse_args()` will typically be called with no arguments, and the `ArgumentParser` will automatically determine the command-line arguments from `sys.argv`. 
16.4.2. ArgumentParser objects

```python
class argparse.ArgumentParser(prog=None, usage=None, description=None, epilog=None, parents=[],
formatter_class=argparse.HelpFormatter, prefix_chars='-',
fromfile_prefix_chars=None, argument_default=None,
conflict_handler='error', add_help=True, allow_abbrev=True)
```

Create a new `ArgumentParser` object. All parameters should be passed as keyword arguments. Each parameter has its own more detailed description below, but in short they are:

- **prog** - The name of the program (default: `sys.argv[0]`)
- **usage** - The string describing the program usage (default: generated from arguments added to parser)
- **description** - Text to display before the argument help (default: none)
- **epilog** - Text to display after the argument help (default: none)
- **parents** - A list of `ArgumentParser` objects whose arguments should also be included
- **formatter_class** - A class for customizing the help output
- **prefix_chars** - The set of characters that prefix optional arguments (default: `'-'`)
- **fromfile_prefix_chars** - The set of characters that prefix files from which additional arguments should be read (default: None)
- **argument_default** - The global default value for arguments (default: None)
- **conflict_handler** - The strategy for resolving conflicting optionals (usually unnecessary)
- **add_help** - Add a `-h/–help` option to the parser (default: True)
- **allow_abbrev** - Allows long options to be abbreviated if the abbreviation is unambiguous. (default: True)
Changed in version 3.5: allow_abbrev parameter was added.

The following sections describe how each of these are used.

16.4.2.1. prog

By default, ArgumentParser objects uses sys.argv[0] to determine how to display the name of the program in help messages. This default is almost always desirable because it will make the help messages match how the program was invoked on the command line. For example, consider a file named myprogram.py with the following code:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument('--foo', help='foo help')
args = parser.parse_args()
```

The help for this program will display myprogram.py as the program name (regardless of where the program was invoked from):

```
$ python myprogram.py --help
usage: myprogram.py [-h] [--foo FOO]

optional arguments:
  -h, --help    show this help message and exit
  --foo FOO     foo help
$ cd ..
$ python subdir\myprogram.py --help
usage: myprogram.py [-h] [--foo FOO]

optional arguments:
  -h, --help    show this help message and exit
  --foo FOO     foo help
```
To change this default behavior, another value can be supplied using the `prog=` argument to `ArgumentParser`:

```python
>>> parser = argparse.ArgumentParser(prog='myprogram')
>>> parser.print_help()
usage: myprogram [-h]

optional arguments:
  -h, --help    show this help message and exit
```

Note that the program name, whether determined from `sys.argv[0]` or from the `prog=` argument, is available to help messages using the `%(prog)s` format specifier.

```python
>>> parser = argparse.ArgumentParser(prog='myprogram')
>>> parser.add_argument('--foo', help='foo of the %(prog)s program')
>>> parser.print_help()
usage: myprogram [-h] [--foo FOO]

optional arguments:
  -h, --help    show this help message and exit
  --foo FOO     foo of the myprogram program
```

### 16.4.2.2. usage

By default, `ArgumentParser` calculates the usage message from the arguments it contains:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--foo', nargs='?', help='foo')
>>> parser.add_argument('bar', nargs='+', help='bar')
>>> parser.print_help()
usage: PROG [-h] [--foo [FOO]] bar [bar ...]
```
positional arguments:
   bar         bar help

optional arguments:
   -h, --help   show this help message and exit
   --foo [FOO]  foo help

The default message can be overridden with the usage= keyword argument:

>>> parser = argparse.ArgumentParser(prog='PROG', usage='%(prog)s [options]
>>> parser.add_argument('--foo', nargs='?', help='foo help
>>> parser.add_argument('bar', nargs='+', help='bar help
>>> parser.print_help()
usage: PROG [options]

positional arguments:
   bar         bar help

optional arguments:
   -h, --help   show this help message and exit
   --foo [FOO]  foo help

The %(prog)s format specifier is available to fill in the program name in your usage messages.

16.4.2.3. description

Most calls to the ArgumentParser constructor will use the description= keyword argument. This argument gives a brief description of what the program does and how it works. In help messages, the description is displayed between the command-line
usage string and the help messages for the various arguments:

```python
>>> parser = argparse.ArgumentParser(description='A foo that bars')
>>> parser.print_help()
usage: argparse.py [-h]

A foo that bars

optional arguments:
  -h, --help  show this help message and exit
```

By default, the description will be line-wrapped so that it fits within the given space. To change this behavior, see the `formatter_class` argument.

### 16.4.2.4. epilog

Some programs like to display additional description of the program after the description of the arguments. Such text can be specified using the `epilog=` argument to `ArgumentParser`:

```python
>>> parser = argparse.ArgumentParser(...
...     description='A foo that bars',
...     epilog='And that's how you'd foo a bar')
>>> parser.print_help()
usage: argparse.py [-h]

A foo that bars

optional arguments:
  -h, --help  show this help message and exit

And that's how you'd foo a bar
```
As with the `description` argument, the `epilog=` text is by default line-wrapped, but this behavior can be adjusted with the `formatter_class` argument to `ArgumentParser`.

### 16.4.2.5. parents

Sometimes, several parsers share a common set of arguments. Rather than repeating the definitions of these arguments, a single parser with all the shared arguments and passed to `parents=` argument to `ArgumentParser` can be used. The `parents=` argument takes a list of `ArgumentParser` objects, collects all the positional and optional actions from them, and adds these actions to the `ArgumentParser` object being constructed:

```python
>>> parent_parser = argparse.ArgumentParser(add_help=True, prefix_chars='--')
>>> parent_parser.add_argument('--parent', type=int)

>>> foo_parser = argparse.ArgumentParser(parents=[parent_parser])
>>> foo_parser.add_argument('foo')
>>> foo_parser.parse_args(['--parent', '2', 'XXX'])
Namespace(foo='XXX', parent=2)

>>> bar_parser = argparse.ArgumentParser(parents=[parent_parser])
>>> bar_parser.add_argument('--bar')
>>> bar_parser.parse_args(['--bar', 'YYY'])
Namespace(bar='YYY', parent=None)
```

Note that most parent parsers will specify `add_help=False`. Otherwise, the `ArgumentParser` will see two `-h/--help` options (one in the parent and one in the child) and raise an error.

**Note:** You must fully initialize the parsers before passing them via...
16.4.2.6. `formatter_class`

`ArgumentParser` objects allow the help formatting to be customized by specifying an alternate formatting class. Currently, there are four such classes:

```python
class argparse.RawDescriptionHelpFormatter
class argparse.RawTextHelpFormatter
class argparse.ArgumentDefaultsHelpFormatter
class argparse.MetavarTypeHelpFormatter
```

`RawDescriptionHelpFormatter` and `RawTextHelpFormatter` give more control over how textual descriptions are displayed. By default, `ArgumentParser` objects line-wrap the `description` and `epilog` texts in command-line help messages:

```python
>>> parser = argparse.ArgumentParser(
...     prog='PROG',
...     description='''this description was indented weird but that is okay''',
...     epilog='''
...     likewise for this epilog whose whitespace will be cleaned up and whose words will be wrapped across a couple lines'''

>>> parser.print_help()
usage: PROG [-h]

this description was indented weird but that is okay

optional arguments:
```
-h, --help  show this help message and exit

likewise for this epilog whose whitespace will be cleaned up and whose words will be wrapped across a couple lines

Passing `RawDescriptionHelpFormatter` as `formatter_class=` indicates that `description` and `epilog` are already correctly formatted and should not be line-wrapped:

```python
>>> parser = argparse.ArgumentParser(
...     prog='PROG',
...     formatter_class=argparse.RawDescriptionHelpFormatter,
...     description=textwrap.dedent('''
...         Please do not mess up this text!
...         -----------------------------
...         I have indented it
...         exactly the way
...         I want it
...         '''))
>>> parser.print_help()
usage: PROG [-h]

Please do not mess up this text!
---------------------------------
    I have indented it
    exactly the way
    I want it

optional arguments:
    -h, --help  show this help message and exit
```

`RawTextHelpFormatter` maintains whitespace for all sorts of help text, including argument descriptions.
**ArgumentDefaultsHelpFormatter** automatically adds information about default values to each of the argument help messages:

```python
>>> parser = argparse.ArgumentParser(
...     prog='PROG',
...     formatter_class=argparse.ArgumentDefaultsHelpFormatter
>>> parser.add_argument('--foo', type=int, default=42)
>>> parser.add_argument('bar', nargs='*', default=[1, 2, 3])
>>> parser.print_help()
usage: PROG [-h] [--foo FOO] [bar [bar ...]]

positional arguments:
    bar        BAR! (default: [1, 2, 3])

optional arguments:
    -h, --help  show this help message and exit
    --foo FOO  FOO! (default: 42)
```

**MetavarTypeHelpFormatter** uses the name of the type argument for each argument as the display name for its values (rather than using the dest as the regular formatter does):

```python
>>> parser = argparse.ArgumentParser(
...     prog='PROG',
...     formatter_class=argparse.MetavarTypeHelpFormatter
>>> parser.add_argument('--foo', type=int)
>>> parser.add_argument('bar', type=float)
>>> parser.print_help()
usage: PROG [-h] [--foo int] float

positional arguments:
    float

optional arguments:
    -h, --help  show this help message and exit
```
16.4.2.7. prefix_chars

Most command-line options will use - as the prefix, e.g. -f/--foo. Parsers that need to support different or additional prefix characters, e.g. for options like +f or /foo, may specify them using the prefix_chars= argument to the ArgumentParser constructor:

```python
>>> parser = argparse.ArgumentParser(prog='PROG',
>>> parser.add_argument('+f')
>>> parser.add_argument('++bar')
>>> parser.parse_args('+f X ++bar Y'.split())
Namespace(bar='Y', f='X')
```

The prefix_chars= argument defaults to '-'. Supplying a set of characters that does not include - will cause -f/--foo options to be disallowed.

16.4.2.8. fromfile_prefix_chars

Sometimes, for example when dealing with a particularly long argument lists, it may make sense to keep the list of arguments in a file rather than typing it out at the command line. If the fromfile_prefix_chars= argument is given to the ArgumentParser constructor, then arguments that start with any of the specified characters will be treated as files, and will be replaced by the arguments they contain. For example:

```python
>>> with open('args.txt', 'w') as fp:
...    fp.write('-f
\bar')
```
Arguments read from a file must by default be one per line (but see also `convert_arg_line_to_args()`) and are treated as if they were in the same place as the original file referencing argument on the command line. So in the example above, the expression `['-f', 'foo', '@args.txt']` is considered equivalent to the expression `['-f', 'foo', '-f', 'bar']`.

The `fromfile_prefix_chars= argument defaults to None, meaning that arguments will never be treated as file references.

16.4.2.9. argument_default

Generally, argument defaults are specified either by passing a default to `add_argument()` or by calling the `set_defaults()` methods with a specific set of name-value pairs. Sometimes however, it may be useful to specify a single parser-wide default for arguments. This can be accomplished by passing the `argument_default=` keyword argument to `ArgumentParser`. For example, to globally suppress attribute creation on `parse_args()` calls, we supply `argument_default=SUPPRESS`:

```python
>>> parser = argparse.ArgumentParser(argument_default=argparse.SUPPRESS)
>>> parser.add_argument('--foo')
>>> parser.add_argument('bar', nargs='?')
>>> parser.parse_args(['--foo', '1', 'BAR'])
Namespace(bar='BAR', foo='1')
>>> parser.parse_args([])
```
16.4.2.10. allow_abbrev

Normally, when you pass an argument list to the parse_args() method of an ArgumentParser, it recognizes abbreviations of long options.

This feature can be disabled by setting allow_abbrev to False:

```python
>>> parser = argparse.ArgumentParser(prog='PROG', allow_abbrev=True)
>>> parser.add_argument('--foobar', action='store_true')
>>> parser.add_argument('--foonley', action='store_false')
```

```
usage: PROG [-h] [--foobar] [--foonley]

PROG: error: unrecognized arguments: --foon
```

New in version 3.5.

16.4.2.11. conflict_handler

ArgumentParser objects do not allow two actions with the same option string. By default, ArgumentParser objects raises an exception if an attempt is made to create an argument with an option string that is already in use:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-f', '--foo', help='old foo help')
>>> parser.add_argument('--foo', help='new foo help')
```

```
Traceback (most recent call last):
  ...
ArgumentError: argument --foo: conflicting option string
```
Sometimes (e.g. when using parents) it may be useful to simply override any older arguments with the same option string. To get this behavior, the value 'resolve' can be supplied to the conflict_handler= argument of ArgumentParser:

```python
generators = [argparse. ArgparseGenerator("
>>> parser = argparse.ArgumentParser(prog='PROG', conflict_handler=argparse.resolve)
>>> parser.add_argument('-f', '--foo', help='old foo help')
>>> parser.add_argument('--foo', help='new foo help')
>>> parser.print_help()
usage: PROG [-h] [-f FOO] [--foo FOO]
optional arguments:
  -h, --help    show this help message and exit
  -f FOO        old foo help
  --foo FOO     new foo help
```

Note that ArgumentParser objects only remove an action if all of its option strings are overridden. So, in the example above, the old -f/--foo action is retained as the -f action, because only the --foo option string was overridden.

### 16.4.2.12. add_help

By default, ArgumentParser objects add an option which simply displays the parser's help message. For example, consider a file named myprogram.py containing the following code:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument('--foo', help='foo help')
args = parser.parse_args()
```
If -h or --help is supplied at the command line, the ArgumentParser help will be printed:

```
$ python myprogram.py --help
usage: myprogram.py [-h] [--foo FOO]

optional arguments:
  -h, --help    show this help message and exit
  --foo FOO     foo help
```

Occasionally, it may be useful to disable the addition of this help option. This can be achieved by passing False as the add_help= argument to ArgumentParser:

```python
>>> parser = argparse.ArgumentParser(prog='PROG', add_help=False)
>>> parser.add_argument('--foo', help='foo help')
>>> parser.print_help()
usage: PROG [--foo FOO]

optional arguments:
  --foo FOO     foo help
```

The help option is typically -h/--help. The exception to this is if the prefix_chars= is specified and does not include -, in which case -h and --help are not valid options. In this case, the first character in prefix_chars is used to prefix the help options:

```python
>>> parser = argparse.ArgumentParser(prog='PROG', prefix_chars='+')
>>> parser.print_help()
usage: PROG [+h]

optional arguments:
  +h, ++help    show this help message and exit
```
16.4.3. The add_argument() method

ArgumentParser.add_argument(name or flags...[, action][, nargs][, const][, default][, type][, choices][, required][, help][, metavar][, dest])

Define how a single command-line argument should be parsed. Each parameter has its own more detailed description below, but in short they are:

- **name or flags** - Either a name or a list of option strings, e.g. foo or -f, --foo.
- **action** - The basic type of action to be taken when this argument is encountered at the command line.
- **nargs** - The number of command-line arguments that should be consumed.
- **const** - A constant value required by some action and nargs selections.
- **default** - The value produced if the argument is absent from the command line.
- **type** - The type to which the command-line argument should be converted.
- **choices** - A container of the allowable values for the argument.
- **required** - Whether or not the command-line option may be omitted (optionals only).
- **help** - A brief description of what the argument does.
- **metavar** - A name for the argument in usage messages.
- **dest** - The name of the attribute to be added to the object returned by parse_args().

The following sections describe how each of these are used.

16.4.3.1. name or flags
The `add_argument()` method must know whether an optional argument, like `-f` or `--foo`, or a positional argument, like a list of filenames, is expected. The first arguments passed to `add_argument()` must therefore be either a series of flags, or a simple argument name. For example, an optional argument could be created like:

```python
>>> parser.add_argument('-f', '--foo')
```

while a positional argument could be created like:

```python
>>> parser.add_argument('bar')
```

When `parse_args()` is called, optional arguments will be identified by the `-` prefix, and the remaining arguments will be assumed to be positional:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-f', '--foo')
>>> parser.add_argument('bar')
>>> parser.parse_args(['BAR'])
Namespace(bar='BAR', foo=None)
>>> parser.parse_args(['BAR', '--foo', 'FOO'])
Namespace(bar='BAR', foo='FOO')
>>> parser.parse_args(['--foo', 'FOO'])
usage: PROG [-h] [-f FOO] bar
PROG: error: too few arguments
```

### 16.4.3.2. action

`ArgumentParser` objects associate command-line arguments with actions. These actions can do just about anything with the command-
line arguments associated with them, though most actions simply add an attribute to the object returned by `parse_args()`. The action keyword argument specifies how the command-line arguments should be handled. The supplied actions are:

- **'store'** - This just stores the argument’s value. This is the default action. For example:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo')
>>> parser.parse_args('--foo 1'.split())
Namespace(foo='1')
```

- **'store_const'** - This stores the value specified by the `const` keyword argument. (Note that the `const` keyword argument defaults to the rather unhelpful `None`.) The 'store_const' action is most commonly used with optional arguments that specify some sort of flag. For example:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action='store_const', const=42)
>>> parser.parse_args('--foo'.split())
Namespace(foo=42)
```

- **'store_true'** and **'store_false'** - These store the values True and False respectively. These are special cases of 'store_const'. For example:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action='store_true')
>>> parser.add_argument('--bar', action='store_false')
>>> parser.parse_args('--foo --bar'.split())
Namespace(bar=False, foo=True)
```
• 'append' - This stores a list, and appends each argument value to the list. This is useful to allow an option to be specified multiple times. Example usage:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action='append')
>>> parser.parse_args('--foo 1 --foo 2'.split())
Namespace(foo=['1', '2'])
```

• 'append_const' - This stores a list, and appends the value specified by the const keyword argument to the list. (Note that the const keyword argument defaults to None.) The 'append_const' action is typically useful when multiple arguments need to store constants to the same list. For example:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--str', dest='types', action='append_const')
>>> parser.add_argument('--int', dest='types', action='append_const')
>>> parser.parse_args('--str --int'.split())
Namespace(types=[<class 'str'>, <class 'int'>])
```

• 'count' - This counts the number of times a keyword argument occurs. For example, this is useful for increasing verbosity levels:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--verbose', '-v', action='count')
>>> parser.parse_args('-vvv'.split())
Namespace(verbose=3)
```

• 'help' - This prints a complete help message for all the options in the current parser and then exits. By default a help action is
automatically added to the parser. See ArgumentParser for details of how the output is created.

- 'version' - This expects a version= keyword argument in the add_argument() call, and prints version information and exits when invoked:

```python
>>> import argparse
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--version', action='version')
>>> parser.parse_args(['--version'])
PROG 2.0
```

You may also specify an arbitrary action by passing an Action subclass or other object that implements the same interface. The recommended way to do this is to extend Action, overriding the __call__ method and optionally the __init__ method.

An example of a custom action:

```python
>>> class FooAction(argparse.Action):
...     def __init__(self, option_strings, dest, nargs=None, **kwargs):
...         if nargs is not None:
...             raise ValueError("nargs not allowed")
...         super(FooAction, self).__init__(option_strings, dest, nargs, **kwargs)
...     def __call__(self, parser, namespace, values, option_string=None):
...         print('%r %r %r' % (namespace, values, option_string))

>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action=FooAction)
>>> parser.add_argument('bar', action=FooAction)
>>> args = parser.parse_args('1 --foo 2'.split())
Namespace(bar=None, foo=None) '1' None
```
For more details, see Action.

### 16.4.3.3. nargs

ArgumentParser objects usually associate a single command-line argument with a single action to be taken. The nargs keyword argument associates a different number of command-line arguments with a single action. The supported values are:

- **N** (an integer). N arguments from the command line will be gathered together into a list. For example:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', nargs=2)
>>> parser.add_argument('bar', nargs=1)
>>> parser.parse_args('c --foo a b'.split())
Namespace(bar=['c'], foo=['a', 'b'])
```

Note that nargs=1 produces a list of one item. This is different from the default, in which the item is produced by itself.

- **?**. One argument will be consumed from the command line if possible, and produced as a single item. If no command-line argument is present, the value from default will be produced. Note that for optional arguments, there is an additional case - the option string is present but not followed by a command-line argument. In this case the value from const will be produced. Some examples to illustrate this:
One of the more common uses of nargs='?' is to allow optional input and output files:

- '}'. All command-line arguments present are gathered into a list.
  Note that it generally doesn’t make much sense to have more than one positional argument with nargs='*', but multiple optional arguments with nargs='*' is possible. For example:
>>> parser.parse_args('a b --foo x y --bar 1 2').split()
Namespace(bar=['1', '2'], baz=['a', 'b'], foo=['x', 'y'])

- '}'. Just like '*', all command-line args present are gathered into a list. Additionally, an error message will be generated if there wasn't at least one command-line argument present. For example:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('foo', nargs='+')
>>> parser.parse_args('a b'.split())
Namespace(foo=['a', 'b'])

usage: PROG [-h] foo [foo ...]
PROG: error: too few arguments
```

- argparse.REMAINDER. All the remaining command-line arguments are gathered into a list. This is commonly useful for command line utilities that dispatch to other command line utilities:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--foo')
>>> parser.add_argument('command')
>>> parser.add_argument('args', nargs=argparse.REMAINDER)
>>> parser.parse_args('--foo B cmd --arg1 XX ZZ').split() 
Namespace(args=['--arg1', 'XX', 'ZZ'], command='cmd')
```

If the nargs keyword argument is not provided, the number of arguments consumed is determined by the action. Generally this means a single command-line argument will be consumed and a single item (not a list) will be produced.
16.4.3.4. const

The const argument of `add_argument()` is used to hold constant values that are not read from the command line but are required for the various `ArgumentParser` actions. The two most common uses of it are:

- When `add_argument()` is called with `action='store_const'` or `action='append_const'`. These actions add the const value to one of the attributes of the object returned by `parse_args()`. See the `action` description for examples.
- When `add_argument()` is called with option strings (like `-f` or `-foo`) and `nargs='?'`. This creates an optional argument that can be followed by zero or one command-line arguments. When parsing the command line, if the option string is encountered with no command-line argument following it, the value of `const` will be assumed instead. See the `nargs` description for examples.

The `const` keyword argument defaults to `None`.

16.4.3.5. default

All optional arguments and some positional arguments may be omitted at the command line. The default keyword argument of `add_argument()`, whose value defaults to `None`, specifies what value should be used if the command-line argument is not present. For optional arguments, the default value is used when the option string was not present at the command line:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', default=42)
```
If the default value is a string, the parser parses the value as if it were a command-line argument. In particular, the parser applies any type conversion argument, if provided, before setting the attribute on the `Namespace` return value. Otherwise, the parser uses the value as is:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--length', default='10', type=int)
>>> parser.add_argument('--width', default=10.5, type=float)
>>> parser.parse_args()
Namespace(length=10, width=10.5)
```

For positional arguments with `nargs` equal to `?` or `*`, the default value is used when no command-line argument was present:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('foo', nargs='?', default=42)
>>> parser.parse_args(['a'].split())
Namespace(foo='a')
>>> parser.parse_args('').split())
Namespace(foo=42)
```

Providing `default=argparse.SUPPRESS` causes no attribute to be added if the command-line argument was not present.
16.4.3.6. type

By default, ArgumentParser objects read command-line arguments in as simple strings. However, quite often the command-line string should instead be interpreted as another type, like a float or int. The type keyword argument of add_argument() allows any necessary type-checking and type conversions to be performed. Common built-in types and functions can be used directly as the value of the type argument:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('foo', type=int)
>>> parser.add_argument('bar', type=open)
>>> parser.parse_args(['2 temp.txt'].split())
Namespace(bar=<_io.TextIOWrapper name='temp.txt' encoding='UTF-8'>, foo=2)
```

See the section on the default keyword argument for information on when the type argument is applied to default arguments.

To ease the use of various types of files, the argparse module provides the factory FileType which takes the mode=, bufsize=, encoding= and errors= arguments of the open() function. For example, FileType('w') can be used to create a writable file:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('bar', type=argparse.FileType('w'))
>>> parser.parse_args(['out.txt'])
Namespace(bar=<_io.TextIOWrapper name='out.txt' encoding='UTF-8'>)
```
type= can take any callable that takes a single string argument and returns the converted value:

```python
>>> def perfect_square(string):
...     value = int(string)
...     sqrt = math.sqrt(value)
...     if sqrt != int(sqrt):
...         msg = "%r is not a perfect square" % str(sqrt)
...         raise argparse.ArgumentTypeError(msg)
...     return value

>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('foo', type=perfect_square)
>>> parser.parse_args('9'.split())
Namespace(foo=9)

>>> parser.parse_args('7'.split())
usage: PROG [-h] foo
PROG: error: argument foo: '7' is not a perfect square
```

The **choices** keyword argument may be more convenient for type checkers that simply check against a range of values:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('foo', type=int, choices=range)

>>> parser.parse_args('7'.split())
Namespace(foo=7)

>>> parser.parse_args('11'.split())
usage: PROG [-h] {5,6,7,8,9}
PROG: error: argument foo: invalid choice: 11 (choose from 5, 6, 7, 8, 9)
```

See the **choices** section for more details.
16.4.3.7. choices

Some command-line arguments should be selected from a restricted set of values. These can be handled by passing a container object as the *choices* keyword argument to *add_argument()*. When the command line is parsed, argument values will be checked, and an error message will be displayed if the argument was not one of the acceptable values:

```python
>>> parser = argparse.ArgumentParser(prog='game.py')
>>> parser.add_argument('move', choices=['rock', 'paper'])
>>> parser.parse_args(['rock'])
Namespace(move='rock')
```

```
usage: game.py [-h] {rock,paper,scissors}
game.py: error: argument move: invalid choice: 'fire' (choose from 'rock', 'paper', 'scissors')
```

Note that inclusion in the *choices* container is checked after any type conversions have been performed, so the type of the objects in the *choices* container should match the *type* specified:

```python
>>> parser = argparse.ArgumentParser(prog='doors.py')
>>> parser.add_argument('door', type=int, choices=range(4))
>>> print(parser.parse_args(['3']))
Namespace(door=3)
```

```
usage: doors.py [-h] {1,2,3}
doors.py: error: argument door: invalid choice: 4 (choose from 1, 2, 3)
```

Any object that supports the *in* operator can be passed as the *choices* value, so *dict* objects, *set* objects, custom containers, etc. are all
In general, the argparse module assumes that flags like -f and --bar indicate *optional* arguments, which can always be omitted at the command line. To make an option *required*, True can be specified for the `required=` keyword argument to `add_argument()`:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', required=True)
>>> parser.parse_args(['--foo', 'BAR'])
Namespace(foo='BAR')
>>> parser.parse_args([])
usage: argparse.py [-h] [--foo FOO]
argparse.py: error: option --foo is required
```

As the example shows, if an option is marked as required, `parse_args()` will report an error if that option is not present at the command line.

**Note:** Required options are generally considered bad form because users expect *options* to be *optional*, and thus they should be avoided when possible.

### 16.4.3.9. help

The `help` value is a string containing a brief description of the argument. When a user requests help (usually by using `-h` or `--help` at the command line), these `help` descriptions will be displayed with each argument:
The help strings can include various format specifiers to avoid repetition of things like the program name or the argument default. The available specifiers include the program name, %(prog)s and most keyword arguments to add_argument(), e.g. %(default)s, %(type)s, etc.:
appear in the help string, you must escape it as `%%`.

`argparse` supports silencing the help entry for certain options, by setting the help value to `argparse.SUPPRESS`:

```python
>>> parser = argparse.ArgumentParser(prog='frobble')
>>> parser.add_argument('--foo', help=argparse.SUPPRESS)
>>> parser.print_help()
usage: frobble [-h]
optional arguments:
  -h, --help    show this help message and exit
```

### 16.4.3.10. metavar

When `ArgumentParser` generates help messages, it needs some way to refer to each expected argument. By default, `ArgumentParser` objects use the `dest` value as the “name” of each object. By default, for positional argument actions, the `dest` value is used directly, and for optional argument actions, the `dest` value is uppercased. So, a single positional argument with `dest='bar'` will be referred to as `bar`. A single optional argument `--foo` that should be followed by a single command-line argument will be referred to as `F00`. An example:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo')
>>> parser.add_argument('bar')
>>> parser.parse_args('X --foo Y'.split())
Namespace(bar='X', foo='Y')
>>> parser.print_help()
usage: [-h] [--foo F00] bar
positional arguments:
```
optional arguments:
- h, --help  show this help message and exit
--foo FOO

An alternative name can be specified with metavar:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', metavar='YYY')
>>> parser.add_argument('bar', metavar='XXX')
>>> parser.parse_args('X --foo Y'.split())
Namespace(bar='X', foo='Y')
>>> parser.print_help()
usage: [-h] [--foo YYYY] XXX

positional arguments:
  XXX

optional arguments:
  -h, --help  show this help message and exit
  --foo YYYY
```

Note that metavar only changes the displayed name - the name of the attribute on the `parse_args()` object is still determined by the `dest` value.

Different values of nargs may cause the metavar to be used multiple times. Providing a tuple to metavar specifies a different display for each of the arguments:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-x', nargs=2)
>>> parser.add_argument('--foo', nargs=2, metavar=('bar',))
>>> parser.print_help()
```
usage: PROG [-h] [-x X X] [--foo bar baz]

optional arguments:
  -h, --help            show this help message and exit
  -x X X
  --foo bar baz

16.4.3.11. dest

Most ArgumentParser actions add some value as an attribute of the object returned by parse_args(). The name of this attribute is determined by the dest keyword argument of add_argument(). For positional argument actions, dest is normally supplied as the first argument to add_argument():

>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('bar')
>>> parser.parse_args('XXX'.split())
Namespace(bar='XXX')

For optional argument actions, the value of dest is normally inferred from the option strings. ArgumentParser generates the value of dest by taking the first long option string and stripping away the initial -- string. If no long option strings were supplied, dest will be derived from the first short option string by stripping the initial - character. Any internal - characters will be converted to _ characters to make sure the string is a valid attribute name. The examples below illustrate this behavior:

>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('-f', '--foo-bar', '--foo')
>>> parser.add_argument('-x', '-y')
dest allows a custom attribute name to be provided:

```python
>>> parser.parse_args(''-f 1 -x 2'.split())
Namespace(foo_bar='1', x='2')
>>> parser.parse_args('--foo 1 -y 2'.split())
Namespace(foo_bar='1', x='2')
```

16.4.3.12. Action classes

Action classes implement the Action API, a callable which returns a callable which processes arguments from the command-line. Any object which follows this API may be passed as the action parameter to `add_argument()`.

```
class argparse.Action(option_strings, dest, nargs=None, const=None, default=None, type=None, choices=None, required=False, help=None, metavar=None)
```

Action objects are used by an ArgumentParser to represent the information needed to parse a single argument from one or more strings from the command line. The Action class must accept the two positional arguments plus any keyword arguments passed to `ArgumentParser.add_argument()` except for the action itself.

Instances of Action (or return value of any callable to the action parameter) should have attributes “dest”, “option_strings”, “default”, “type”, “required”, “help”, etc. defined. The easiest way to ensure these attributes are defined is to call `Action.__init__`.  

Action instances should be callable, so subclasses must override the `__call__` method, which should accept four parameters:

- **parser** - The ArgumentParser object which contains this action.
- **namespace** - The `Namespace` object that will be returned by `parse_args()`. Most actions add an attribute to this object using `setattr()`.
- **values** - The associated command-line arguments, with any type conversions applied. Type conversions are specified with the `type` keyword argument to `add_argument()`.
- **option_string** - The option string that was used to invoke this action. The `option_string` argument is optional, and will be absent if the action is associated with a positional argument.

The `__call__` method may perform arbitrary actions, but will typically set attributes on the namespace based on `dest` and `values`. 
16.4.4. The parse_args() method

ArgumentParser.parse_args(args=None, namespace=None)

Convert argument strings to objects and assign them as attributes of the namespace. Return the populated namespace.

Previous calls to add_argument() determine exactly what objects are created and how they are assigned. See the documentation for add_argument() for details.

By default, the argument strings are taken from sys.argv, and a new empty Namespace object is created for the attributes.

16.4.4.1. Option value syntax

The parse_args() method supports several ways of specifying the value of an option (if it takes one). In the simplest case, the option and its value are passed as two separate arguments:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-x')
>>> parser.add_argument('--foo')
>>> parser.parse_args('-x X'.split())
Namespace(x='X', foo=None)
>>> parser.parse_args('--foo=FOO'.split())
Namespace(x=None, foo='FOO')
```

For long options (options with names longer than a single character), the option and value can also be passed as a single command-line argument, using = to separate them:

```python
>>> parser.parse_args('--foo=FOO'.split())
```
For short options (options only one character long), the option and its value can be concatenated:

```python
>>> parser.parse_args('-xX'.split())
Namespace(foo=None, x='X')
```

Several short options can be joined together, using only a single - prefix, as long as only the last option (or none of them) requires a value:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-x', action='store_true')
>>> parser.add_argument('-y', action='store_true')
>>> parser.add_argument('-z')
>>> parser.parse_args('-xyzZ'.split())
Namespace(x=True, y=True, z='Z')
```

### 16.4.4.2. Invalid arguments

While parsing the command line, `parse_args()` checks for a variety of errors, including ambiguous options, invalid types, invalid options, wrong number of positional arguments, etc. When it encounters such an error, it exits and prints the error along with a usage message:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--foo', type=int)
>>> parser.add_argument('bar', nargs='?')

>>> # invalid type
>>> parser.parse_args(['--foo', 'spam'])
usage: PROG [-h] [--foo FOO] [bar]
PROG: error: argument --foo: invalid int value: 'spam'
```
16.4.4.3. Arguments containing -

The `parse_args()` method attempts to give errors whenever the user has clearly made a mistake, but some situations are inherently ambiguous. For example, the command-line argument `-1` could either be an attempt to specify an option or an attempt to provide a positional argument. The `parse_args()` method is cautious here: positional arguments may only begin with `-` if they look like negative numbers and there are no options in the parser that look like negative numbers:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-x')
>>> parser.add_argument('foo', nargs='?')

>>> # no negative number options, so -1 is a positional
>>> parser.parse_args(['-x', '-1'])
Namespace(foo=None, x='-1')

>>> # no negative number options, so -1 and -5 are positional
>>> parser.parse_args(['-x', '-1', '-5'])
Namespace(foo='-5', x='-1')
```

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
```
If you have positional arguments that must begin with - and don’t look like negative numbers, you can insert the pseudo-argument '---' which tells `parse_args()` that everything after that is a positional argument:

```python
>>> parser.parse_args([ '--', '-f' ])
Namespace(foo='-f', one=None)
```

### 16.4.4.4. Argument abbreviations (prefix matching)

The `parse_args()` method by default allows long options to be abbreviated to a prefix, if the abbreviation is unambiguous (the prefix matches a unique option):

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
```
An error is produced for arguments that could produce more than one options. This feature can be disabled by setting allow_abbrev to False.

16.4.4.5. Beyond sys.argv

Sometimes it may be useful to have an ArgumentParser parse arguments other than those of sys.argv. This can be accomplished by passing a list of strings to parse_args(). This is useful for testing at the interactive prompt:
16.4.4.6. The Namespace object

class argparse.Namespace

    Simple class used by default by `parse_args()` to create an object holding attributes and return it.

This class is deliberately simple, just an `object` subclass with a readable string representation. If you prefer to have dict-like view of the attributes, you can use the standard Python idiom, `vars()`:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo')
>>> args = parser.parse_args(['--foo', 'BAR'])
>>> vars(args)
{'foo': 'BAR'}
```

It may also be useful to have an `ArgumentParser` assign attributes to an already existing object, rather than a new `Namespace` object. This can be achieved by specifying the `namespace=` keyword argument:

```python
>>> class C:
...     pass
...
>>> c = C()
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo')
>>> parser.parse_args(args=['--foo', 'BAR'], namespace=c)
>>> c.foo
'BAR'
```
16.4.5. Other utilities

16.4.5.1. Sub-commands

ArgumentParser.add_subparsers([title][, description][, prog]
[, parser_class][, action][, option_string][, dest][, help][, metavar])

Many programs split up their functionality into a number of sub-
commands, for example, the svn program can invoke sub-
commands like svn checkout, svn update, and svn commit. Splitting up functionality this way can be a particularly good idea
when a program performs several different functions which require
different kinds of command-line arguments. ArgumentParser
supports the creation of such sub-commands with the
add_subparsers() method. The add_subparsers() method
is normally called with no arguments and returns a special action
object. This object has a single method, add_parser(), which
takes a command name and any ArgumentParser constructor
arguments, and returns an ArgumentParser object that can be
modified as usual.

Description of parameters:

- **title** - title for the sub-parser group in help output; by default
  “subcommands” if description is provided, otherwise uses title
  for positional arguments
- **description** - description for the sub-parser group in help
  output, by default None
- **prog** - usage information that will be displayed with sub-
  command help, by default the name of the program and any
  positional arguments before the subparser argument
- **parser_class** - class which will be used to create sub-parser
instances, by default the class of the current parser (e.g. ArgumentParser)

- **action** - the basic type of action to be taken when this argument is encountered at the command line
- **dest** - name of the attribute under which sub-command name will be stored; by default None and no value is stored
- **help** - help for sub-parser group in help output, by default None
- **metavar** - string presenting available sub-commands in help; by default it is None and presents sub-commands in form {cmd1, cmd2, ..}

Some example usage:

```python
>>> # create the top-level parser
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--foo', action='store_true')
>>> subparsers = parser.add_subparsers(help='sub-command help')
>>> # create the parser for the "a" command
>>> parser_a = subparsers.add_parser('a', help='a help')
>>> parser_a.add_argument('bar', type=int, help='bar help')
>>> # create the parser for the "b" command
>>> parser_b = subparsers.add_parser('b', help='b help')
>>> parser_b.add_argument('--baz', choices='XYZ',)
>>> # parse some argument lists
>>> parser.parse_args(['a', '12'])
Namespace(bar=12, foo=False)
>>> parser.parse_args(['--foo', 'b', '--baz', 'Z'])
Namespace(baz='Z', foo=True)
```

Note that the object returned by `parse_args()` will only contain attributes for the main parser and the subparser that was selected
by the command line (and not any other subparsers). So in the example above, when the a command is specified, only the foo and bar attributes are present, and when the b command is specified, only the foo and baz attributes are present.

Similarly, when a help message is requested from a subparser, only the help for that particular parser will be printed. The help message will not include parent parser or sibling parser messages. (A help message for each subparser command, however, can be given by supplying the help= argument to add_parser() as above.)

```python
>>> parser.parse_args(['--help'])
usage: PROG [-h] [--foo] {a,b} ...

positional arguments:
  {a,b}     sub-command help
    a       a help
    b       b help

optional arguments:
   -h, --help  show this help message and exit
   --foo     foo help

>>> parser.parse_args(['a', '--help'])
usage: PROG a [-h] bar

positional arguments:
  bar       bar help

optional arguments:
   -h, --help  show this help message and exit

>>> parser.parse_args(['b', '--help'])
usage: PROG b [-h] [--baz {X,Y,Z}]
```
optional arguments:
   -h, --help     show this help message and exit
   --baz {X,Y,Z}  baz help

The add_subparsers() method also supports title and description keyword arguments. When either is present, the subparser's commands will appear in their own group in the help output. For example:

```python
>>> parser = argparse.ArgumentParser()
>>> subparsers = parser.add_subparsers(title='subcommands',
                  description='additional help')
>>> subparsers.add_parser('foo')
>>> subparsers.add_parser('bar')
>>> parser.parse_args(['-h'])
usage: [-h] {foo,bar} ...
optional arguments:
   -h, --help     show this help message and exit
subcommands:
   valid subcommands
     {foo,bar}  additional help
```

Furthermore, add_parser supports an additional aliases argument, which allows multiple strings to refer to the same subparser. This example, like svn, aliases co as a shorthand for checkout:

```python
>>> parser = argparse.ArgumentParser()
>>> subparsers = parser.add_subparsers()```
One particularly effective way of handling sub-commands is to combine the use of the `add_subparsers()` method with calls to `set_defaults()` so that each subparser knows which Python function it should execute. For example:

```python
>>> # sub-command functions
>>> def foo(args):
...     print(args.x * args.y)
...
>>> def bar(args):
...     print('((%s))' % args.z)
...
>>> # create the top-level parser
>>> parser = argparse.ArgumentParser()
>>> subparsers = parser.add_subparsers()

>>> # create the parser for the "foo" command
>>> parser_foo = subparsers.add_parser('foo')
>>> parser_foo.add_argument('-x', type=int, default=1)
>>> parser_foo.add_argument('y', type=float)
>>> parser_foo.set_defaults(func=foo)

>>> # create the parser for the "bar" command
>>> parser_bar = subparsers.add_parser('bar')
>>> parser_bar.add_argument('z')
>>> parser_bar.set_defaults(func=bar)

>>> # parse the args and call whatever function was selected
>>> args = parser.parse_args('foo 1 -x 2'.split())
>>> args.func(args)
```
This way, you can let `parse_args()` do the job of calling the appropriate function after argument parsing is complete. Associating functions with actions like this is typically the easiest way to handle the different actions for each of your subparsers. However, if it is necessary to check the name of the subparser that was invoked, the `dest` keyword argument to the `add_subparsers()` call will work:

```python
>> parser = argparse.ArgumentParser()
>> subparsers = parser.add_subparsers(dest='subparser_name')
>> subparser1 = subparsers.add_parser('1')
>> subparser1.add_argument('-x')
>> subparser2 = subparsers.add_parser('2')
>> subparser2.add_argument('y')
>> parser.parse_args(['2', 'frobble'])
Namespace(subparser_name='2', y='frobble')
```

16.4.5.2. FileType objects

```python
class argparse.FileType(mode='r', bufsize=-1, encoding=None, errors=None)
```

The `FileType` factory creates objects that can be passed to the type argument of `ArgumentParser.add_argument()`. Arguments that have `FileType` objects as their type will open command-line arguments as files with the requested modes, buffer
sizes, encodings and error handling (see the open() function for more details):

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--raw', type=argparse.FileType)
>>> parser.add_argument('out', type=argparse.FileType)
>>> parser.parse_args(['--raw', 'raw.dat', 'file.txt'])
Namespace(out=<_io.TextIOWrapper name='file.txt' mode='w' encoding='UTF-8'>,
          raw=<_io.FileIO name='raw.dat' mode='wb'>)
```

FileType objects understand the pseudo-argument '-' and automatically convert this into sys.stdin for readable FileType objects and sys.stdout for writable FileType objects:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('infile', type=argparse.FileType)
>>> parser.parse_args(['-'])
Namespace(infile=<_io.TextIOWrapper name='<stdin>' encoding='UTF-8'>)
```

New in version 3.4: The encodings and errors keyword arguments.

### 16.4.5.3. Argument groups

**ArgumentParser.add_argument_group**(title=None, description=None)

By default, ArgumentParser groups command-line arguments into “positional arguments” and “optional arguments” when displaying help messages. When there is a better conceptual grouping of arguments than this default one, appropriate groups can be created using the add_argument_group() method:

```python
>>> parser = argparse.ArgumentParser(prog='PROG',
                                       group = parser.add_argument_group('group'))
```
The `add_argument_group()` method returns an argument group object which has an `add_argument()` method just like a regular `ArgumentParser`. When an argument is added to the group, the parser treats it just like a normal argument, but displays the argument in a separate group for help messages. The `add_argument_group()` method accepts `title` and `description` arguments which can be used to customize this display:
Note that any arguments not in your user-defined groups will end up back in the usual “positional arguments” and “optional arguments” sections.

16.4.5.4. Mutual exclusion

ArgumentParser.

Create a mutually exclusive group. argparse will make sure that only one of the arguments in the mutually exclusive group was present on the command line:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> group = parser.add_mutually_exclusive_group()
>>> group.add_argument('--foo', action='store_true')
>>> group.add_argument('--bar', action='store_false')
>>> parser.parse_args(['--foo'])
Namespace(bar=True, foo=True)
>>> parser.parse_args(['--bar'])
Namespace(bar=False, foo=False)
>>> parser.parse_args(['--foo', '--bar'])
usage: PROG [-h] [--foo | --bar]
PROG: error: argument --bar: not allowed with argument --foo
```

The add_mutually_exclusive_group() method also accepts a required argument, to indicate that at least one of the mutually exclusive arguments is required:

```python
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> group = parser.add_mutually_exclusive_group(required=True)
>>> group.add_argument('--foo', action='store_true')
>>> group.add_argument('--bar', action='store_false')
>>> parser.parse_args([])
usage: PROG [-h] (-foo | -bar)
```
Note that currently mutually exclusive argument groups do not support the title and description arguments of add_argument_group().

16.4.5.5. Parser defaults

ArgumentParser.set_defaults(**kwargs)

Most of the time, the attributes of the object returned by parse_args() will be fully determined by inspecting the command-line arguments and the argument actions. set_defaults() allows some additional attributes that are determined without any inspection of the command line to be added:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('foo', type=int)
>>> parser.set_defaults(bar=42, baz='badger')
>>> parser.parse_args(['736'])
Namespace(bar=42, baz='badger', foo=736)
```

Note that parser-level defaults always override argument-level defaults:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', default='bar')
>>> parser.set_defaults(foo='spam')
>>> parser.parse_args([])
Namespace(foo='spam')
```

Parser-level defaults can be particularly useful when working with
multiple parsers. See the `add_subparsers()` method for an example of this type.

**ArgumentParser.get_default(dest)**

Get the default value for a namespace attribute, as set by either `add_argument()` or by `set_defaults()`:

```python
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', default='badger')
>>> parser.get_default('foo')
'badger'
```

### 16.4.5.6. Printing help

In most typical applications, `parse_args()` will take care of formatting and printing any usage or error messages. However, several formatting methods are available:

**ArgumentParser.print_usage(file=None)**

Print a brief description of how the `ArgumentParser` should be invoked on the command line. If `file` is None, `sys.stdout` is assumed.

**ArgumentParser.print_help(file=None)**

Print a help message, including the program usage and information about the arguments registered with the `ArgumentParser`. If `file` is None, `sys.stdout` is assumed.

There are also variants of these methods that simply return a string instead of printing it:

**ArgumentParser.format_usage()**
Return a string containing a brief description of how the ArgumentParser should be invoked on the command line.

ArgumentParser.\texttt{format\_help()}

Return a string containing a help message, including the program usage and information about the arguments registered with the ArgumentParser.

16.4.5.7. Partial parsing

ArgumentParser.\texttt{parse\_known\_args(args=None, namespace=None)}

Sometimes a script may only parse a few of the command-line arguments, passing the remaining arguments on to another script or program. In these cases, the \texttt{parse\_known\_args()} method can be useful. It works much like \texttt{parse\_args()} except that it does not produce an error when extra arguments are present. Instead, it returns a two item tuple containing the populated namespace and the list of remaining argument strings.

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action='store_true')
>>> parser.add_argument('bar')
>>> parser.parse_known_args(['--foo', '--badger', 'BAR'])
(Namespace(bar='BAR', foo=True), ['--badger', 'spam'])
```

\textbf{Warning: } Prefix matching rules apply to \texttt{parse\_known\_args()}. The parser may consume an option even if it's just a prefix of one of its known options, instead of leaving it in the remaining arguments list.
16.4.5.8. Customizing file parsing

ArgumentParser\texttt{.convert\_arg\_line\_to\_args}(\texttt{arg\_line})

Arguments that are read from a file (see the \texttt{fromfile\_prefix\_chars} keyword argument to the \texttt{ArgumentParser} constructor) are read one argument per line. \texttt{convert\_arg\_line\_to\_args()} can be overridden for fancier reading.

This method takes a single argument \texttt{arg\_line} which is a string read from the argument file. It returns a list of arguments parsed from this string. The method is called once per line read from the argument file, in order.

A useful override of this method is one that treats each space-separated word as an argument:

\begin{verbatim}
def convert_arg_line_to_args(self, arg_line):
    return arg_line.split()
\end{verbatim}

16.4.5.9. Exiting methods

ArgumentParser\texttt{.exit}(\texttt{status=0, message=None})

This method terminates the program, exiting with the specified \texttt{status} and, if given, it prints a \texttt{message} before that.

ArgumentParser\texttt{.error}(\texttt{message})

This method prints a usage message including the \texttt{message} to the standard error and terminates the program with a status code of 2.
16.4.6. Upgrading optparse code

Originally, the `argparse` module had attempted to maintain compatibility with `optparse`. However, `optparse` was difficult to extend transparently, particularly with the changes required to support the new `nargs=` specifiers and better usage messages. When most everything in `optparse` had either been copy-pasted over or monkey-patched, it no longer seemed practical to try to maintain the backwards compatibility.

The `argparse` module improves on the standard library `optparse` module in a number of ways including:

- Handling positional arguments.
- Supporting sub-commands.
- Allowing alternative option prefixes like `+` and `/`.
- Handling zero-or-more and one-or-more style arguments.
- Producing more informative usage messages.
- Providing a much simpler interface for custom type and action.

A partial upgrade path from `optparse` to `argparse`:

- Replace all `optparse.OptionParser.add_option()` calls with `ArgumentParser.add_argument()` calls.
- Replace `(options, args) = parser.parse_args()` with `args = parser.parse_args()` and add additional `ArgumentParser.add_argument()` calls for the positional arguments. Keep in mind that what was previously called `options`, now in `argparse` context is called `args`.
- Replace callback actions and the `callback_*` keyword arguments with `type` or `action` arguments.
- Replace string names for type keyword arguments with the
corresponding type objects (e.g. int, float, complex, etc).

- Replace strings with implicit arguments such as `%default` or `%prog` with the standard Python syntax to use dictionaries to format strings, that is, `%{default}s` and `%{prog}s`.
- Replace the `OptionParser` constructor `version` argument with a call to `parser.add_argument('--version', action='version', version='<the version>')`.

16.5. **getopt** — C-style parser for command line options

**Source code:** Lib/getopt.py

**Note:** The `getopt` module is a parser for command line options whose API is designed to be familiar to users of the C `getopt()` function. Users who are unfamiliar with the C `getopt()` function or who would like to write less code and get better help and error messages should consider using the `argparse` module instead.

This module helps scripts to parse the command line arguments in `sys.argv`. It supports the same conventions as the Unix `getopt()` function (including the special meanings of arguments of the form `-` and `--`). Long options similar to those supported by GNU software may be used as well via an optional third argument.

This module provides two functions and an exception:

```python
getopt.getopt(args, shortopts, longopts=[])  
```

Parses command line options and parameter list. `args` is the argument list to be parsed, without the leading reference to the running program. Typically, this means `sys.argv[1:]`. `shortopts` is the string of option letters that the script wants to recognize, with options that require an argument followed by a colon (`':'`; i.e., the same format that Unix `getopt()` uses).

**Note:** Unlike GNU `getopt()`, after a non-option argument, all further arguments are considered also non-options. This is similar
to the way non-GNU Unix systems work.

`longopts`, if specified, must be a list of strings with the names of the long options which should be supported. The leading '---' characters should not be included in the option name. Long options which require an argument should be followed by an equal sign ('='). Optional arguments are not supported. To accept only long options, `shortopts` should be an empty string. Long options on the command line can be recognized so long as they provide a prefix of the option name that matches exactly one of the accepted options. For example, if `longopts` is `['foo', 'frob']`, the option `--fo` will match as `--foo`, but `--f` will not match uniquely, so `GetoptError` will be raised.

The return value consists of two elements: the first is a list of `(option, value)` pairs; the second is the list of program arguments left after the option list was stripped (this is a trailing slice of `args`). Each option-and-value pair returned has the option as its first element, prefixed with a hyphen for short options (e.g., '-x') or two hyphens for long options (e.g., '--long-option'), and the option argument as its second element, or an empty string if the option has no argument. The options occur in the list in the same order in which they were found, thus allowing multiple occurrences. Long and short options may be mixed.

`getopt.gnu_getopt(args, shortopts, longopts=[])`

This function works like `getopt()`, except that GNU style scanning mode is used by default. This means that option and non-option arguments may be intermixed. The `getopt()` function stops processing options as soon as a non-option argument is encountered.
If the first character of the option string is ' + ', or if the environment variable POSIXLY_CORRECT is set, then option processing stops as soon as a non-option argument is encountered.

**exception getopt.**GetoptError

This is raised when an unrecognized option is found in the argument list or when an option requiring an argument is given none. The argument to the exception is a string indicating the cause of the error. For long options, an argument given to an option which does not require one will also cause this exception to be raised. The attributes msg and opt give the error message and related option; if there is no specific option to which the exception relates, opt is an empty string.

**exception getopt.**error

Alias for **GetoptError**; for backward compatibility.

An example using only Unix style options:

```python
>>> import getopt
>>> args = '-a -b -cfoo -d bar a1 a2'.split()
>>> args
['-a', '-b', '-cfoo', '-d', 'bar', 'a1', 'a2']
>>> optlist, args = getopt.getopt(args, 'abc:d:')
>>> optlist
[('-a', ''), ('-b', ''), ('-c', 'foo'), ('-d', 'bar')]
>>> args
['a1', 'a2']
```

Using long option names is equally easy:

```python
>>> s = ' --condition=foo --testing --output-file abc
def'
>>> args = s.split()
```
In a script, typical usage is something like this:

```python
import getopt, sys

def main():
    try:
        opts, args = getopt.getopt(sys.argv[1:], "ho:v")
    except getopt.GetoptError as err:
        # print help information and exit:
        print(err)  # will print something like "option -a not recognized"
    usage()  
    sys.exit(2)

    output = None
    verbose = False

    for o, a in opts:
        if o == "-v":
            verbose = True
        elif o in ("-h", "--help"):
            usage()
            sys.exit()
        elif o in ("-o", "--output"):
            output = a
        else:
            assert False, "unhandled option"

    # ...

if __name__ == "__main__":
```

```python
```
Note that an equivalent command line interface could be produced with less code and more informative help and error messages by using the `argparse` module:

```python
import argparse

if __name__ == '__main__':
    parser = argparse.ArgumentParser()
    parser.add_argument('-o', '--output')
    parser.add_argument('-v', dest='verbose', action=argparse.store_true)
    args = parser.parse_args()
    # ... do something with args.output ...
    # ... do something with args.verbose ..
```

See also:

**Module argparse**

Alternative command line option and argument parsing library.
16.6. **logging** — Logging facility for Python

**Source code:** `Lib/logging/__init__.py`

This module defines functions and classes which implement a flexible event logging system for applications and libraries.

The key benefit of having the logging API provided by a standard library module is that all Python modules can participate in logging, so your application log can include your own messages integrated with messages from third-party modules.

The module provides a lot of functionality and flexibility. If you are unfamiliar with logging, the best way to get to grips with it is to see the tutorials (see the links on the right).

The basic classes defined by the module, together with their functions, are listed below.

- Loggers expose the interface that application code directly uses.
- Handlers send the log records (created by loggers) to the appropriate destination.
- Filters provide a finer grained facility for determining which log records to output.
- Formatters specify the layout of log records in the final output.
16.6.1. Logger Objects

Loggers have the following attributes and methods. Note that Loggers are never instantiated directly, but always through the module-level function `logging.getLogger(name)`. Multiple calls to `getLogger()` with the same name will always return a reference to the same Logger object.

The name is potentially a period-separated hierarchical value, like `foo.bar.baz` (though it could also be just plain `foo`, for example). Loggers that are further down in the hierarchical list are children of loggers higher up in the list. For example, given a logger with a name of `foo`, loggers with names of `foo.bar`, `foo.bar.baz`, and `foo.bam` are all descendants of `foo`. The logger name hierarchy is analogous to the Python package hierarchy, and identical to it if you organise your loggers on a per-module basis using the recommended construction `logging.getLogger(__name__)`. That's because in a module, `__name__` is the module's name in the Python package namespace.

```python
class logging.Logger

Logger.propagate
```

If this evaluates to true, events logged to this logger will be passed to the handlers of higher level (ancestor) loggers, in addition to any handlers attached to this logger. Messages are passed directly to the ancestor loggers' handlers - neither the level nor filters of the ancestor loggers in question are considered.

If this evaluates to false, logging messages are not passed to the handlers of ancestor loggers.
The constructor sets this attribute to True.

**Note:** If you attach a handler to a logger *and* one or more of its ancestors, it may emit the same record multiple times. In general, you should not need to attach a handler to more than one logger - if you just attach it to the appropriate logger which is highest in the logger hierarchy, then it will see all events logged by all descendant loggers, provided that their propagate setting is left set to True. A common scenario is to attach handlers only to the root logger, and to let propagation take care of the rest.

**Logger.setLevel(lvl)**

Sets the threshold for this logger to *lvl*. Logging messages which are less severe than *lvl* will be ignored. When a logger is created, the level is set to **NOTSET** (which causes all messages to be processed when the logger is the root logger, or delegation to the parent when the logger is a non-root logger). Note that the root logger is created with level WARNING.

The term ‘delegation to the parent’ means that if a logger has a level of **NOTSET**, its chain of ancestor loggers is traversed until either an ancestor with a level other than **NOTSET** is found, or the root is reached.

If an ancestor is found with a level other than **NOTSET**, then that ancestor’s level is treated as the effective level of the logger where the ancestor search began, and is used to determine how a logging event is handled.

If the root is reached, and it has a level of **NOTSET**, then all messages will be processed. Otherwise, the root’s level will be used as the effective level.
See **Logging Levels** for a list of levels.

*Changed in version 3.2:* The `lvl` parameter now accepts a string representation of the level such as ‘INFO’ as an alternative to the integer constants such as INFO. Note, however, that levels are internally stored as integers, and methods such as e.g. `getEffectiveLevel()` and `isEnabledFor()` will return(expect to be passed integers.

**Logger**. **isEnabledFor**( lvl )

Indicates if a message of severity `lvl` would be processed by this logger. This method checks first the module-level level set by `logging.disable(lvl)` and then the logger’s effective level as determined by `getEffectiveLevel()`.

**Logger**. **getEffectiveLevel**( )

Indicates the effective level for this logger. If a value other than NOTSET has been set using `setLevel()`, it is returned. Otherwise, the hierarchy is traversed towards the root until a value other than NOTSET is found, and that value is returned. The value returned is an integer, typically one of `logging.DEBUG`, `logging.INFO` etc.

**Logger**. **getChild**( suffix )

Returns a logger which is a descendant to this logger, as determined by the suffix. Thus, `logging.getLogger('abc').getChild('def.ghi')` would return the same logger as would be returned by `logging.getLogger('abc.def.ghi')`. This is a convenience method, useful when the parent logger is named using e.g. `__name__` rather than a literal string.
New in version 3.2.

Logger .debug(msg, *args, **kwargs)
Logs a message with level DEBUG on this logger. The msg is the message format string, and the args are the arguments which are merged into msg using the string formatting operator. (Note that this means that you can use keywords in the format string, together with a single dictionary argument.)

There are three keyword arguments in kwargs which are inspected: exc_info, stack_info, and extra.

If exc_info does not evaluate as false, it causes exception information to be added to the logging message. If an exception tuple (in the format returned by sys.exc_info()) or an exception instance is provided, it is used; otherwise, sys.exc_info() is called to get the exception information.

The second optional keyword argument is stack_info, which defaults to False. If true, stack information is added to the logging message, including the actual logging call. Note that this is not the same stack information as that displayed through specifying exc_info: The former is stack frames from the bottom of the stack up to the logging call in the current thread, whereas the latter is information about stack frames which have been unwound, following an exception, while searching for exception handlers.

You can specify stack_info independently of exc_info, e.g. to just show how you got to a certain point in your code, even when no exceptions were raised. The stack frames are printed following a header line which says:

Stack (most recent call last):
This mimics the Traceback (most recent call last): which is used when displaying exception frames.

The third keyword argument is *extra* which can be used to pass a dictionary which is used to populate the __dict__ of the LogRecord created for the logging event with user-defined attributes. These custom attributes can then be used as you like. For example, they could be incorporated into logged messages. For example:

```python
FORMAT = '%(asctime)-15s %(clientip)s %(user)-8s %(message)s'
logging.basicConfig(format=FORMAT)
d = {'clientip': '192.168.0.1', 'user': 'fbloggs'}
logger = logging.getLogger('tcpserver')
logger.warning('Protocol problem: %s', 'connection reset')
```

would print something like

```
2006-02-08 22:20:02,165 192.168.0.1 fbloggs Protocol problem:
```

The keys in the dictionary passed in *extra* should not clash with the keys used by the logging system. (See the **Formatter** documentation for more information on which keys are used by the logging system.)

If you choose to use these attributes in logged messages, you need to exercise some care. In the above example, for instance, the **Formatter** has been set up with a format string which expects ‘clientip’ and ‘user’ in the attribute dictionary of the LogRecord. If these are missing, the message will not be logged because a string formatting exception will occur. So in this case, you always need to pass the *extra* dictionary with these keys.
While this might be annoying, this feature is intended for use in specialized circumstances, such as multi-threaded servers where the same code executes in many contexts, and interesting conditions which arise are dependent on this context (such as remote client IP address and authenticated user name, in the above example). In such circumstances, it is likely that specialized Formatters would be used with particular Handlers.

*New in version 3.2:* The stack_info parameter was added.

*Changed in version 3.5:* The exc_info parameter can now accept exception instances.

**Logger.info**(*msg*, *args*, **kwargs*)
Logs a message with level INFO on this logger. The arguments are interpreted as for debug().

**Logger.warning**(*msg*, *args*, **kwargs*)
Logs a message with level WARNING on this logger. The arguments are interpreted as for debug().

**Note:** There is an obsolete method warn which is functionally identical to warning. As warn is deprecated, please do not use it - use warning instead.

**Logger.error**(*msg*, *args*, **kwargs*)
Logs a message with level ERROR on this logger. The arguments are interpreted as for debug().

**Logger.critical**(*msg*, *args*, **kwargs*)
Logs a message with level CRITICAL on this logger. The arguments are interpreted as for debug().
Logger.log(lvl, msg, *args, **kwargs)
Logs a message with integer level lvl on this logger. The other arguments are interpreted as for debug().

Logger.exception(msg, *args, **kwargs)
Logs a message with level ERROR on this logger. The arguments are interpreted as for debug(). Exception info is added to the logging message. This method should only be called from an exception handler.

Logger.addFilter(filt)
Adds the specified filter filt to this logger.

Logger.removeFilter(filt)
Removes the specified filter filt from this logger.

Logger.filter(record)
Applies this logger’s filters to the record and returns a true value if the record is to be processed. The filters are consulted in turn, until one of them returns a false value. If none of them return a false value, the record will be processed (passed to handlers). If one returns a false value, no further processing of the record occurs.

Logger.addHandler(hdlr)
Adds the specified handler hdlr to this logger.

Logger.removeHandler(hdlr)
Removes the specified handler hdlr from this logger.

Logger.findCaller(stack_info=False)
Finds the caller’s source filename and line number. Returns the filename, line number, function name and stack information as a 4-
element tuple. The stack information is returned as *None* unless *stack_info* is *True*.

**Logger**. `handle(record)`

Handles a record by passing it to all handlers associated with this logger and its ancestors (until a false value of *propagate* is found). This method is used for unpickled records received from a socket, as well as those created locally. Logger-level filtering is applied using `filter()`.

**Logger**. `makeRecord(name, lvl, fn, lno, msg, args, exc_info, func=None, extra=None, sinfo=None)`

This is a factory method which can be overridden in subclasses to create specialized `LogRecord` instances.

**Logger**. `hasHandlers()`

Checks to see if this logger has any handlers configured. This is done by looking for handlers in this logger and its parents in the logger hierarchy. Returns True if a handler was found, else False. The method stops searching up the hierarchy whenever a logger with the ‘propagate’ attribute set to False is found - that will be the last logger which is checked for the existence of handlers.

*New in version 3.2.*
The numeric values of logging levels are given in the following table. These are primarily of interest if you want to define your own levels, and need them to have specific values relative to the predefined levels. If you define a level with the same numeric value, it overwrites the predefined value; the predefined name is lost.

<table>
<thead>
<tr>
<th>Level</th>
<th>Numeric value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRITICAL</td>
<td>50</td>
</tr>
<tr>
<td>ERROR</td>
<td>40</td>
</tr>
<tr>
<td>WARNING</td>
<td>30</td>
</tr>
<tr>
<td>INFO</td>
<td>20</td>
</tr>
<tr>
<td>DEBUG</td>
<td>10</td>
</tr>
<tr>
<td>NOTSET</td>
<td>0</td>
</tr>
</tbody>
</table>
16.6.3. Handler Objects

Handlers have the following attributes and methods. Note that Handler is never instantiated directly; this class acts as a base for more useful subclasses. However, the __init__() method in subclasses needs to call Handler.__init__().

Handler.__init__(level=NOTSET)

Initializes the Handler instance by setting its level, setting the list of filters to the empty list and creating a lock (using createLock()) for serializing access to an I/O mechanism.

Handler.createLock()

Initializes a thread lock which can be used to serialize access to underlying I/O functionality which may not be threadsafe.

Handler.acquire()

Acquires the thread lock created with createLock().

Handler.release()

Releases the thread lock acquired with acquire().

Handler.setLevel(lvl)

Sets the threshold for this handler to lvl. Logging messages which are less severe than lvl will be ignored. When a handler is created, the level is set to NOTSET (which causes all messages to be processed).

See Logging Levels for a list of levels.

Changed in version 3.2: The lvl parameter now accepts a string representation of the level such as ‘INFO’ as an alternative to the
integer constants such as INFO.

**Handler**. `setFormatter(form)`
Sets the Formatter for this handler to `form`.

**Handler**. `addFilter(filt)`
Adds the specified filter `filt` to this handler.

**Handler**. `removeFilter(filt)`
Removes the specified filter `filt` from this handler.

**Handler**. `filter(record)`
Applies this handler's filters to the record and returns a true value if the record is to be processed. The filters are consulted in turn, until one of them returns a false value. If none of them return a false value, the record will be emitted. If one returns a false value, the handler will not emit the record.

**Handler**. `flush()`
Ensure all logging output has been flushed. This version does nothing and is intended to be implemented by subclasses.

**Handler**. `close()`
Tidy up any resources used by the handler. This version does no output but removes the handler from an internal list of handlers which is closed when `shutdown()` is called. Subclasses should ensure that this gets called from overridden `close()` methods.

**Handler**. `handle(record)`
Conditionally emits the specified logging record, depending on filters which may have been added to the handler. Wraps the actual emission of the record with acquisition/release of the I/O thread
lock.

**Handler**. `handleError(record)`

This method should be called from handlers when an exception is encountered during an `emit()` call. If the module-level attribute `raiseExceptions` is `False`, exceptions get silently ignored. This is what is mostly wanted for a logging system - most users will not care about errors in the logging system, they are more interested in application errors. You could, however, replace this with a custom handler if you wish. The specified record is the one which was being processed when the exception occurred. (The default value of `raiseExceptions` is `True`, as that is more useful during development).

**Handler**. `format(record)`

Do formatting for a record - if a formatter is set, use it. Otherwise, use the default formatter for the module.

**Handler**. `emit(record)`

Do whatever it takes to actually log the specified logging record. This version is intended to be implemented by subclasses and so raises a `NotImplementedError`.

For a list of handlers included as standard, see `logging.handlers`. 
16.6.4. Formatter Objects

Formatter objects have the following attributes and methods. They are responsible for converting a LogRecord to (usually) a string which can be interpreted by either a human or an external system. The base Formatter allows a formatting string to be specified. If none is supplied, the default value of '%(message)s' is used, which just includes the message in the logging call. To have additional items of information in the formatted output (such as a timestamp), keep reading.

A Formatter can be initialized with a format string which makes use of knowledge of the LogRecord attributes - such as the default value mentioned above making use of the fact that the user’s message and arguments are pre-formatted into a LogRecord's message attribute. This format string contains standard Python %-style mapping keys. See section printf-style String Formatting for more information on string formatting.

The useful mapping keys in a LogRecord are given in the section on LogRecord attributes.

class logging.Formatter(fmt=None, datefmt=None, style='%')

Returns a new instance of the Formatter class. The instance is initialized with a format string for the message as a whole, as well as a format string for the date/time portion of a message. If no fmt is specified, '%(message)s' is used. If no datefmt is specified, the ISO8601 date format is used.

The style parameter can be one of '%', '{' or '$' and determines how the format string will be merged with its data: using one of %-
formatting, `str.format()` or `string.Template`. See Using particular formatting styles throughout your application for more information on using `{}` and `$`-formatting for log messages.

*Changed in version 3.2:* The `style` parameter was added.

**format** (*record*)

The record's attribute dictionary is used as the operand to a string formatting operation. Returns the resulting string. Before formatting the dictionary, a couple of preparatory steps are carried out. The *message* attribute of the record is computed using `msg % args`. If the formatting string contains '(asctime)', `formatTime()` is called to format the event time. If there is exception information, it is formatted using `formatException()` and appended to the message. Note that the formatted exception information is cached in attribute `exc_text`. This is useful because the exception information can be pickled and sent across the wire, but you should be careful if you have more than one `Formatter` subclass which customizes the formatting of exception information. In this case, you will have to clear the cached value after a formatter has done its formatting, so that the next formatter to handle the event doesn't use the cached value but recalculates it afresh.

If stack information is available, it's appended after the exception information, using `formatStack()` to transform it if necessary.

**formatTime** (*record, datefmt=None*)

This method should be called from `format()` by a formatter which wants to make use of a formatted time. This method can be overridden in formatters to provide for any specific
requirement, but the basic behavior is as follows: if `datefmt` (a string) is specified, it is used with `time.strftime()` to format the creation time of the record. Otherwise, the ISO8601 format is used. The resulting string is returned.

This function uses a user-configurable function to convert the creation time to a tuple. By default, `time.localtime()` is used; to change this for a particular formatter instance, set the converter attribute to a function with the same signature as `time.localtime()` or `time.gmtime()`. To change it for all formatters, for example if you want all logging times to be shown in GMT, set the converter attribute in the Formatter class.

*Changed in version 3.3:* Previously, the default ISO 8601 format was hard-coded as in this example: `2010-09-06 22:38:15.292` where the part before the comma is handled by a strftime format string `'\%Y-%m-%d \%H:%M:%S'`, and the part after the comma is a millisecond value. Because strftime does not have a format placeholder for milliseconds, the millisecond value is appended using another format string, `'\%s,\%03d'` – and both of these format strings have been hardcoded into this method. With the change, these strings are defined as class-level attributes which can be overridden at the instance level when desired. The names of the attributes are `default_time_format` (for the strftime format string) and `default_msec_format` (for appending the millisecond value).

**formatException**(exc_info)

Formats the specified exception information (a standard exception tuple as returned by `sys.exc_info()`) as a string. This default implementation just uses
traceback.print_exception(). The resulting string is returned.

**formatStack**(*stack_info*)

Formats the specified stack information (a string as returned by *traceback.print_stack()*), but with the last newline removed) as a string. This default implementation just returns the input value.
16.6.5. Filter Objects

Filters can be used by Handlers and Loggers for more sophisticated filtering than is provided by levels. The base filter class only allows events which are below a certain point in the logger hierarchy. For example, a filter initialized with ‘A.B’ will allow events logged by loggers ‘A.B’, ‘A.B.C’, ‘A.B.C.D’, ‘A.B.D’ etc. but not ‘A.BB’, ‘B.A.B’ etc. If initialized with the empty string, all events are passed.

```python
class logging.Filter(name="")
    Returns an instance of the Filter class. If name is specified, it names a logger which, together with its children, will have its events allowed through the filter. If name is the empty string, allows every event.

    filter(record)
    Is the specified record to be logged? Returns zero for no, nonzero for yes. If deemed appropriate, the record may be modified in-place by this method.
```

Note that filters attached to handlers are consulted before an event is emitted by the handler, whereas filters attached to loggers are consulted whenever an event is logged (using `debug()`, `info()`, etc.), before sending an event to handlers. This means that events which have been generated by descendant loggers will not be filtered by a logger’s filter setting, unless the filter has also been applied to those descendant loggers.

You don’t actually need to subclass Filter: you can pass any instance which has a filter method with the same semantics.

*Changed in version 3.2:* You don’t need to create specialized Filter
classes, or use other classes with a `filter` method: you can use a function (or other callable) as a filter. The filtering logic will check to see if the filter object has a `filter` attribute: if it does, it's assumed to be a `Filter` and its `filter()` method is called. Otherwise, it's assumed to be a callable and called with the record as the single parameter. The returned value should conform to that returned by `filter()`.

Although filters are used primarily to filter records based on more sophisticated criteria than levels, they get to see every record which is processed by the handler or logger they're attached to: this can be useful if you want to do things like counting how many records were processed by a particular logger or handler, or adding, changing or removing attributes in the LogRecord being processed. Obviously changing the LogRecord needs to be done with some care, but it does allow the injection of contextual information into logs (see Using Filters to impart contextual information).
16.6.6. LogRecord Objects

LogRecord instances are created automatically by the Logger every time something is logged, and can be created manually via makeLogRecord() (for example, from a pickled event received over the wire).

class logging.LogRecord(name, level, pathname, lineno, msg, args, exc_info, func=None, sinfo=None)

Contains all the information pertinent to the event being logged.

The primary information is passed in msg and args, which are combined using msg % args to create the message field of the record.

Parameters:

- **name** – The name of the logger used to log the event represented by this LogRecord. Note that this name will always have this value, even though it may be emitted by a handler attached to a different (ancestor) logger.
- **level** – The numeric level of the logging event (one of DEBUG, INFO etc.) Note that this is converted to two attributes of the LogRecord: levelno for the numeric value andlevelname for the corresponding level name.
- **pathname** – The full pathname of the source file where the logging call was made.
- **lineno** – The line number in the source file where the logging call was made.
- **msg** – The event description message, possibly a format string with placeholders for variable data.
**args** – Variable data to merge into the *msg* argument to obtain the event description.

**exc_info** – An exception tuple with the current exception information, or *None* if no exception information is available.

**func** – The name of the function or method from which the logging call was invoked.

**sinfo** – A text string representing stack information from the base of the stack in the current thread, up to the logging call.

**getLogRecordFactory()**

Returns the message for this *LogRecord* instance after merging any user-supplied arguments with the message. If the user-supplied message argument to the logging call is not a string, *str()* is called on it to convert it to a string. This allows use of user-defined classes as messages, whose *__str__* method can return the actual format string to be used.

*Changed in version 3.2:* The creation of a *LogRecord* has been made more configurable by providing a factory which is used to create the record. The factory can be set using *getLogRecordFactory()* and *setLogRecordFactory()* (see this for the factory's signature).

This functionality can be used to inject your own values into a *LogRecord* at creation time. You can use the following pattern:

```python
old_factory = logging.getLogRecordFactory()

def record_factory(*args, **kwargs):
    record = old_factory(*args, **kwargs)
    record.custom_attribute = 0xdecafbad
    return record
```
logging.setLogRecordFactory(record_factory)

With this pattern, multiple factories could be chained, and as long as they don’t overwrite each other’s attributes or unintentionally overwrite the standard attributes listed above, there should be no surprises.
16.6.7. LogRecord attributes

The LogRecord has a number of attributes, most of which are derived from the parameters to the constructor. (Note that the names do not always correspond exactly between the LogRecord constructor parameters and the LogRecord attributes.) These attributes can be used to merge data from the record into the format string. The following table lists (in alphabetical order) the attribute names, their meanings and the corresponding placeholder in a %-style format string.

If you are using {}-formatting (str.format()), you can use {attrname} as the placeholder in the format string. If you are using $-formatting (string.Template), use the form ${attrname}. In both cases, of course, replace attrname with the actual attribute name you want to use.

In the case of {}-formatting, you can specify formatting flags by placing them after the attribute name, separated from it with a colon. For example: a placeholder of {msecs:03d} would format a millisecond value of 4 as 004. Refer to the str.format() documentation for full details on the options available to you.

<table>
<thead>
<tr>
<th>Attribute name</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>args</td>
<td>You shouldn’t need to format this yourself.</td>
<td>The tuple of arguments merged into msg to produce message.</td>
</tr>
</tbody>
</table>
|                |                         | Human-readable time when the LogRecord was created. By default this is of the form ‘2003-
<table>
<thead>
<tr>
<th>Field</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>asctime</td>
<td>%(asctime)s</td>
<td>Time when the LogRecord was created (as returned by time.time()). (the numbers after the comma are millisecond portion of the time).</td>
</tr>
<tr>
<td>created</td>
<td>%(created)f</td>
<td>Time when the LogRecord was created (as returned by time.time()).</td>
</tr>
<tr>
<td>exc_info</td>
<td></td>
<td>Exception tuple (à la sys.exc_info) or, if no exception has occurred, None.</td>
</tr>
<tr>
<td>filename</td>
<td>%(filename)s</td>
<td>Filename portion of pathname.</td>
</tr>
<tr>
<td>funcName</td>
<td>%(funcName)s</td>
<td>Name of function containing the logging call.</td>
</tr>
<tr>
<td>levelname</td>
<td>%(levelname)s</td>
<td>Text logging level for the message ('DEBUG', 'INFO', 'WARNING', 'ERROR', 'CRITICAL').</td>
</tr>
<tr>
<td>levelno</td>
<td>%(levelname)s</td>
<td>Numeric logging level for the message (DEBUG, INFO, WARNING, ERROR, CRITICAL).</td>
</tr>
<tr>
<td>lineno</td>
<td>%(lineno)d</td>
<td>Source line number where the logging call was issued (if available).</td>
</tr>
<tr>
<td>module</td>
<td>%(module)s</td>
<td>Module (name portion of filename).</td>
</tr>
<tr>
<td>Field</td>
<td>Format String</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>----------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>msecs</td>
<td>%(msecs)d</td>
<td>Millisecond portion of the time when the LogRecord was created.</td>
</tr>
<tr>
<td>message</td>
<td>%(message)s</td>
<td>The logged message, computed as msg % args. This is set when Formatter.format() is invoked.</td>
</tr>
<tr>
<td>msg</td>
<td>You shouldn't need to format this yourself.</td>
<td>The format string passed in the original logging call. Merged with args to produce message, or an arbitrary object (see Using arbitrary objects as messages).</td>
</tr>
<tr>
<td>name</td>
<td>%(name)s</td>
<td>Name of the logger used to log the call.</td>
</tr>
<tr>
<td>pathname</td>
<td>%(pathname)s</td>
<td>Full pathname of the source file where the logging call was issued (if available).</td>
</tr>
<tr>
<td>process</td>
<td>%(process)d</td>
<td>Process ID (if available).</td>
</tr>
<tr>
<td>processName</td>
<td>%(processName)s</td>
<td>Process name (if available).</td>
</tr>
<tr>
<td>relativeCreated</td>
<td>% (relativeCreated)d</td>
<td>Time in milliseconds when the LogRecord was created, relative to the time the logging module was loaded.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stack frame information (where available) from</td>
</tr>
</tbody>
</table>
You shouldn't need to format this yourself. the bottom of the stack in the current thread, up to and including the stack frame of the logging call which resulted in the creation of this record.

<table>
<thead>
<tr>
<th>stack_info</th>
<th>thread</th>
<th>threadName</th>
</tr>
</thead>
<tbody>
<tr>
<td>You shouldn't need to format this yourself.</td>
<td>%(thread)d</td>
<td>%(threadName)s</td>
</tr>
</tbody>
</table>

Thread ID (if available).

Thread name (if available).

*Changed in version 3.1: processName was added.*
16.6.8. LoggerAdapter Objects

LoggerAdapter instances are used to conveniently pass contextual information into logging calls. For a usage example, see the section on adding contextual information to your logging output.

```python
class logging.LoggerAdapter(logger, extra)
    Returns an instance of LoggerAdapter initialized with an underlying Logger instance and a dict-like object.

    process(msg, kwargs)
        Modifies the message and/or keyword arguments passed to a logging call in order to insert contextual information. This implementation takes the object passed as extra to the constructor and adds it to kwargs using key ‘extra’. The return value is a (msg, kwargs) tuple which has the (possibly modified) versions of the arguments passed in.
```

In addition to the above, LoggerAdapter supports the following methods of Logger: debug(), info(), warning(), error(), exception(), critical(), log(), isEnabledFor(), getEffectiveLevel(), setLevel() and hasHandlers(). These methods have the same signatures as their counterparts in Logger, so you can use the two types of instances interchangeably.

*Changed in version 3.2:* The isEnabledFor(), getEffectiveLevel(), setLevel() and hasHandlers() methods were added to LoggerAdapter. These methods delegate to the underlying logger.
16.6.9. Thread Safety

The logging module is intended to be thread-safe without any special work needing to be done by its clients. It achieves this though using threading locks; there is one lock to serialize access to the module's shared data, and each handler also creates a lock to serialize access to its underlying I/O.

If you are implementing asynchronous signal handlers using the `signal` module, you may not be able to use logging from within such handlers. This is because lock implementations in the `threading` module are not always re-entrant, and so cannot be invoked from such signal handlers.
16.6.10. Module-Level Functions

In addition to the classes described above, there are a number of module-level functions.

**logging.getLogger**(name=None)

Return a logger with the specified name or, if name is None, return a logger which is the root logger of the hierarchy. If specified, the name is typically a dot-separated hierarchical name like 'a', 'a.b' or 'a.b.c.d'. Choice of these names is entirely up to the developer who is using logging.

All calls to this function with a given name return the same logger instance. This means that logger instances never need to be passed between different parts of an application.

**logging.getLoggerClass()**

Return either the standard Logger class, or the last class passed to setLoggerClass(). This function may be called from within a new class definition, to ensure that installing a customized Logger class will not undo customizations already applied by other code. For example:

```python
class MyLogger(logging.getLoggerClass()):
    # ... override behaviour here
```

**logging.getLogRecordFactory()**

Return a callable which is used to create a LogRecord.

*New in version 3.2:* This function has been provided, along with setLogRecordFactory(), to allow developers more control over
how the **LogRecord** representing a logging event is constructed.

See **setLogRecordFactory()** for more information about the how the factory is called.

```
logging.debug(msg, *args, **kwargs)
```

Logs a message with level DEBUG on the root logger. The *msg* is the message format string, and the *args* are the arguments which are merged into *msg* using the string formatting operator. (Note that this means that you can use keywords in the format string, together with a single dictionary argument.)

There are three keyword arguments in *kwargs* which are inspected: *exc_info* which, if it does not evaluate as false, causes exception information to be added to the logging message. If an exception tuple (in the format returned by **sys.exc_info()**) is provided, it is used; otherwise, **sys.exc_info()** is called to get the exception information.

The second optional keyword argument is *stack_info*, which defaults to False. If true, stack information is added to the logging message, including the actual logging call. Note that this is not the same stack information as that displayed through specifying *exc_info*: The former is stack frames from the bottom of the stack up to the logging call in the current thread, whereas the latter is information about stack frames which have been unwound, following an exception, while searching for exception handlers.

You can specify *stack_info* independently of *exc_info*, e.g. to just show how you got to a certain point in your code, even when no exceptions were raised. The stack frames are printed following a header line which says:
Stack (most recent call last):

This mimics the Traceback (most recent call last): which is used when displaying exception frames.

The third optional keyword argument is extra which can be used to pass a dictionary which is used to populate the __dict__ of the LogRecord created for the logging event with user-defined attributes. These custom attributes can then be used as you like. For example, they could be incorporated into logged messages. For example:

```python
FORMAT = '%(asctime)-15s %(clientip)s %(user)-8s %(message)s'
logging.basicConfig(format=FORMAT)
d = {'clientip': '192.168.0.1', 'user': 'fbloggs'}
logging.warning('Protocol problem: %s', 'connection reset')
```

would print something like:

```
2006-02-08 22:20:02,165 192.168.0.1 fbloggs Protocol
```

The keys in the dictionary passed in extra should not clash with the keys used by the logging system. (See the Formatter documentation for more information on which keys are used by the logging system.)

If you choose to use these attributes in logged messages, you need to exercise some care. In the above example, for instance, the Formatter has been set up with a format string which expects ‘clientip’ and ‘user’ in the attribute dictionary of the LogRecord. If these are missing, the message will not be logged because a string formatting exception will occur. So in this case, you always need to
pass the extra dictionary with these keys.

While this might be annoying, this feature is intended for use in specialized circumstances, such as multi-threaded servers where the same code executes in many contexts, and interesting conditions which arise are dependent on this context (such as remote client IP address and authenticated user name, in the above example). In such circumstances, it is likely that specialized Formatters would be used with particular Handlers.

*New in version 3.2:* The stack_info parameter was added.

logging.info\((msg, *args, **kwargs)\)
Logs a message with level INFO on the root logger. The arguments are interpreted as for debug().

logging.warning\((msg, *args, **kwargs)\)
Logs a message with level WARNING on the root logger. The arguments are interpreted as for debug().

**Note:** There is an obsolete function warn which is functionally identical to warning. As warn is deprecated, please do not use it - use warning instead.

logging.error\((msg, *args, **kwargs)\)
Logs a message with level ERROR on the root logger. The arguments are interpreted as for debug().

logging.critical\((msg, *args, **kwargs)\)
Logs a message with level CRITICAL on the root logger. The arguments are interpreted as for debug().
logging.**exception**(msg, *args, **kwargs)

Logs a message with level ERROR on the root logger. The arguments are interpreted as for `debug()`. Exception info is added to the logging message. This function should only be called from an exception handler.

logging.**log**(level, msg, *args, **kwargs)

Logs a message with level *level* on the root logger. The other arguments are interpreted as for `debug()`.

**Note:** The above module-level convenience functions, which delegate to the root logger, call `basicConfig()` to ensure that at least one handler is available. Because of this, they should *not* be used in threads, in versions of Python earlier than 2.7.1 and 3.2, unless at least one handler has been added to the root logger *before* the threads are started. In earlier versions of Python, due to a thread safety shortcoming in `basicConfig()`, this can (under rare circumstances) lead to handlers being added multiple times to the root logger, which can in turn lead to multiple messages for the same event.

logging.**disable**(lvl)

Provides an overriding level *lvl* for all loggers which takes precedence over the logger’s own level. When the need arises to temporarily throttle logging output down across the whole application, this function can be useful. Its effect is to disable all logging calls of severity *lvl* and below, so that if you call it with a value of INFO, then all INFO and DEBUG events would be discarded, whereas those of severity WARNING and above would be processed according to the logger’s effective level. If `logging.disable(logging.NOTSET)` is called, it effectively...
removes this overriding level, so that logging output again depends on the effective levels of individual loggers.

logging.addLevelName(lvl, levelName)

Associates level lvl with text levelName in an internal dictionary, which is used to map numeric levels to a textual representation, for example when a Formatter formats a message. This function can also be used to define your own levels. The only constraints are that all levels used must be registered using this function, levels should be positive integers and they should increase in increasing order of severity.

**Note:** If you are thinking of defining your own levels, please see the section on Custom Levels.

logging.getLevelName(lvl)

Returns the textual representation of logging level lvl. If the level is one of the predefined levels CRITICAL, ERROR, WARNING, INFO or DEBUG then you get the corresponding string. If you have associated levels with names using addLevelName() then the name you have associated with lvl is returned. If a numeric value corresponding to one of the defined levels is passed in, the corresponding string representation is returned. Otherwise, the string ‘Level %s’ % lvl is returned.

**Note:** Levels are internally integers (as they need to be compared in the logging logic). This function is used to convert between an integer level and the level name displayed in the formatted log output by means of the %(levelname)s format specifier (see LogRecord attributes).

*Changed in version 3.4:* In Python versions earlier than 3.4, this
function could also be passed a text level, and would return the corresponding numeric value of the level. This undocumented behaviour was considered a mistake, and was removed in Python 3.4, but reinstated in 3.4.2 due to retain backward compatibility.

logging.makeLogRecord(attrdict)

Creates and returns a new LogRecord instance whose attributes are defined by attrdict. This function is useful for taking a pickled LogRecord attribute dictionary, sent over a socket, and reconstituting it as a LogRecord instance at the receiving end.

logging.basicConfig(**kwargs)

Does basic configuration for the logging system by creating a StreamHandler with a default Formatter and adding it to the root logger. The functions debug(), info(), warning(), error() and critical() will call basicConfig() automatically if no handlers are defined for the root logger.

This function does nothing if the root logger already has handlers configured for it.

**Note:** This function should be called from the main thread before other threads are started. In versions of Python prior to 2.7.1 and 3.2, if this function is called from multiple threads, it is possible (in rare circumstances) that a handler will be added to the root logger more than once, leading to unexpected results such as messages being duplicated in the log.

The following keyword arguments are supported.

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Specifies that a FileHandler be created, using</td>
</tr>
<tr>
<td>filename</td>
<td>the specified filename, rather than a StreamHandler.</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------------------------------------------</td>
</tr>
<tr>
<td>filemode</td>
<td>Specifies the mode to open the file, if filename is specified (if filemode is unspecified, it defaults to 'a').</td>
</tr>
<tr>
<td>format</td>
<td>Use the specified format string for the handler.</td>
</tr>
<tr>
<td>datefmt</td>
<td>Use the specified date/time format.</td>
</tr>
<tr>
<td>style</td>
<td>If format is specified, use this style for the format string. One of ‘%’, ‘{’ or ‘$’ for %-formatting, str.format() or string.Template respectively, and defaulting to ‘%’ if not specified.</td>
</tr>
<tr>
<td>level</td>
<td>Set the root logger level to the specified level.</td>
</tr>
<tr>
<td>stream</td>
<td>Use the specified stream to initialize the StreamHandler. Note that this argument is incompatible with ‘filename’ - if both are present, a ValueError is raised.</td>
</tr>
<tr>
<td>handlers</td>
<td>If specified, this should be an iterable of already created handlers to add to the root logger. Any handlers which don’t already have a formatter set will be assigned the default formatter created in this function. Note that this argument is incompatible with ‘filename’ or ‘stream’ - if both are present, a ValueError is raised.</td>
</tr>
</tbody>
</table>

*Changed in version 3.2:* The style argument was added.

*Changed in version 3.3:* The handlers argument was added. Additional checks were added to catch situations where incompatible arguments are specified (e.g. handlers together with stream or filename, or stream together with filename).

logging.shutdown()
Informs the logging system to perform an orderly shutdown by flushing and closing all handlers. This should be called at application exit and no further use of the logging system should be made after this call.

**logging.setLoggerClass(klass)**

Tells the logging system to use the class `klass` when instantiating a logger. The class should define `__init__()` such that only a name argument is required, and the `__init__()` should call `Logger.__init__()` . This function is typically called before any loggers are instantiated by applications which need to use custom logger behavior.

**logging.setLogRecordFactory(factory)**

Set a callable which is used to create a `LogRecord`.

### Parameters:

- **factory** – The factory callable to be used to instantiate a log record.

*New in version 3.2:* This function has been provided, along with `getLogRecordFactory()`, to allow developers more control over how the `LogRecord` representing a logging event is constructed.

The factory has the following signature:

```
factory(name, level, fn, lno, msg, args, exc_info, func=None, sinfo=None, **kwargs)
```

- **name:** The logger name.
- **level:** The logging level (numeric).
- **fn:** The full pathname of the file where the logging call was made.
<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>lno:</td>
<td>The line number in the file where the logging call was made.</td>
</tr>
<tr>
<td>msg:</td>
<td>The logging message.</td>
</tr>
<tr>
<td>args:</td>
<td>The arguments for the logging message.</td>
</tr>
<tr>
<td>exc_info:</td>
<td>An exception tuple, or None.</td>
</tr>
<tr>
<td>func:</td>
<td>The name of the function or method which invoked the logging call.</td>
</tr>
<tr>
<td>sinfo:</td>
<td>A stack traceback such as is provided by <code>traceback.print_stack()</code>, showing the call hierarchy.</td>
</tr>
<tr>
<td>kwargs:</td>
<td>Additional keyword arguments.</td>
</tr>
</tbody>
</table>
logging.**lastResort**

A “handler of last resort” is available through this attribute. This is a `StreamHandler` writing to `sys.stderr` with a level of `WARNING`, and is used to handle logging events in the absence of any logging configuration. The end result is to just print the message to `sys.stderr`. This replaces the earlier error message saying that “no handlers could be found for logger XYZ”. If you need the earlier behaviour for some reason, `lastResort` can be set to `None`.

*New in version 3.2.*
16.6.12. Integration with the warnings module

The `captureWarnings()` function can be used to integrate `logging` with the `warnings` module.

```python
logging.captureWarnings(capture)
```

This function is used to turn the capture of warnings by logging on and off.

If `capture` is True, warnings issued by the `warnings` module will be redirected to the logging system. Specifically, a warning will be formatted using `warnings.formatwarning()` and the resulting string logged to a logger named 'py.warnings' with a severity of WARNING.

If `capture` is False, the redirection of warnings to the logging system will stop, and warnings will be redirected to their original destinations (i.e. those in effect before `captureWarnings(True)` was called).

See also:

- **Module logging.config**
  Configuration API for the logging module.

- **Module logging.handlers**
  Useful handlers included with the logging module.

- **PEP 282 - A Logging System**
  The proposal which described this feature for inclusion in the Python standard library.
Original Python logging package

This is the original source for the `logging` package. The version of the package available from this site is suitable for use with Python 1.5.2, 2.1.x and 2.2.x, which do not include the `logging` package in the standard library.
16.7. `logging.config` —
Logging configuration

Source code: Lib/logging/config.py

This section describes the API for configuring the logging module.
16.7.1. Configuration functions

The following functions configure the logging module. They are located in the `logging.config` module. Their use is optional — you can configure the logging module using these functions or by making calls to the main API (defined in `logging` itself) and defining handlers which are declared either in `logging` or `logging.handlers`.

`logging.config.dictConfig(config)`

Takes the logging configuration from a dictionary. The contents of this dictionary are described in Configuration dictionary schema below.

If an error is encountered during configuration, this function will raise a `ValueError`, `TypeError`, `AttributeError` or `ImportError` with a suitably descriptive message. The following is a (possibly incomplete) list of conditions which will raise an error:

- A level which is not a string or which is a string not corresponding to an actual logging level.
- A propagate value which is not a boolean.
- An id which does not have a corresponding destination.
- A non-existent handler id found during an incremental call.
- An invalid logger name.
- Inability to resolve to an internal or external object.

Parsing is performed by the DictConfigurator class, whose constructor is passed the dictionary used for configuration, and has a configure() method. The `logging.config` module has a callable attribute
dictConfigClass which is initially set to DictConfigurator. You can replace the value of dictConfigClass with a suitable implementation of your own.

dictConfig() calls dictConfigClass passing the specified dictionary, and then calls the configure() method on the returned object to put the configuration into effect:

```python
def dictConfig(config):
    dictConfigClass(config).configure()
```

For example, a subclass of DictConfigurator could call DictConfigurator.__init__() in its own __init__(), then set up custom prefixes which would be usable in the subsequent configure() call. dictConfigClass would be bound to this new subclass, and then dictConfig() could be called exactly as in the default, uncustomized state.

*New in version 3.2.*

logging.config.fileConfig(fname, defaults=None, disable_existing_loggers=True)

Reads the logging configuration from a configparser-format file. The format of the file should be as described in Configuration file format. This function can be called several times from an application, allowing an end user to select from various pre-canned configurations (if the developer provides a mechanism to present the choices and load the chosen configuration).

- **fname** – A filename, or a file-like object, or an instance derived from RawConfigParser. If a
Parameters:

RawConfigParser-derived instance is passed, it is used as is. Otherwise, a ConfigParser is instantiated, and the configuration read by it from the object passed in `fname`. If that has a `readline()` method, it is assumed to be a file-like object and read using `read_file()`; otherwise, it is assumed to be a filename and passed to `read()`.

- **defaults** – Defaults to be passed to the ConfigParser can be specified in this argument.

- **disable_existing_loggers** – If specified as `False`, loggers which exist when this call is made are left enabled. The default is `True` because this enables old behaviour in a backward-compatible way. This behaviour is to disable any existing loggers unless they or their ancestors are explicitly named in the logging configuration.

*Changed in version 3.4:* An instance of a subclass of `RawConfigParser` is now accepted as a value for `fname`. This facilitates:

- Use of a configuration file where logging configuration is just part of the overall application configuration.
- Use of a configuration read from a file, and then modified by the using application (e.g. based on command-line parameters or other aspects of the runtime environment) before being passed to `fileConfig`.

```python
logging.config.listen(port=DEFAULT_LOGGING_CONFIG_PORT, verify=None)
```

Starts up a socket server on the specified port, and listens for new
configurations. If no port is specified, the module's default
DEFAULT_LOGGING_CONFIG_PORT is used. Logging
configurations will be sent as a file suitable for processing by
fileConfig(). Returns a Thread instance on which you can call
start() to start the server, and which you can join() when
appropriate. To stop the server, call stopListening().

The verify argument, if specified, should be a callable which
should verify whether bytes received across the socket are valid
and should be processed. This could be done by encrypting and/or
signing what is sent across the socket, such that the verify
callable can perform signature verification and/or decryption. The
verify callable is called with a single argument - the bytes
received across the socket - and should return the bytes to be
processed, or None to indicate that the bytes should be discarded.
The returned bytes could be the same as the passed in bytes (e.g.
when only verification is done), or they could be completely
different (perhaps if decryption were performed).

To send a configuration to the socket, read in the configuration file
and send it to the socket as a string of bytes preceded by a four-
byte length string packed in binary using struct.pack('>{L},
n).

Note: Because portions of the configuration are passed through
eval(), use of this function may open its users to a security risk.
While the function only binds to a socket on localhost, and so
does not accept connections from remote machines, there are
scenarios where untrusted code could be run under the account
of the process which calls listen(). Specifically, if the process
calling listen() runs on a multi-user machine where users
cannot trust each other, then a malicious user could arrange to run essentially arbitrary code in a victim user’s process, simply by connecting to the victim’s `listen()` socket and sending a configuration which runs whatever code the attacker wants to have executed in the victim’s process. This is especially easy to do if the default port is used, but not hard even if a different port is used). To avoid the risk of this happening, use the verify argument to `listen()` to prevent unrecognised configurations from being applied.

*Changed in version 3.4.: The verify argument was added.*

`logging.config.stopListening()`

Stops the listening server which was created with a call to `listen()`. This is typically called before calling `join()` on the return value from `listen()`. 
16.7.2. Configuration dictionary schema

Describing a logging configuration requires listing the various objects to create and the connections between them; for example, you may create a handler named ‘console’ and then say that the logger named ‘startup’ will send its messages to the ‘console’ handler. These objects aren’t limited to those provided by the logging module because you might write your own formatter or handler class. The parameters to these classes may also need to include external objects such as sys.stderr. The syntax for describing these objects and connections is defined in Object connections below.

16.7.2.1. Dictionary Schema Details

The dictionary passed to dictConfig() must contain the following keys:

- **version** - to be set to an integer value representing the schema version. The only valid value at present is 1, but having this key allows the schema to evolve while still preserving backwards compatibility.

All other keys are optional, but if present they will be interpreted as described below. In all cases below where a ‘configuring dict’ is mentioned, it will be checked for the special '()' key to see if a custom instantiation is required. If so, the mechanism described in User-defined objects below is used to create an instance; otherwise, the context is used to determine what to instantiate.

- **formatters** - the corresponding value will be a dict in which each key is a formatter id and each value is a dict describing how to
configure the corresponding **Formatter** instance.

The configuring dict is searched for keys `format` and `datefmt` (with defaults of `None`) and these are used to construct a **Formatter** instance.

- **filters** - the corresponding value will be a dict in which each key is a filter id and each value is a dict describing how to configure the corresponding Filter instance.

  The configuring dict is searched for the key `name` (defaulting to the empty string) and this is used to construct a **logging.Filter** instance.

- **handlers** - the corresponding value will be a dict in which each key is a handler id and each value is a dict describing how to configure the corresponding Handler instance.

  The configuring dict is searched for the following keys:

  - class (mandatory). This is the fully qualified name of the handler class.
  - level (optional). The level of the handler.
  - formatter (optional). The id of the formatter for this handler.
  - filters (optional). A list of ids of the filters for this handler.

  All *other* keys are passed through as keyword arguments to the handler's constructor. For example, given the snippet:

```python
handlers:
  console:
    class : logging.StreamHandler
    formatter: brief
```
the handler with id console is instantiated as a `logging.StreamHandler`, using `sys.stdout` as the underlying stream. The handler with id file is instantiated as a `logging.handlers.RotatingFileHandler` with the keyword arguments `filename='logconfig.log'`, `maxBytes=1024`, `backupCount=3`.

- **loggers** - the corresponding value will be a dict in which each key is a logger name and each value is a dict describing how to configure the corresponding Logger instance.

  The configuring dict is searched for the following keys:

  - **level** (optional). The level of the logger.
  - **propagate** (optional). The propagation setting of the logger.
  - **filters** (optional). A list of ids of the filters for this logger.
  - **handlers** (optional). A list of ids of the handlers for this logger.

  The specified loggers will be configured according to the level, propagation, filters and handlers specified.

- **root** - this will be the configuration for the root logger. Processing of the configuration will be as for any logger, except that the
propagate setting will not be applicable.

- **incremental** - whether the configuration is to be interpreted as incremental to the existing configuration. This value defaults to False, which means that the specified configuration replaces the existing configuration with the same semantics as used by the existing `fileConfig()` API.

  If the specified value is True, the configuration is processed as described in the section on Incremental Configuration.

- **disable_existing_loggers** - whether any existing loggers are to be disabled. This setting mirrors the parameter of the same name in `fileConfig()`. If absent, this parameter defaults to True. This value is ignored if `incremental` is True.

### 16.7.2.2. Incremental Configuration

It is difficult to provide complete flexibility for incremental configuration. For example, because objects such as filters and formatters are anonymous, once a configuration is set up, it is not possible to refer to such anonymous objects when augmenting a configuration.

Furthermore, there is not a compelling case for arbitrarily altering the object graph of loggers, handlers, filters, formatters at run-time, once a configuration is set up; the verbosity of loggers and handlers can be controlled just by setting levels (and, in the case of loggers, propagation flags). Changing the object graph arbitrarily in a safe way is problematic in a multi-threaded environment; while not impossible, the benefits are not worth the complexity it adds to the implementation.

Thus, when the `incremental` key of a configuration dict is present
and is True, the system will completely ignore any formatters and filters entries, and process only the level settings in the handlers entries, and the level and propagate settings in the loggers and root entries.

Using a value in the configuration dict lets configurations to be sent over the wire as pickled dicts to a socket listener. Thus, the logging verbosity of a long-running application can be altered over time with no need to stop and restart the application.

16.7.2.3. Object connections

The schema describes a set of logging objects - loggers, handlers, formatters, filters - which are connected to each other in an object graph. Thus, the schema needs to represent connections between the objects. For example, say that, once configured, a particular logger has attached to it a particular handler. For the purposes of this discussion, we can say that the logger represents the source, and the handler the destination, of a connection between the two. Of course in the configured objects this is represented by the logger holding a reference to the handler. In the configuration dict, this is done by giving each destination object an id which identifies it unambiguously, and then using the id in the source object’s configuration to indicate that a connection exists between the source and the destination object with that id.

So, for example, consider the following YAML snippet:

```yaml
formatters:
  brief:
    # configuration for formatter with id 'brief' goes here
  precise:
    # configuration for formatter with id 'precise'
```
handlers:
  h1: #This is an id
      # configuration of handler with id 'h1' goes here
      formatter: brief
  h2: #This is another id
      # configuration of handler with id 'h2' goes here
      formatter: precise
loggers:
  foo.bar.baz:
      # other configuration for logger 'foo.bar.baz'
      handlers: [h1, h2]

(Note: YAML used here because it’s a little more readable than the equivalent Python source form for the dictionary.)

The ids for loggers are the logger names which would be used programmatically to obtain a reference to those loggers, e.g. foo.bar.baz. The ids for Formatters and Filters can be any string value (such as brief, precise above) and they are transient, in that they are only meaningful for processing the configuration dictionary and used to determine connections between objects, and are not persisted anywhere when the configuration call is complete.

The above snippet indicates that logger named foo.bar.baz should have two handlers attached to it, which are described by the handler ids h1 and h2. The formatter for h1 is that described by id brief, and the formatter for h2 is that described by id precise.

16.7.2.4. User-defined objects

The schema supports user-defined objects for handlers, filters and formatters. (Loggers do not need to have different types for different instances, so there is no support in this configuration schema for user-
defined logger classes.)

Objects to be configured are described by dictionaries which detail their configuration. In some places, the logging system will be able to infer from the context how an object is to be instantiated, but when a user-defined object is to be instantiated, the system will not know how to do this. In order to provide complete flexibility for user-defined object instantiation, the user needs to provide a ‘factory’ - a callable which is called with a configuration dictionary and which returns the instantiated object. This is signalled by an absolute import path to the factory being made available under the special key '()' . Here's a concrete example:

```yaml
formatters:
    brief:
        format: '%(message)s'
    default:
        format: '%(asctime)s %(levelname)-8s %(name)-15s %(message)s'
        datefmt: '%Y-%m-%d %H:%M:%S'
    custom:
        (): my.package.customFormatterFactory
        bar: baz
        spam: 99.9
        answer: 42
```

The above YAML snippet defines three formatters. The first, with id brief, is a standard `logging.Formatter` instance with the specified format string. The second, with id default, has a longer format and also defines the time format explicitly, and will result in a `logging.Formatter` initialized with those two format strings. Shown in Python source form, the brief and default formatters have configuration sub-dictionaries:
and:

```python
{
    'format': '%(asctime)s %%(levelname)-8s %%(name)-15s %%(message)s
    'datefmt': '%Y-%m-%d %H:%M:%S'
}
```

respectively, and as these dictionaries do not contain the special key '()', the instantiation is inferred from the context: as a result, standard `logging.Formatter` instances are created. The configuration sub-dictionary for the third formatter, with id custom, is:

```python
{
    '()': 'my.package.customFormatterFactory',
    'bar': 'baz',
    'spam': 99.9,
    'answer': 42
}
```

and this contains the special key '()', which means that user-defined instantiation is wanted. In this case, the specified factory callable will be used. If it is an actual callable it will be used directly - otherwise, if you specify a string (as in the example) the actual callable will be located using normal import mechanisms. The callable will be called with the remaining items in the configuration sub-dictionary as keyword arguments. In the above example, the formatter with id custom will be assumed to be returned by the call:

```python
my.package.customFormatterFactory(bar='baz', spam=99.9
```
The key '()' has been used as the special key because it is not a valid keyword parameter name, and so will not clash with the names of the keyword arguments used in the call. The '()' also serves as a mnemonic that the corresponding value is a callable.

16.7.2.5. Access to external objects

There are times where a configuration needs to refer to objects external to the configuration, for example `sys.stderr`. If the configuration dict is constructed using Python code, this is straightforward, but a problem arises when the configuration is provided via a text file (e.g. JSON, YAML). In a text file, there is no standard way to distinguish `sys.stderr` from the literal string 'sys.stderr'. To facilitate this distinction, the configuration system looks for certain special prefixes in string values and treat them specially. For example, if the literal string 'ext://sys.stderr' is provided as a value in the configuration, then the ext:// will be stripped off and the remainder of the value processed using normal import mechanisms.

The handling of such prefixes is done in a way analogous to protocol handling: there is a generic mechanism to look for prefixes which match the regular expression `^(?P<prefix>[a-z]+)://(?P<suffix>.*&)` whereby, if the prefix is recognised, the suffix is processed in a prefix-dependent manner and the result of the processing replaces the string value. If the prefix is not recognised, then the string value will be left as-is.

16.7.2.6. Access to internal objects
As well as external objects, there is sometimes also a need to refer to objects in the configuration. This will be done implicitly by the configuration system for things that it knows about. For example, the string value 'DEBUG' for a level in a logger or handler will automatically be converted to the value `logging.DEBUG`, and the handlers, filters and formatter entries will take an object id and resolve to the appropriate destination object.

However, a more generic mechanism is needed for user-defined objects which are not known to the `logging` module. For example, consider `logging.handlers.MemoryHandler`, which takes a target argument which is another handler to delegate to. Since the system already knows about this class, then in the configuration, the given target just needs to be the object id of the relevant target handler, and the system will resolve to the handler from the id. If, however, a user defines a `my.package.MyHandler` which has an alternate handler, the configuration system would not know that the alternate referred to a handler. To cater for this, a generic resolution system allows the user to specify:

```
handlers:
    file:
      # configuration of file handler goes here
    custom:
      (): my.package.MyHandler
      alternate: cfg://handlers.file
```

The literal string 'cfg://handlers.file' will be resolved in an analogous way to strings with the `ext://` prefix, but looking in the configuration itself rather than the import namespace. The mechanism allows access by dot or by index, in a similar way to that provided by
Thus, given the following snippet:

```python
handlers:
    email:
        class: logging.handlers.SMTPHandler
        mailhost: localhost
        fromaddr: my_app@domain.tld
        toaddrs:
            - support_team@domain.tld
            - dev_team@domain.tld
        subject: Houston, we have a problem.
```

in the configuration, the string 'cfg://handlers' would resolve to the dict with key handlers, the string 'cfg://handlers.email' would resolve to the dict with key email in the handlers dict, and so on. The string 'cfg://handlers.email.toaddrs[1]' would resolve to 'dev_team.domain.tld' and the string 'cfg://handlers.email.toaddrs[0]' would resolve to the value 'support_team@domain.tld'. The subject value could be accessed using either 'cfg://handlers.email.subject' or, equivalently, 'cfg://handlers.email[subject]'. The latter form only needs to be used if the key contains spaces or non-alphanumeric characters. If an index value consists only of decimal digits, access will be attempted using the corresponding integer value, falling back to the string value if needed.

Given a string cfg://handlers.myhandler.mykey.123, this will resolve to `config_dict['handlers']['myhandler']['mykey']['123']`. If the string is specified as cfg://handlers.myhandler.mykey[123], the system will attempt to retrieve the value from `config_dict['handlers']['myhandler']['mykey'][123]`, and fall back to
config_dict['handlers']['myhandler']['mykey']['123'] if that fails.

16.7.2.7. Import resolution and custom importers

Import resolution, by default, uses the built-in `__import__()` function to do its importing. You may want to replace this with your own importing mechanism: if so, you can replace the importer attribute of the DictConfigurator or its superclass, the BaseConfigurator class. However, you need to be careful because of the way functions are accessed from classes via descriptors. If you are using a Python callable to do your imports, and you want to define it at class level rather than instance level, you need to wrap it with `staticmethod()`. For example:

```python
from importlib import import_module
from logging.config import BaseConfigurator

BaseConfigurator.importer = staticmethod(import_module)
```

You don't need to wrap with `staticmethod()` if you're setting the import callable on a configurator `instance`. 
16.7.3. Configuration file format

The configuration file format understood by `fileConfig()` is based on `configparser` functionality. The file must contain sections called `[loggers]`, `[handlers]` and `[formatters]` which identify by name the entities of each type which are defined in the file. For each such entity, there is a separate section which identifies how that entity is configured. Thus, for a logger named log01 in the `[loggers]` section, the relevant configuration details are held in a section `[logger_log01]`. Similarly, a handler called hand01 in the `[handlers]` section will have its configuration held in a section called `[handler_hand01]`, while a formatter called form01 in the `[formatters]` section will have its configuration specified in a section called `[formatter_form01]`. The root logger configuration must be specified in a section called `[logger_root]`.

**Note:** The `fileConfig()` API is older than the `dictConfig()` API and does not provide functionality to cover certain aspects of logging. For example, you cannot configure `Filter` objects, which provide for filtering of messages beyond simple integer levels, using `fileConfig()`. If you need to have instances of `Filter` in your logging configuration, you will need to use `dictConfig()`. Note that future enhancements to configuration functionality will be added to `dictConfig()`, so it's worth considering transitioning to this newer API when it's convenient to do so.

Examples of these sections in the file are given below.

```
[loggers]
keys=root,log02,log03,log04,log05,log06,log07
```
The root logger must specify a level and a list of handlers. An example of a root logger section is given below.

```
[logger_root]
level=NOTSET
handlers=hand01
```

The level entry can be one of DEBUG, INFO, WARNING, ERROR, CRITICAL or NOTSET. For the root logger only, NOTSET means that all messages will be logged. Level values are \texttt{eval()}uated in the context of the logging package's namespace.

The handlers entry is a comma-separated list of handler names, which must appear in the \texttt{[handlers]} section. These names must appear in the \texttt{[handlers]} section and have corresponding sections in the configuration file.

For loggers other than the root logger, some additional information is required. This is illustrated by the following example.

```
[logger_parser]
level=DEBUG
handlers=hand01
propagate=1
qualname=compiler.parser
```
The level and handlers entries are interpreted as for the root logger, except that if a non-root logger's level is specified as NOTSET, the system consults loggers higher up the hierarchy to determine the effective level of the logger. The propagate entry is set to 1 to indicate that messages must propagate to handlers higher up the logger hierarchy from this logger, or 0 to indicate that messages are not propagated to handlers up the hierarchy. The qualname entry is the hierarchical channel name of the logger, that is to say the name used by the application to get the logger.

Sections which specify handler configuration are exemplified by the following.

```
[handler_hand01]
class=StreamHandler
level=NOTSET
formatter=form01
args=(sys.stdout,)
```

The class entry indicates the handler's class (as determined by `eval()` in the logging package's namespace). The level is interpreted as for loggers, and NOTSET is taken to mean 'log everything'.

The formatter entry indicates the key name of the formatter for this handler. If blank, a default formatter (`logging._defaultFormatter`) is used. If a name is specified, it must appear in the `[formatters]` section and have a corresponding section in the configuration file.

The args entry, when `eval()`uated in the context of the logging package's namespace, is the list of arguments to the constructor for the handler class. Refer to the constructors for the relevant handlers,
or to the examples below, to see how typical entries are constructed.

```
[handler_hand02]
class=FileHandler
level=DEBUG
formatter=form02
args=('python.log', 'w')

[handler_hand03]
class=handlers.SocketHandler
level=INFO
formatter=form03
args=('localhost', handlers.DEFAULT_TCP_LOGGING_PORT)

[handler_hand04]
class=handlers.DatagramHandler
level=WARNING
formatter=form04
args=('localhost', handlers.DEFAULT_UDP_LOGGING_PORT)

[handler_hand05]
class=handlers.SysLogHandler
level=ERROR
formatter=form05
args=((('localhost', handlers.SYSLOG_UDP_PORT), 'msg'))

[handler_hand06]
class=handlers.NTEventLogHandler
level=CRITICAL
formatter=form06
args=('Python Application', '', 'Application')

[handler_hand07]
class=handlers.SMTPHandler
level=WARNING
formatter=form07
args=('localhost', 'from@abc', ['user1@abc', 'user2@abc'])
```
Sections which specify formatter configuration are typified by the following.

```
[formatter_form01]
format=F1 %(asctime)s %(levelname)s %(message)s
datefmt=
class=logging.Formatter
```

The format entry is the overall format string, and the datefmt entry is the strftime()-compatible date/time format string. If empty, the package substitutes ISO8601 format date/times, which is almost equivalent to specifying the date format string '%Y-%m-%d %H:%M:%S'. The ISO8601 format also specifies milliseconds, which are appended to the result of using the above format string, with a comma separator. An example time in ISO8601 format is 2003-01-23 00:29:50,411.

The class entry is optional. It indicates the name of the formatter’s class (as a dotted module and class name.) This option is useful for
instantiating a `Formatter` subclass. Subclasses of `Formatter` can present exception tracebacks in an expanded or condensed format.

**Note:** Due to the use of `eval()` as described above, there are potential security risks which result from using the `listen()` to send and receive configurations via sockets. The risks are limited to where multiple users with no mutual trust run code on the same machine; see the `listen()` documentation for more information.

**See also:**

**Module** `logging`

API reference for the logging module.

**Module** `logging.handlers`

Useful handlers included with the logging module.
16. Generic Operating System Services
16.8. **logging.handlers** — Logging handlers

**Source code:** Lib/logging/handlers.py

The following useful handlers are provided in the package. Note that three of the handlers (`StreamHandler`, `FileHandler` and `NullHandler`) are actually defined in the `logging` module itself, but have been documented here along with the other handlers.
16.8.1. StreamHandler

The StreamHandler class, located in the core logging package, sends logging output to streams such as sys.stdout, sys.stderr or any file-like object (or, more precisely, any object which supports write() and flush() methods).

class logging.StreamHandler(stream=None)

Returns a new instance of the StreamHandler class. If stream is specified, the instance will use it for logging output; otherwise, sys.stderr will be used.

emit(record)

If a formatter is specified, it is used to format the record. The record is then written to the stream with a terminator. If exception information is present, it is formatted using traceback.print_exception() and appended to the stream.

flush()

Flushes the stream by calling its flush() method. Note that the close() method is inherited from Handler and so does no output, so an explicit flush() call may be needed at times.

Changed in version 3.2: The StreamHandler class now has a terminator attribute, default value '\n', which is used as the terminator when writing a formatted record to a stream. If you don't want this newline termination, you can set the handler instance's terminator attribute to the empty string. In earlier versions, the terminator was hardcoded as '\n'.

16.8.2. FileHandler

The `FileHandler` class, located in the core `logging` package, sends logging output to a disk file. It inherits the output functionality from `StreamHandler`.

class logging.FileHandler(filename, mode='a', encoding=None, delay=False)

Returns a new instance of the `FileHandler` class. The specified file is opened and used as the stream for logging. If `mode` is not specified, 'a' is used. If `encoding` is not `None`, it is used to open the file with that encoding. If `delay` is true, then file opening is deferred until the first call to `emit()`. By default, the file grows indefinitely.

`close()`

Closes the file.

`emit(record)`

Outputs the record to the file.
16.8.3. NullHandler

*New in version 3.1.*

The `NullHandler` class, located in the core `logging` package, does not do any formatting or output. It is essentially a ‘no-op’ handler for use by library developers.

```python
class logging.NullHandler
    Returns a new instance of the NullHandler class.

def emit(record):
    This method does nothing.

def handle(record):
    This method does nothing.

def createLock():
    This method returns None for the lock, since there is no underlying I/O to which access needs to be serialized.
```

See [Configuring Logging for a Library](#) for more information on how to use `NullHandler`.
16.8.4. WatchedFileHandler

The `WatchedFileHandler` class, located in the `logging.handlers` module, is a FileHandler which watches the file it is logging to. If the file changes, it is closed and reopened using the file name.

A file change can happen because of usage of programs such as `newsyslog` and `logrotate` which perform log file rotation. This handler, intended for use under Unix/Linux, watches the file to see if it has changed since the last emit. (A file is deemed to have changed if its device or inode have changed.) If the file has changed, the old file stream is closed, and the file opened to get a new stream.

This handler is not appropriate for use under Windows, because under Windows open log files cannot be moved or renamed - logging opens the files with exclusive locks - and so there is no need for such a handler. Furthermore, `ST_INO` is not supported under Windows; `stat()` always returns zero for this value.

class logging.handlers.WatchedFileHandler(filename[, mode[, encoding[, delay]]])

Returns a new instance of the `WatchedFileHandler` class. The specified file is opened and used as the stream for logging. If `mode` is not specified, 'a' is used. If `encoding` is not `None`, it is used to open the file with that encoding. If `delay` is true, then file opening is deferred until the first call to `emit()`. By default, the file grows indefinitely.

`emit(record)`

Outputs the record to the file, but first checks to see if the file
has changed. If it has, the existing stream is flushed and closed and the file opened again, before outputting the record to the file.
16.8.5. BaseRotatingHandler

The `BaseRotatingHandler` class, located in the `logging.handlers` module, is the base class for the rotating file handlers, `RotatingFileHandler` and `TimedRotatingFileHandler`. You should not need to instantiate this class, but it has attributes and methods you may need to override.

```python
class logging.handlers.BaseRotatingHandler(filename, mode, encoding=None, delay=False)
```

The parameters are as for FileHandler. The attributes are:

**namer**

If this attribute is set to a callable, the `rotation_filename()` method delegates to this callable. The parameters passed to the callable are those passed to `rotation_filename()`.

**Note:** The namer function is called quite a few times during rollover, so it should be as simple and as fast as possible. It should also return the same output every time for a given input, otherwise the rollover behaviour may not work as expected.

*New in version 3.3.*

**rotator**

If this attribute is set to a callable, the `rotate()` method delegates to this callable. The parameters passed to the callable are those passed to `rotate()`.

*New in version 3.3.*
**rotation_filename**(default_name)

Modify the filename of a log file when rotating.

This is provided so that a custom filename can be provided.

The default implementation calls the ‘namer’ attribute of the handler, if it’s callable, passing the default name to it. If the attribute isn’t callable (the default is None), the name is returned unchanged.

<table>
<thead>
<tr>
<th>Parameters:</th>
<th>default_name – The default name for the log file.</th>
</tr>
</thead>
</table>

*New in version 3.3.*

**rotate**(source, dest)

When rotating, rotate the current log.

The default implementation calls the ‘rotator’ attribute of the handler, if it's callable, passing the source and dest arguments to it. If the attribute isn’t callable (the default is None), the source is simply renamed to the destination.

| Parameters: | • source – The source filename. This is normally the base filename, e.g. ‘test.log’.
|-------------|--------|
|             | • dest – The destination filename. This is normally what the source is rotated to, e.g. ‘test.log.1’.

*New in version 3.3.*

The reason the attributes exist is to save you having to subclass - you can use the same callables for instances of RotatingFileHandler and TimedRotatingFileHandler. If either the namer or rotator
callable raises an exception, this will be handled in the same way as any other exception during an emit() call, i.e. via the handleError() method of the handler.

If you need to make more significant changes to rotation processing, you can override the methods.

For an example, see Using a rotator and namer to customize log rotation processing.
16.8.6. RotatingFileHandler

The **RotatingFileHandler** class, located in the `logging.handlers` module, supports rotation of disk log files.

class logging.handlers.RotatingFileHandler(filename, mode='a', maxBytes=0, backupCount=0, encoding=None, delay=0)

Returns a new instance of the **RotatingFileHandler** class. The specified file is opened and used as the stream for logging. If *mode* is not specified, 'a' is used. If *encoding* is not *None*, it is used to open the file with that encoding. If *delay* is true, then file opening is deferred until the first call to `emit()`. By default, the file grows indefinitely.

You can use the *maxBytes* and *backupCount* values to allow the file to *rollover* at a predetermined size. When the size is about to be exceeded, the file is closed and a new file is silently opened for output. Rollover occurs whenever the current log file is nearly *maxBytes* in length; if either of *maxBytes* or *backupCount* is zero, rollover never occurs. If *backupCount* is non-zero, the system will save old log files by appending the extensions '.1', '.2' etc., to the filename. For example, with a *backupCount* of 5 and a base file name of app.log, you would get app.log, app.log.1, app.log.2, up to app.log.5. The file being written to is always app.log. When this file is filled, it is closed and renamed to app.log.1, and if files app.log.1, app.log.2, etc. exist, then they are renamed to app.log.2, app.log.3 etc. respectively.

**doRollover()**

Does a rollover, as described above.
\texttt{emit}(\textit{record})

Outputs the record to the file, catering for rollover as described previously.
16.8.7. TimedRotatingFileHandler

The `TimedRotatingFileHandler` class, located in the `logging.handlers` module, supports rotation of disk log files at certain timed intervals.

```python
class logging.handlers.TimedRotatingFileHandler(filename, when='h', interval=1, backupCount=0, encoding=None, delay=False, utc=False, atTime=None)

Returns a new instance of the `TimedRotatingFileHandler` class. The specified file is opened and used as the stream for logging. On rotating it also sets the filename suffix. Rotating happens based on the product of `when` and `interval`.

You can use the `when` to specify the type of `interval`. The list of possible values is below. Note that they are not case sensitive.

<table>
<thead>
<tr>
<th>Value</th>
<th>Type of interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>'S'</td>
<td>Seconds</td>
</tr>
<tr>
<td>'M'</td>
<td>Minutes</td>
</tr>
<tr>
<td>'H'</td>
<td>Hours</td>
</tr>
<tr>
<td>'D'</td>
<td>Days</td>
</tr>
<tr>
<td>'W0'-'W6'</td>
<td>Weekday</td>
</tr>
<tr>
<td>'midnight'</td>
<td>Roll over at midnight</td>
</tr>
</tbody>
</table>

When using weekday-based rotation, specify ‘W0’ for Monday, ‘W1’ for Tuesday, and so on up to ‘W6’ for Sunday. In this case, the value passed for `interval` isn’t used.
The system will save old log files by appending extensions to the filename. The extensions are date-and-time based, using the strftime format `%Y-%m-%d_%H-%M-%S` or a leading portion thereof, depending on the rollover interval.

When computing the next rollover time for the first time (when the handler is created), the last modification time of an existing log file, or else the current time, is used to compute when the next rotation will occur.

If the `utc` argument is true, times in UTC will be used; otherwise local time is used.

If `backupCount` is nonzero, at most `backupCount` files will be kept, and if more would be created when rollover occurs, the oldest one is deleted. The deletion logic uses the interval to determine which files to delete, so changing the interval may leave old files lying around.

If `delay` is true, then file opening is deferred until the first call to `emit()`.

If `atTime` is not None, it must be a `datetime.time` instance which specifies the time of day when rollover occurs, for the cases where rollover is set to happen “at midnight” or “on a particular weekday”.

*Changed in version 3.4: `atTime` parameter was added.*

**doRollover()**

Does a rollover, as described above.

**emit(record)**
Outputs the record to the file, catering for rollover as described above.
16.8.8. SocketHandler

The `SocketHandler` class, located in the `logging.handlers` module, sends logging output to a network socket. The base class uses a TCP socket.

class logging.handlers.SocketHandler(host, port)

    Returns a new instance of the `SocketHandler` class intended to communicate with a remote machine whose address is given by `host` and `port`.

*Changed in version 3.4:* If `port` is specified as None, a Unix domain socket is created using the value in `host` - otherwise, a TCP socket is created.

`close()`

    Closes the socket.

`emit()`

    Pickles the record’s attribute dictionary and writes it to the socket in binary format. If there is an error with the socket, silently drops the packet. If the connection was previously lost, re-establishes the connection. To unpickle the record at the receiving end into a `LogRecord`, use the `makeLogRecord()` function.

`handleError()`

    Handles an error which has occurred during `emit()`. The most likely cause is a lost connection. Closes the socket so that we can retry on the next event.

`makeSocket()`
This is a factory method which allows subclasses to define the precise type of socket they want. The default implementation creates a TCP socket (`socket.SOCK_STREAM`).

**makePickle(record)**

Pickles the record's attribute dictionary in binary format with a length prefix, and returns it ready for transmission across the socket.

Note that pickles aren't completely secure. If you are concerned about security, you may want to override this method to implement a more secure mechanism. For example, you can sign pickles using HMAC and then verify them on the receiving end, or alternatively you can disable unpickling of global objects on the receiving end.

**send(packet)**

Send a pickled string `packet` to the socket. This function allows for partial sends which can happen when the network is busy.

**createSocket()**

Tries to create a socket; on failure, uses an exponential back-off algorithm. On initial failure, the handler will drop the message it was trying to send. When subsequent messages are handled by the same instance, it will not try connecting until some time has passed. The default parameters are such that the initial delay is one second, and if after that delay the connection still can't be made, the handler will double the delay each time up to a maximum of 30 seconds.

This behaviour is controlled by the following handler attributes:

- `retryStart` (initial delay, defaulting to 1.0 seconds).
- retryFactor (multiplier, defaulting to 2.0).
- retryMax (maximum delay, defaulting to 30.0 seconds).

This means that if the remote listener starts up after the handler has been used, you could lose messages (since the handler won’t even attempt a connection until the delay has elapsed, but just silently drop messages during the delay period).
16.8.9. DatagramHandler

The `DatagramHandler` class, located in the `logging.handlers` module, inherits from `SocketHandler` to support sending logging messages over UDP sockets.

class logging.handlers.DatagramHandler(host, port)

Returns a new instance of the `DatagramHandler` class intended to communicate with a remote machine whose address is given by `host` and `port`.

*Changed in version 3.4:* If `port` is specified as `None`, a Unix domain socket is created using the value in `host` - otherwise, a TCP socket is created.

**emit()**

Pickles the record's attribute dictionary and writes it to the socket in binary format. If there is an error with the socket, silently drops the packet. To unpickle the record at the receiving end into a `LogRecord`, use the `makeLogRecord()` function.

**makeSocket()**

The factory method of `SocketHandler` is here overridden to create a UDP socket (`socket.SOCK_DGRAM`).

**send(s)**

Send a pickled string to a socket.
16.8.10. SysLogHandler

The `SysLogHandler` class, located in the `logging.handlers` module, supports sending logging messages to a remote or local Unix syslog.

```python
class logging.handlers.SysLogHandler(address=('localhost', SYSLOG_UDP_PORT), facility=LOG_USER, socktype=socket.SOCK_DGRAM)
```

Returns a new instance of the `SysLogHandler` class intended to communicate with a remote Unix machine whose address is given by `address` in the form of a `(host, port)` tuple. If `address` is not specified, ('localhost', 514) is used. The address is used to open a socket. An alternative to providing a `(host, port)` tuple is providing an address as a string, for example '/dev/log'. In this case, a Unix domain socket is used to send the message to the syslog. If `facility` is not specified, LOG_USER is used. The type of socket opened depends on the `socktype` argument, which defaults to `socket.SOCK_DGRAM` and thus opens a UDP socket. To open a TCP socket (for use with the newer syslog daemons such as rsyslog), specify a value of `socket.SOCK_STREAM`.

Note that if your server is not listening on UDP port 514, `SysLogHandler` may appear not to work. In that case, check what address you should be using for a domain socket - it’s system dependent. For example, on Linux it’s usually '/dev/log' but on OS/X it's '/var/run/syslog'. You’ll need to check your platform and use the appropriate address (you may need to do this check at runtime if your application needs to run on several platforms). On Windows, you pretty much have to use the UDP option.
Changed in version 3.2: socktype was added.

**close()**

Closes the socket to the remote host.

**emit(record)**

The record is formatted, and then sent to the syslog server. If exception information is present, it is *not* sent to the server.

*Changed in version 3.2.1:* (See: issue 12168.) In earlier versions, the message sent to the syslog daemons was always terminated with a NUL byte, because early versions of these daemons expected a NUL terminated message - even though it’s not in the relevant specification (RF 5424). More recent versions of these daemons don’t expect the NUL byte but strip it off if it’s there, and even more recent daemons (which adhere more closely to RFC 5424) pass the NUL byte on as part of the message.

To enable easier handling of syslog messages in the face of all these differing daemon behaviours, the appending of the NUL byte has been made configurable, through the use of a class-level attribute, `append_nul`. This defaults to True (preserving the existing behaviour) but can be set to False on a `SysLogHandler` instance in order for that instance to *not* append the NUL terminator.

*Changed in version 3.3:* (See: issue 12419.) In earlier versions, there was no facility for an “ident” or “tag” prefix to identify the source of the message. This can now be specified using a class-level attribute, defaulting to "" to preserve existing behaviour, but which can be overridden on a `SysLogHandler`
instance in order for that instance to prepend the ident to every message handled. Note that the provided ident must be text, not bytes, and is prepended to the message exactly as is.

**encodePriority**\((facility, priority)\)

Encodes the facility and priority into an integer. You can pass in strings or integers - if strings are passed, internal mapping dictionaries are used to convert them to integers.

The symbolic LOG_ values are defined in *SysLogHandler* and mirror the values defined in the sys/syslog.h header file.

### Priorities

<table>
<thead>
<tr>
<th>Name (string)</th>
<th>Symbolic value</th>
</tr>
</thead>
<tbody>
<tr>
<td>alert</td>
<td>LOG_ALERT</td>
</tr>
<tr>
<td>crit or critical</td>
<td>LOG_CRIT</td>
</tr>
<tr>
<td>debug</td>
<td>LOG_DEBUG</td>
</tr>
<tr>
<td>emerg or panic</td>
<td>LOG_EMERG</td>
</tr>
<tr>
<td>err or error</td>
<td>LOG_ERR</td>
</tr>
<tr>
<td>info</td>
<td>LOG_INFO</td>
</tr>
<tr>
<td>notice</td>
<td>LOG_NOTICE</td>
</tr>
<tr>
<td>warn or warning</td>
<td>LOG_WARNING</td>
</tr>
</tbody>
</table>

### Facilities

<table>
<thead>
<tr>
<th>Name (string)</th>
<th>Symbolic value</th>
</tr>
</thead>
<tbody>
<tr>
<td>auth</td>
<td>LOG_AUTH</td>
</tr>
<tr>
<td>authpriv</td>
<td>LOG_AUTHPRIV</td>
</tr>
<tr>
<td>cron</td>
<td>LOG_CRON</td>
</tr>
<tr>
<td>daemon</td>
<td>LOG_DAEMON</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>ftp</td>
<td>LOG_FTP</td>
</tr>
<tr>
<td>kern</td>
<td>LOG_KERN</td>
</tr>
<tr>
<td>lpr</td>
<td>LOG_LPR</td>
</tr>
<tr>
<td>mail</td>
<td>LOG_MAIL</td>
</tr>
<tr>
<td>news</td>
<td>LOG_NEWS</td>
</tr>
<tr>
<td>syslog</td>
<td>LOG_SYSLOG</td>
</tr>
<tr>
<td>user</td>
<td>LOG_USER</td>
</tr>
<tr>
<td>uucp</td>
<td>LOG_UUCP</td>
</tr>
<tr>
<td>local0</td>
<td>LOG_LOCAL0</td>
</tr>
<tr>
<td>local1</td>
<td>LOG_LOCAL1</td>
</tr>
<tr>
<td>local2</td>
<td>LOG_LOCAL2</td>
</tr>
<tr>
<td>local3</td>
<td>LOG_LOCAL3</td>
</tr>
<tr>
<td>local4</td>
<td>LOG_LOCAL4</td>
</tr>
<tr>
<td>local5</td>
<td>LOG_LOCAL5</td>
</tr>
<tr>
<td>local6</td>
<td>LOG_LOCAL6</td>
</tr>
<tr>
<td>local7</td>
<td>LOG_LOCAL7</td>
</tr>
</tbody>
</table>

**mapPriority()**

Maps a logging level name to a syslog priority name. You may need to override this if you are using custom levels, or if the default algorithm is not suitable for your needs. The default algorithm maps DEBUG, INFO, WARNING, ERROR and CRITICAL to the equivalent syslog names, and all other level names to 'warning'.

16.8.11. NTEventLogHandler

The **NTEventLogHandler** class, located in the `logging.handlers` module, supports sending logging messages to a local Windows NT, Windows 2000 or Windows XP event log. Before you can use it, you need Mark Hammond’s Win32 extensions for Python installed.

```python
class logging.handlers.NTEventLogHandler(appname, dllname=None, logtype='Application')
```

Returns a new instance of the **NTEventLogHandler** class. The `appname` is used to define the application name as it appears in the event log. An appropriate registry entry is created using this name. The `dllname` should give the fully qualified pathname of a .dll or .exe which contains message definitions to hold in the log (if not specified, 'win32service.pyd' is used - this is installed with the Win32 extensions and contains some basic placeholder message definitions. Note that use of these placeholders will make your event logs big, as the entire message source is held in the log. If you want slimmer logs, you have to pass in the name of your own .dll or .exe which contains the message definitions you want to use in the event log). The `logtype` is one of 'Application', 'System' or 'Security', and defaults to 'Application'.

**close()**

At this point, you can remove the application name from the registry as a source of event log entries. However, if you do this, you will not be able to see the events as you intended in the Event Log Viewer - it needs to be able to access the registry to get the .dll name. The current version does not do this.

```python
emit(record)
```
Determines the message ID, event category and event type, and then logs the message in the NT event log.

**getEventCategory**(*record*)

Returns the event category for the record. Override this if you want to specify your own categories. This version returns 0.

**getEventType**(*record*)

Returns the event type for the record. Override this if you want to specify your own types. This version does a mapping using the handler’s typemap attribute, which is set up in `__init__()` to a dictionary which contains mappings for DEBUG, INFO, WARNING, ERROR and CRITICAL. If you are using your own levels, you will either need to override this method or place a suitable dictionary in the handler’s typemap attribute.

**getMessageID**(*record*)

Returns the message ID for the record. If you are using your own messages, you could do this by having the `msg` passed to the logger being an ID rather than a format string. Then, in here, you could use a dictionary lookup to get the message ID. This version returns 1, which is the base message ID in win32service.pyd.
16.8.12. SMTPHandler

The **SMTPHandler** class, located in the `logging.handlers` module, supports sending logging messages to an email address via SMTP.

```python
class logging.handlers.SMTPHandler(mailhost, fromaddr, toaddrs, subject, credentials=None, secure=None, timeout=1.0)
```

Returns a new instance of the **SMTPHandler** class. The instance is initialized with the from and to addresses and subject line of the email. The `toaddrs` should be a list of strings. To specify a non-standard SMTP port, use the (host, port) tuple format for the `mailhost` argument. If you use a string, the standard SMTP port is used. If your SMTP server requires authentication, you can specify a (username, password) tuple for the `credentials` argument.

To specify the use of a secure protocol (TLS), pass in a tuple to the `secure` argument. This will only be used when authentication credentials are supplied. The tuple should be either an empty tuple, or a single-value tuple with the name of a keyfile, or a 2-value tuple with the names of the keyfile and certificate file. (This tuple is passed to the `smtplib.SMTP.starttls()` method.)

A timeout can be specified for communication with the SMTP server using the `timeout` argument.

*New in version 3.3:* The `timeout` argument was added.

**emit(record)**

Formats the record and sends it to the specified addressees.

**getSubject(record)**
If you want to specify a subject line which is record-dependent, override this method.
16.8.13. MemoryHandler

The `MemoryHandler` class, located in the `logging.handlers` module, supports buffering of logging records in memory, periodically flushing them to a `target` handler. Flushing occurs whenever the buffer is full, or when an event of a certain severity or greater is seen.

`MemoryHandler` is a subclass of the more general `BufferingHandler`, which is an abstract class. This buffers logging records in memory. Whenever each record is added to the buffer, a check is made by calling `shouldFlush()` to see if the buffer should be flushed. If it should, then `flush()` is expected to do the flushing.

```python
class logging.handlers.BufferingHandler(capacity):
    Initializes the handler with a buffer of the specified capacity.

    emit(record)
        Appends the record to the buffer. If `shouldFlush()` returns true, calls `flush()` to process the buffer.

    flush()
        You can override this to implement custom flushing behavior. This version just zaps the buffer to empty.

    shouldFlush(record)
        Returns true if the buffer is up to capacity. This method can be overridden to implement custom flushing strategies.
```

```python
class logging.handlers.MemoryHandler(capacity, flushLevel=ERROR, target=None):
    Returns a new instance of the `MemoryHandler` class. The
instance is initialized with a buffer size of capacity. If flushLevel is not specified, ERROR is used. If no target is specified, the target will need to be set using setTarget() before this handler does anything useful.

**close()**

Calls flush(), sets the target to None and clears the buffer.

**flush()**

For a MemoryHandler, flushing means just sending the buffered records to the target, if there is one. The buffer is also cleared when this happens. Override if you want different behavior.

**setTarget(target)**

Sets the target handler for this handler.

**shouldFlush(record)**

Checks for buffer full or a record at the flushLevel or higher.
16.8.14. HTTPHandler

The HTTPHandler class, located in the `logging.handlers` module, supports sending logging messages to a Web server, using either GET or POST semantics.

```python
class logging.handlers.HTTPHandler(host, url, method='GET', secure=False, credentials=None, context=None)
```

Returns a new instance of the HTTPHandler class. The `host` can be of the form `host:port`, should you need to use a specific port number. If no `method` is specified, GET is used. If `secure` is true, a HTTPS connection will be used. The `context` parameter may be set to a `ssl.SSLContext` instance to configure the SSL settings used for the HTTPS connection. If `credentials` is specified, it should be a 2-tuple consisting of userid and password, which will be placed in a HTTP ‘Authorization’ header using Basic authentication. If you specify credentials, you should also specify `secure=True` so that your userid and password are not passed in cleartext across the wire.

*Changed in version 3.5:* The `context` parameter was added.

```python
mapLogRecord(record)
```

Provides a dictionary, based on `record`, which is to be URL-encoded and sent to the web server. The default implementation just returns `record.__dict__`. This method can be overridden if e.g. only a subset of `LogRecord` is to be sent to the web server, or if more specific customization of what’s sent to the server is required.

```python
emit(record)
```
Sends the record to the Web server as an URL-encoded dictionary. The `mapLogRecord()` method is used to convert the record to the dictionary to be sent.

**Note:** Since preparing a record for sending it to a Web server is not the same as a generic formatting operation, using `setFormatter()` to specify a `Formatter` for a `HTTPHandler` has no effect. Instead of calling `format()`, this handler calls `mapLogRecord()` and then `urllib.parse.urlencode()` to encode the dictionary in a form suitable for sending to a Web server.
16.8.15. QueueHandler

New in version 3.2.

The QueueHandler class, located in the logging.handlers module, supports sending logging messages to a queue, such as those implemented in the queue or multiprocessing modules.

Along with the QueueListener class, QueueHandler can be used to let handlers do their work on a separate thread from the one which does the logging. This is important in Web applications and also other service applications where threads servicing clients need to respond as quickly as possible, while any potentially slow operations (such as sending an email via SMTPHandler) are done on a separate thread.

class logging.handlers.QueueHandler(queue)

Returns a new instance of the QueueHandler class. The instance is initialized with the queue to send messages to. The queue can be any queue-like object; it's used as-is by the enqueue() method, which needs to know how to send messages to it.

emit(record)

Enqueues the result of preparing the LogRecord.

prepare(record)

Prepares a record for queuing. The object returned by this method is enqueued.

The base implementation formats the record to merge the message and arguments, and removes unpickleable items from the record in-place.
You might want to override this method if you want to convert the record to a dict or JSON string, or send a modified copy of the record while leaving the original intact.

**enqueue(record)**

Enqueues the record on the queue using `put_nowait()`; you may want to override this if you want to use blocking behaviour, or a timeout, or a customized queue implementation.
16.8.16. QueueListener

New in version 3.2.

The QueueListener class, located in the logging.handlers module, supports receiving logging messages from a queue, such as those implemented in the queue or multiprocessing modules. The messages are received from a queue in an internal thread and passed, on the same thread, to one or more handlers for processing. While QueueListener is not itself a handler, it is documented here because it works hand-in-hand with QueueHandler.

Along with the QueueHandler class, QueueListener can be used to let handlers do their work on a separate thread from the one which does the logging. This is important in Web applications and also other service applications where threads servicing clients need to respond as quickly as possible, while any potentially slow operations (such as sending an email via SMTPHandler) are done on a separate thread.

```python
class logging.handlers.QueueListener(queue, *handlers, respect_handler_level=False)
```

Returns a new instance of the QueueListener class. The instance is initialized with the queue to send messages to and a list of handlers which will handle entries placed on the queue. The queue can be any queue-like object; it's passed as-is to the dequeue() method, which needs to know how to get messages from it. If respect_handler_level is True, a handler's level is respected (compared with the level for the message) when deciding whether to pass messages to that handler; otherwise, the behaviour is as in previous Python versions - to always pass each message to each handler.
Changed in version 3.5: The respect_handler_levels argument was added.

**dequeue**(block)

Dequeues a record and return it, optionally blocking.

The base implementation uses get(). You may want to override this method if you want to use timeouts or work with custom queue implementations.

**prepare**(record)

Prepare a record for handling.

This implementation just returns the passed-in record. You may want to override this method if you need to do any custom marshalling or manipulation of the record before passing it to the handlers.

**handle**(record)

Handle a record.

This just loops through the handlers offering them the record to handle. The actual object passed to the handlers is that which is returned from **prepare()**.

**start**()

Starts the listener.

This starts up a background thread to monitor the queue for LogRecords to process.

**stop**()

Stops the listener.
This asks the thread to terminate, and then waits for it to do so. Note that if you don’t call this before your application exits, there may be some records still left on the queue, which won’t be processed.

**enqueue_sentinel()**

Writes a sentinel to the queue to tell the listener to quit. This implementation uses `put_nowait()`. You may want to override this method if you want to use timeouts or work with custom queue implementations.

*New in version 3.3.*

### See also:

- **Module logging**
  API reference for the logging module.
- **Module logging.config**
  Configuration API for the logging module.
16.9. getpass — Portable password input

The `getpass` module provides two functions:

```python
getpass.getpass(prompt='Password: ', stream=None)
```

Prompt the user for a password without echoing. The user is prompted using the string `prompt`, which defaults to 'Password: '. On Unix, the prompt is written to the file-like object `stream` using the replace error handler if needed. `stream` defaults to the controlling terminal (``/dev/tty``) or if that is unavailable to `sys.stderr` (this argument is ignored on Windows).

If echo free input is unavailable `getpass()` falls back to printing a warning message to `stream` and reading from `sys.stdin` and issuing a `GetPassWarning`.

Availability: Macintosh, Unix, Windows.

---

**Note:** If you call `getpass` from within IDLE, the input may be done in the terminal you launched IDLE from rather than the idle window itself.

---

**exception getpass.GetPassWarning**

A `UserWarning` subclass issued when password input may be echoed.

```python
getpass.getuser()
```

Return the “login name” of the user. Availability: Unix, Windows.
This function checks the environment variables LOGNAME, USER, LNAME and USERNAME, in order, and returns the value of the first one which is set to a non-empty string. If none are set, the login name from the password database is returned on systems which support the `pwd` module, otherwise, an exception is raised.
16.10. **curses** — Terminal handling for character-cell displays

The **curses** module provides an interface to the curses library, the de-facto standard for portable advanced terminal handling.

While curses is most widely used in the Unix environment, versions are available for Windows, DOS, and possibly other systems as well. This extension module is designed to match the API of ncurses, an open-source curses library hosted on Linux and the BSD variants of Unix.

**Note:** Since version 5.4, the ncurses library decides how to interpret non-ASCII data using the `n1_langinfo` function. That means that you have to call `locale.setlocale()` in the application and encode Unicode strings using one of the system’s available encodings. This example uses the system’s default encoding:

```python
import locale
locale.setlocale(locale.LC_ALL, '')
code = locale.getpreferredencoding()
```

Then use `code` as the encoding for `str.encode()` calls.

**See also:**

**Module** **curses.ascii**

Utilities for working with ASCII characters, regardless of your locale settings.
Module **curses.panel**
A panel stack extension that adds depth to curses windows.

Module **curses.textpad**
Editable text widget for curses supporting **Emacs**-like bindings.

**Curses Programming with Python**
Tutorial material on using curses with Python, by Andrew Kuchling and Eric Raymond.

The **Tools/demo/** directory in the Python source distribution contains some example programs using the curses bindings provided by this module.
16.10.1. Functions

The module `curses` defines the following exception:

```
exception curses.error

Exception raised when a curses library function returns an error.
```

| Note: | Whenever x or y arguments to a function or a method are optional, they default to the current cursor location. Whenever attr is optional, it defaults to A_NORMAL. |

The module `curses` defines the following functions:

- **curses.baudrate()**
  
  Return the output speed of the terminal in bits per second. On software terminal emulators it will have a fixed high value. Included for historical reasons; in former times, it was used to write output loops for time delays and occasionally to change interfaces depending on the line speed.

- **curses.beep()**
  
  Emit a short attention sound.

- **curses.can_change_color()**
  
  Return True or False, depending on whether the programmer can change the colors displayed by the terminal.

- **curses.cbreak()**
  
  Enter cbreak mode. In cbreak mode (sometimes called “rare” mode) normal tty line buffering is turned off and characters are available to be read one by one. However, unlike raw mode,
special characters (interrupt, quit, suspend, and flow control) retain their effects on the tty driver and calling program. Calling first \texttt{raw()} then \texttt{cbreak()} leaves the terminal in cbreak mode.

\texttt{curses.color\_content(color\_number)}

Return the intensity of the red, green, and blue (RGB) components in the color \texttt{color\_number}, which must be between 0 and \texttt{COLORS}. A 3-tuple is returned, containing the R,G,B values for the given color, which will be between 0 (no component) and 1000 (maximum amount of component).

\texttt{curses.color\_pair(color\_number)}

Return the attribute value for displaying text in the specified color. This attribute value can be combined with \texttt{A\_STANDOUT}, \texttt{A\_REVERSE}, and the other \texttt{A\_*} attributes. \texttt{pair\_number()} is the counterpart to this function.

\texttt{curses.curs\_set(visibility)}

Set the cursor state. \texttt{visibility} can be set to 0, 1, or 2, for invisible, normal, or very visible. If the terminal supports the visibility requested, the previous cursor state is returned; otherwise, an exception is raised. On many terminals, the “visible” mode is an underline cursor and the “very visible” mode is a block cursor.

\texttt{curses.def\_prog\_mode()}

Save the current terminal mode as the “program” mode, the mode when the running program is using curses. (Its counterpart is the “shell” mode, for when the program is not in curses.) Subsequent calls to \texttt{reset\_prog\_mode()} will restore this mode.

\texttt{curses.def\_shell\_mode()}

Save the current terminal mode as the “shell” mode, the mode
when the running program is not using curses. (Its counterpart is the “program” mode, when the program is using curses capabilities.) Subsequent calls to \texttt{reset\_shell\_mode()} will restore this mode.

\textbf{curses.\texttt{delay\_output}(ms)}

Insert an \texttt{ms} millisecond pause in output.

\textbf{curses.\texttt{doupdate}()}

Update the physical screen. The curses library keeps two data structures, one representing the current physical screen contents and a virtual screen representing the desired next state. The \texttt{doupdate()} ground updates the physical screen to match the virtual screen.

The virtual screen may be updated by a \texttt{noutrefresh()} call after write operations such as \texttt{addstr()} have been performed on a window. The normal \texttt{refresh()} call is simply \texttt{noutrefresh()} followed by \texttt{doupdate()}; if you have to update multiple windows, you can speed performance and perhaps reduce screen flicker by issuing \texttt{noutrefresh()} calls on all windows, followed by a single \texttt{doupdate()}.

\textbf{curses.\texttt{echo}()}

Enter echo mode. In echo mode, each character input is echoed to the screen as it is entered.

\textbf{curses.\texttt{endwin}()}

De-initialize the library, and return terminal to normal status.

\textbf{curses.\texttt{erasechar}()}

Return the user’s current erase character. Under Unix operating
systems this is a property of the controlling tty of the curses program, and is not set by the curses library itself.

curses.filter()

The filter() routine, if used, must be called before initscr() is called. The effect is that, during those calls, LINES is set to 1; the capabilities clear, cup, cud, cud1, cuu1, cuu, vpa are disabled; and the home string is set to the value of cr. The effect is that the cursor is confined to the current line, and so are screen updates. This may be used for enabling character-at-a-time line editing without touching the rest of the screen.

curses.flash()

Flash the screen. That is, change it to reverse-video and then change it back in a short interval. Some people prefer such as ‘visible bell’ to the audible attention signal produced by beep().

curses.flushinp()

Flush all input buffers. This throws away any typeahead that has been typed by the user and has not yet been processed by the program.

curses.getmouse()

After getch() returns KEY_MOUSE to signal a mouse event, this method should be call to retrieve the queued mouse event, represented as a 5-tuple (id, x, y, z, bstate). id is an ID value used to distinguish multiple devices, and x, y, z are the event’s coordinates. (z is currently unused.) bstate is an integer value whose bits will be set to indicate the type of event, and will be the bitwise OR of one or more of the following constants, where n is the button number from 1 to 4: BUTTONNn_PRESSED, BUTTONNn_RELEASED, BUTTONNn_CLICKED,
BUTTONn_DOUBLE_CLICKED, BUTTONn_TRIPLE_CLICKED,
BUTTON_SHIFT, BUTTON_CTRL, BUTTON_ALT.

curses.getsyx()
Return the current coordinates of the virtual screen cursor in y and x. If leaveok is currently true, then -1,-1 is returned.

curses.getwin(file)
Read window related data stored in the file by an earlier putwin() call. The routine then creates and initializes a new window using that data, returning the new window object.

curses.has_colors()
Return True if the terminal can display colors; otherwise, return False.

curses.has_ic()
Return True if the terminal has insert- and delete-character capabilities. This function is included for historical reasons only, as all modern software terminal emulators have such capabilities.

curses.has_il()
Return True if the terminal has insert- and delete-line capabilities, or can simulate them using scrolling regions. This function is included for historical reasons only, as all modern software terminal emulators have such capabilities.

curses.has_key(ch)
Take a key value ch, and return True if the current terminal type recognizes a key with that value.

curses.halfdelay(tenths)
Used for half-delay mode, which is similar to cbreak mode in that characters typed by the user are immediately available to the program. However, after blocking for tenths tenths of seconds, an exception is raised if nothing has been typed. The value of tenths must be a number between 1 and 255. Use nocbreak() to leave half-delay mode.

curses.init_color(color_number, r, g, b)

Change the definition of a color, taking the number of the color to be changed followed by three RGB values (for the amounts of red, green, and blue components). The value of color_number must be between 0 and COLORS. Each of r, g, b, must be a value between 0 and 1000. When init_color() is used, all occurrences of that color on the screen immediately change to the new definition. This function is a no-op on most terminals; it is active only if can_change_color() returns 1.

curses.init_pair(pair_number, fg, bg)

Change the definition of a color-pair. It takes three arguments: the number of the color-pair to be changed, the foreground color number, and the background color number. The value of pair_number must be between 1 and COLOR_PAIRS - 1 (the 0 color pair is wired to white on black and cannot be changed). The value of fg and bg arguments must be between 0 and COLORS. If the color-pair was previously initialized, the screen is refreshed and all occurrences of that color-pair are changed to the new definition.

curses.initscr()

Initialize the library. Return a WindowObject which represents the whole screen.

Note: If there is an error opening the terminal, the underlying
curses library may cause the interpreter to exit.

curses.is_term_resized(nlines, ncols)
    Return True if resize_term() would modify the window structure, False otherwise.

curses.isendwin()
    Return True if endwin() has been called (that is, the curses library has been deinitialized).

curses.keyname(k)
    Return the name of the key numbered k. The name of a key generating printable ASCII character is the key's character. The name of a control-key combination is a two-character string consisting of a caret followed by the corresponding printable ASCII character. The name of an alt-key combination (128-255) is a string consisting of the prefix 'M-' followed by the name of the corresponding ASCII character.

curses.killchar()
    Return the user's current line kill character. Under Unix operating systems this is a property of the controlling tty of the curses program, and is not set by the curses library itself.

curses.longname()
    Return a string containing the terminfo long name field describing the current terminal. The maximum length of a verbose description is 128 characters. It is defined only after the call to initscr().

curses.meta(yes)
    If yes is 1, allow 8-bit characters to be input. If yes is 0, allow only 7-bit chars.
curses.mouseinterval(interval)
Set the maximum time in milliseconds that can elapse between press and release events in order for them to be recognized as a click, and return the previous interval value. The default value is 200 msec, or one fifth of a second.

curses.mousemask(mousemask)
Set the mouse events to be reported, and return a tuple (availmask, oldmask). availmask indicates which of the specified mouse events can be reported; on complete failure it returns 0. oldmask is the previous value of the given window's mouse event mask. If this function is never called, no mouse events are ever reported.

curses.napms(ms)
Sleep for ms milliseconds.

curses.newpad(nlines, ncols)
Create and return a pointer to a new pad data structure with the given number of lines and columns. A pad is returned as a window object.

A pad is like a window, except that it is not restricted by the screen size, and is not necessarily associated with a particular part of the screen. Pads can be used when a large window is needed, and only a part of the window will be on the screen at one time. Automatic refreshes of pads (such as from scrolling or echoing of input) do not occur. The refresh() and noutrefresh() methods of a pad require 6 arguments to specify the part of the pad to be displayed and the location on the screen to be used for the display. The arguments are pminrow, pmincol, sminrow, smincol, smaxrow, smaxcol; the p arguments refer to the upper left
corner of the pad region to be displayed and the s arguments define a clipping box on the screen within which the pad region is to be displayed.

curses.newwin(nlines, ncols)
curses.newwin(nlines, ncols, begin_y, begin_x)

Return a new window, whose left-upper corner is at (begin_y, begin_x), and whose height/width is nlines/ncols.

By default, the window will extend from the specified position to the lower right corner of the screen.

curses.nl()

Enter newline mode. This mode translates the return key into newline on input, and translates newline into return and line-feed on output. Newline mode is initially on.

curses.nocbreak()

Leave cbreak mode. Return to normal “cooked” mode with line buffering.

curses.noecho()

Leave echo mode. Echoing of input characters is turned off.

curses.nonl()

Leave newline mode. Disable translation of return into newline on input, and disable low-level translation of newline into newline/return on output (but this does not change the behavior of addch('\n'), which always does the equivalent of return and line feed on the virtual screen). With translation off, curses can sometimes speed up vertical motion a little; also, it will be able to detect the return key on input.
curses.noqiflush()
When the noqiflush() routine is used, normal flush of input and output queues associated with the INTR, QUIT and SUSP characters will not be done. You may want to call noqiflush() in a signal handler if you want output to continue as though the interrupt had not occurred, after the handler exits.

curses.noraw()
Leave raw mode. Return to normal “cooked” mode with line buffering.

curses.pair_content(pair_number)
Return a tuple (fg, bg) containing the colors for the requested color pair. The value of pair_number must be between 1 and COLOR_PAIRS - 1.

curses.pair_number(attr)
Return the number of the color-pair set by the attribute value attr. color_pair() is the counterpart to this function.

curses.putp(string)
Equivalent to tputs(str, 1, putchar); emit the value of a specified terminfo capability for the current terminal. Note that the output of putp() always goes to standard output.

curses.qiflush([flag])
If flag is False, the effect is the same as calling noqiflush(). If flag is True, or no argument is provided, the queues will be flushed when these control characters are read.

curses.raw()
Enter raw mode. In raw mode, normal line buffering and processing of interrupt, quit, suspend, and flow control keys are turned off; characters are presented to curses input functions one by one.

curses.reset_prog_mode()

Restore the terminal to “program” mode, as previously saved by def_prog_mode().

curses.reset_shell_mode()

Restore the terminal to “shell” mode, as previously saved by def_shell_mode().

curses.resetty()

Restore the state of the terminal modes to what it was at the last call to savetty().

curses.resize_term(nlines, ncols)

Backend function used by resizeterm(), performing most of the work; when resizing the windows, resize_term() blank-fills the areas that are extended. The calling application should fill in these areas with appropriate data. The resize_term() function attempts to resize all windows. However, due to the calling convention of pads, it is not possible to resize these without additional interaction with the application.

curses.resizeterm(nlines, ncols)

Resize the standard and current windows to the specified dimensions, and adjusts other bookkeeping data used by the curses library that record the window dimensions (in particular the SIGWINCH handler).

curses.savetty()
Save the current state of the terminal modes in a buffer, usable by `resetty()`.

```
curses.setsyx(y, x)
```
Set the virtual screen cursor to \( y, x \). If \( y \) and \( x \) are both -1, then `leaveok` is set.

```
curses.setupterm([termstr, fd])
```
Initialize the terminal. `termstr` is a string giving the terminal name; if omitted, the value of the TERM environment variable will be used. `fd` is the file descriptor to which any initialization sequences will be sent; if not supplied, the file descriptor for `sys.stdout` will be used.

```
curses.start_color()
```
Must be called if the programmer wants to use colors, and before any other color manipulation routine is called. It is good practice to call this routine right after `initscr()`.

`start_color()` initializes eight basic colors (black, red, green, yellow, blue, magenta, cyan, and white), and two global variables in the `curses` module, `COLORS` and `COLOR_PAIRS`, containing the maximum number of colors and color-pairs the terminal can support. It also restores the colors on the terminal to the values they had when the terminal was just turned on.

```
curses.termattrs()
```
Return a logical OR of all video attributes supported by the terminal. This information is useful when a curses program needs complete control over the appearance of the screen.

```
curses.termname()
```
Return the value of the environment variable TERM, truncated to 14 characters.

**curses.tigetflag(capname)**

Return the value of the Boolean capability corresponding to the terminfo capability name `capname`. The value -1 is returned if `capname` is not a Boolean capability, or 0 if it is canceled or absent from the terminal description.

**curses.tigetnum(capname)**

Return the value of the numeric capability corresponding to the terminfo capability name `capname`. The value -2 is returned if `capname` is not a numeric capability, or -1 if it is canceled or absent from the terminal description.

**curses.tigetstr(capname)**

Return the value of the string capability corresponding to the terminfo capability name `capname`. None is returned if `capname` is not a string capability, or is canceled or absent from the terminal description.

**curses.tparm(str[, ...])**

Instantiate the string `str` with the supplied parameters, where `str` should be a parameterized string obtained from the terminfo database. E.g. `tparm(tigetstr("cup"), 5, 3)` could result in `b'\033[6;4H'`, the exact result depending on terminal type.

**curses.typeahead(fd)**

Specify that the file descriptor `fd` be used for typeahead checking. If `fd` is -1, then no typeahead checking is done.

The curses library does “line-breakout optimization” by looking for
typeahead periodically while updating the screen. If input is found, and it is coming from a tty, the current update is postponed until refresh or doupdate is called again, allowing faster response to commands typed in advance. This function allows specifying a different file descriptor for typeahead checking.

curses.unctrl(ch)
Return a string which is a printable representation of the character ch. Control characters are displayed as a caret followed by the character, for example as ^C. Printing characters are left as they are.

curses.ungetch(ch)
Push ch so the next getch() will return it.

**Note:** Only one ch can be pushed before getch() is called.

curses.update_lines_cols()
Update LINES and COLS. Useful for detecting manual screen resize.

*New in version 3.5.*

curses.unget_wch(ch)
Push ch so the next get_wch() will return it.

**Note:** Only one ch can be pushed before get_wch() is called.

*New in version 3.3.*

curses.ungetmouse(id, x, y, z, bstate)
Push a KEY_MOUSE event onto the input queue, associating the
given state data with it.

curses.use_env(flag)
If used, this function should be called before initscr() or
newterm are called. When flag is False, the values of lines and
columns specified in the terminfo database will be used, even if
environment variables LINES and COLUMNS (used by default) are
set, or if curses is running in a window (in which case default
behavior would be to use the window size if LINES and COLUMNS
are not set).

curses.use_default_colors()
Allow use of default values for colors on terminals supporting this
feature. Use this to support transparency in your application. The
default color is assigned to the color number -1. After calling this
function, init_pair(x, curses.COLOR_RED, -1) initializes,
for instance, color pair x to a red foreground color on the default
background.

curses.wrapper(func, ...)
Initialize curses and call another callable object, func, which should
be the rest of your curses-using application. If the application
raises an exception, this function will restore the terminal to a sane
state before re-raising the exception and generating a traceback.
The callable object func is then passed the main window ‘stdscr’ as
its first argument, followed by any other arguments passed to
wrapper(). Before calling func, wrapper() turns on cbreak
mode, turns off echo, enables the terminal keypad, and initializes
colors if the terminal has color support. On exit (whether normally
or by exception) it restores cooked mode, turns on echo, and
disables the terminal keypad.
16.10.2. Window Objects

Window objects, as returned by `initscr()` and `newwin()` above, have the following methods and attributes:

```python
class Window:
    def addch(self, ch[, attr])
        Paint character `ch` at `(y, x)` with attributes `attr`, overwriting any character previously painter at that location. By default, the character position and attributes are the current settings for the window object.

    def addnstr(self, str[, attr])
        Paint at most `n` characters of the string `str` at `(y, x)` with attributes `attr`, overwriting anything previously on the display.

    def addstr(self, str[, attr])
        Paint the string `str` at `(y, x)` with attributes `attr`, overwriting anything previously on the display.

    def attroff(self, attr)
        Remove attribute `attr` from the “background” set applied to all writes to the current window.
```

Note: A character means a C character (an ASCII code), rather than a Python character (a string of length 1). (This note is true whenever the documentation mentions a character.) The built-in `ord()` is handy for conveying strings to codes.
**window.**`attron(attr)`

Add attribute `attr` from the “background” set applied to all writes to the current window.

**window.**`attrset(attr)`

Set the “background” set of attributes to `attr`. This set is initially 0 (no attributes).

**window.**`bkgd(ch[, attr])`  

Set the background property of the window to the character `ch`, with attributes `attr`. The change is then applied to every character position in that window:

- The attribute of every character in the window is changed to the new background attribute.
- Wherever the former background character appears, it is changed to the new background character.

**window.**`bkgdset(ch[, attr])`  

Set the window's background. A window's background consists of a character and any combination of attributes. The attribute part of the background is combined (OR’ed) with all non-blank characters that are written into the window. Both the character and attribute parts of the background are combined with the blank characters. The background becomes a property of the character and moves with the character through any scrolling and insert/delete line/character operations.

**window.**`border([ls[, rs[, ts[, bs[, tl[, tr[, bl[, br]]]]]]]])`  

Draw a border around the edges of the window. Each parameter specifies the character to use for a specific part of the border; see the table below for more details. The characters can be specified
as integers or as one-character strings.

**Note:** A 0 value for any parameter will cause the default character to be used for that parameter. Keyword parameters can *not* be used. The defaults are listed in this table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ls</td>
<td>Left side</td>
<td>ACS_VLINE</td>
</tr>
<tr>
<td>rs</td>
<td>Right side</td>
<td>ACS_VLINE</td>
</tr>
<tr>
<td>ts</td>
<td>Top</td>
<td>ACS_HLINE</td>
</tr>
<tr>
<td>bs</td>
<td>Bottom</td>
<td>ACS_HLINE</td>
</tr>
<tr>
<td>tl</td>
<td>Upper-left corner</td>
<td>ACS_ULCORNER</td>
</tr>
<tr>
<td>tr</td>
<td>Upper-right corner</td>
<td>ACS_URCORNER</td>
</tr>
<tr>
<td>bl</td>
<td>Bottom-left corner</td>
<td>ACS_LLCORNER</td>
</tr>
<tr>
<td>br</td>
<td>Bottom-right corner</td>
<td>ACS_LRCORNER</td>
</tr>
</tbody>
</table>

`window.box([vertch, horch])`

Similar to `border()`, but both `ls` and `rs` are `vertch` and both `ts` and `bs` are `horch`. The default corner characters are always used by this function.

`window.chgat(attr)`
`window.chgat(num, attr)`
`window.chgat(y, x, attr)`
`window.chgat(y, x, num, attr)`

Set the attributes of `num` characters at the current cursor position, or at position `(y, x)` if supplied. If no value of `num` is given or `num = -1`, the attribute will be set on all the characters to the end of the line. This function does not move the cursor. The changed line
will be touched using the `touchline()` method so that the contents will be redisplayed by the next window refresh.

`window.clear()`  
Like `erase()`, but also cause the whole window to be repainted upon next call to `refresh()`.

`window.clearok(yes)`  
If `yes` is 1, the next call to `refresh()` will clear the window completely.

`window.clrtobot()`  
Erase from cursor to the end of the window: all lines below the cursor are deleted, and then the equivalent of `clrtoeol()` is performed.

`window.clrtoeol()`  
Erase from cursor to the end of the line.

`window.cursyncup()`  
Update the current cursor position of all the ancestors of the window to reflect the current cursor position of the window.

`window.delch([y, x])`  
Delete any character at `(y, x)`.

`window.deleteln()`  
Delete the line under the cursor. All following lines are moved up by one line.

`window.derwin(begin_y, begin_x)`
`window.derwin(nlines, ncols, begin_y, begin_x)`
An abbreviation for “derive window”, `derwin()` is the same as calling `subwin()`, except that `begin_y` and `begin_x` are relative to the origin of the window, rather than relative to the entire screen. Return a window object for the derived window.

```python
window.echochar(ch[, attr])
```
Add character `ch` with attribute `attr`, and immediately call `refresh()` on the window.

```python
window.enclose(y, x)
```
Test whether the given pair of screen-relative character-cell coordinates are enclosed by the given window, returning True or False. It is useful for determining what subset of the screen windows enclose the location of a mouse event.

```python
window.encoding
```
Encoding used to encode method arguments (Unicode strings and characters). The encoding attribute is inherited from the parent window when a subwindow is created, for example with `window.subwin()`. By default, the locale encoding is used (see `locale.getpreferredencoding()`).

*New in version 3.3.*

```python
window.erase()
```
Clear the window.

```python
window.getbegyx()
```
Return a tuple `(y, x)` of co-ordinates of upper-left corner.

```python
window.getbkgd()
```
Return the given window’s current background character/attribute
window.getch([y, x])
Get a character. Note that the integer returned does not have to be in ASCII range: function keys, keypad keys and so on return numbers higher than 256. In no-delay mode, -1 is returned if there is no input, else getch() waits until a key is pressed.

window.get_wch([y, x])
Get a wide character. Return a character for most keys, or an integer for function keys, keypad keys, and other special keys.

New in version 3.3.

window.getkey([y, x])
Get a character, returning a string instead of an integer, as getch() does. Function keys, keypad keys and other special keys return a multibyte string containing the key name. In no-delay mode, an exception is raised if there is no input.

window.getmaxyx()
Return a tuple (y, x) of the height and width of the window.

window.getparyx()
Return the beginning coordinates of this window relative to its parent window into two integer variables y and x. Return -1, -1 if this window has no parent.

window.getstr([y, x])
Read a string from the user, with primitive line editing capacity.

window.getyx()
Return a tuple \((y, x)\) of current cursor position relative to the window's upper-left corner.

```python
window.hline(ch, n)
window.hline(y, x, ch, n)
```
Display a horizontal line starting at \((y, x)\) with length \(n\) consisting of the character \(ch\).

```python
window.idcok(flag)
```
If \(flag\) is False, curses no longer considers using the hardware insert/delete character feature of the terminal; if \(flag\) is True, use of character insertion and deletion is enabled. When curses is first initialized, use of character insert/delete is enabled by default.

```python
window.idlok(yes)
```
If called with \(yes\) equal to 1, curses will try and use hardware line editing facilities. Otherwise, line insertion/deletion are disabled.

```python
window.immedok(flag)
```
If \(flag\) is True, any change in the window image automatically causes the window to be refreshed; you no longer have to call `refresh()` yourself. However, it may degrade performance considerably, due to repeated calls to `wrefresh`. This option is disabled by default.

```python
window.inch([y, x])
```
Return the character at the given position in the window. The bottom 8 bits are the character proper, and upper bits are the attributes.

```python
window.insch(ch[, attr])
window.insch(y, x, ch[, attr])
```
Paint character \( ch \) at \((y, x)\) with attributes \( attr \), moving the line from position \( x \) right by one character.

\texttt{window.insdelln(nlines)}

Insert \( nlines \) lines into the specified window above the current line. The \( nlines \) bottom lines are lost. For negative \( nlines \), delete \( nlines \) lines starting with the one under the cursor, and move the remaining lines up. The bottom \( nlines \) lines are cleared. The current cursor position remains the same.

\texttt{window.insertln()}

Insert a blank line under the cursor. All following lines are moved down by one line.

\texttt{window.insnstr(str[, attr])}
\texttt{window.insnstr(y, x, str[, attr])}

Insert a character string (as many characters as will fit on the line) before the character under the cursor, up to \( n \) characters. If \( n \) is zero or negative, the entire string is inserted. All characters to the right of the cursor are shifted right, with the rightmost characters on the line being lost. The cursor position does not change (after moving to \( y, x \), if specified).

\texttt{window.insstr(str[, attr])}
\texttt{window.insstr(y, x, str[, attr])}

Insert a character string (as many characters as will fit on the line) before the character under the cursor. All characters to the right of the cursor are shifted right, with the rightmost characters on the line being lost. The cursor position does not change (after moving to \( y, x \), if specified).
window.instr([n])

window.instr(y, x[, n])

Return a string of characters, extracted from the window starting at the current cursor position, or at y, x if specified. Attributes are stripped from the characters. If n is specified, instr() returns a string at most n characters long (exclusive of the trailing NUL).

window.is_linetouched(line)

Return True if the specified line was modified since the last call to refresh(); otherwise return False. Raise a curses.error exception if line is not valid for the given window.

window.is_wintouched()

Return True if the specified window was modified since the last call to refresh(); otherwise return False.

window.keypad(yes)

If yes is 1, escape sequences generated by some keys (keypad, function keys) will be interpreted by curses. If yes is 0, escape sequences will be left as is in the input stream.

window.leaveok(yes)

If yes is 1, cursor is left where it is on update, instead of being at “cursor position.” This reduces cursor movement where possible. If possible the cursor will be made invisible.

If yes is 0, cursor will always be at “cursor position” after an update.

window.move(new_y, new_x)

Move cursor to (new_y, new_x).

window.mvderwin(y, x)
Move the window inside its parent window. The screen-relative parameters of the window are not changed. This routine is used to display different parts of the parent window at the same physical position on the screen.

```c
window.mvwin(new_y, new_x)
```
Move the window so its upper-left corner is at (new_y, new_x).

```c
window.nodelay(yes)
```
If yes is 1, `getch()` will be non-blocking.

```c
window.notimeout(yes)
```
If yes is 1, escape sequences will not be timed out.

If yes is 0, after a few milliseconds, an escape sequence will not be interpreted, and will be left in the input stream as is.

```c
window.noutrefresh()
```
Mark for refresh but wait. This function updates the data structure representing the desired state of the window, but does not force an update of the physical screen. To accomplish that, call `doupdate()`.

```c
window.overlay(destwin[, sminrow, smincol, dminrow, dmincol, dmaxrow, dmaxcol])
```
Overlay the window on top of destwin. The windows need not be the same size, only the overlapping region is copied. This copy is non-destructive, which means that the current background character does not overwrite the old contents of destwin.

To get fine-grained control over the copied region, the second form of `overlay()` can be used. `sminrow` and `smincol` are the upper-
left coordinates of the source window, and the other variables mark a rectangle in the destination window.

```plaintext
window.overwrite(destwin[, sminrow, smincol, dminrow, dmincol, dmaxrow, dmaxcol])
```

Overwrite the window on top of `destwin`. The windows need not be the same size, in which case only the overlapping region is copied. This copy is destructive, which means that the current background character overwrites the old contents of `destwin`.

To get fine-grained control over the copied region, the second form of `overwrite()` can be used. `sminrow` and `smincol` are the upper-left coordinates of the source window, the other variables mark a rectangle in the destination window.

```plaintext
window.putwin(file)
```

Write all data associated with the window into the provided file object. This information can be later retrieved using the `getwin()` function.

```plaintext
window.redrawln(beg, num)
```

Indicate that the `num` screen lines, starting at line `beg`, are corrupted and should be completely redrawn on the next `refresh()` call.

```plaintext
window.redrawwin()
```

Touch the entire window, causing it to be completely redrawn on the next `refresh()` call.

```plaintext
window.refresh([pminrow, pmincol, sminrow, smincol, smaxrow, smaxcol])
```

Update the display immediately (sync actual screen with previous
The 6 optional arguments can only be specified when the window is a pad created with `newpad()`. The additional parameters are needed to indicate what part of the pad and screen are involved. `pminrow` and `pmincol` specify the upper left-hand corner of the rectangle to be displayed in the pad. `sminrow`, `smincol`, `smaxrow`, and `smaxcol` specify the edges of the rectangle to be displayed on the screen. The lower right-hand corner of the rectangle to be displayed in the pad is calculated from the screen coordinates, since the rectangles must be the same size. Both rectangles must be entirely contained within their respective structures. Negative values of `pminrow`, `pmincol`, `sminrow`, or `smaxcol` are treated as if they were zero.

**window.resize(nlines, ncols)**

Reallocate storage for a curses window to adjust its dimensions to the specified values. If either dimension is larger than the current values, the window's data is filled with blanks that have the current background rendition (as set by `bkgdset()`) merged into them.

**window.scroll([lines=1])**

Scroll the screen or scrolling region upward by `lines` lines.

**window.scrolllok(flag)**

Control what happens when the cursor of a window is moved off the edge of the window or scrolling region, either as a result of a newline action on the bottom line, or typing the last character of the last line. If `flag` is false, the cursor is left on the bottom line. If `flag` is true, the window is scrolled up one line. Note that in order to get the physical scrolling effect on the terminal, it is also necessary to call `idlok()`.
window.setscrreg(top, bottom)
    Set the scrolling region from line top to line bottom. All scrolling actions will take place in this region.

window.standend()
    Turn off the standout attribute. On some terminals this has the side effect of turning off all attributes.

window.standout()
    Turn on attribute A_STANDOUT.

window.subpad(begin_y, begin_x)
window.subpad(nlines, ncols, begin_y, begin_x)
    Return a sub-window, whose upper-left corner is at (begin_y, begin_x), and whose width/height is ncols/nlines.

window.subwin(begin_y, begin_x)
window.subwin(nlines, ncols, begin_y, begin_x)
    Return a sub-window, whose upper-left corner is at (begin_y, begin_x), and whose width/height is ncols/nlines.

    By default, the sub-window will extend from the specified position to the lower right corner of the window.

window.syncdown()
    Touch each location in the window that has been touched in any of its ancestor windows. This routine is called by refresh(), so it should almost never be necessary to call it manually.

window.syncok(flag)
    If called with flag set to True, then syncup() is called automatically whenever there is a change in the window.
window.syncup()  
Touch all locations in ancestors of the window that have been changed in the window.

window.timeout(delay)  
Set blocking or non-blocking read behavior for the window. If delay is negative, blocking read is used (which will wait indefinitely for input). If delay is zero, then non-blocking read is used, and -1 will be returned by getch() if no input is waiting. If delay is positive, then getch() will block for delay milliseconds, and return -1 if there is still no input at the end of that time.

window.touchline(start, count[, changed])  
Pretend count lines have been changed, starting with line start. If changed is supplied, it specifies whether the affected lines are marked as having been changed (changed=1) or unchanged (changed=0).

window.touchwin()  
Pretend the whole window has been changed, for purposes of drawing optimizations.

window.untouchwin()  
Mark all lines in the window as unchanged since the last call to refresh().

window.vline(ch, n)  
window.vline(y, x, ch, n)  
Display a vertical line starting at (y, x) with length n consisting of the character ch.
16.10.3. Constants

The `curses` module defines the following data members:

`curses.ERR`

Some curses routines that return an integer, such as `getch()`, return `ERR` upon failure.

`curses.OK`

Some curses routines that return an integer, such as `napms()`, return `OK` upon success.

`curses.version`

A string representing the current version of the module. Also available as `__version__`.

Several constants are available to specify character cell attributes:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_ALTCCHARSET</td>
<td>Alternate character set mode.</td>
</tr>
<tr>
<td>A_BLINK</td>
<td>Blink mode.</td>
</tr>
<tr>
<td>A_BOLD</td>
<td>Bold mode.</td>
</tr>
<tr>
<td>A_DIM</td>
<td>Dim mode.</td>
</tr>
<tr>
<td>A_NORMAL</td>
<td>Normal attribute.</td>
</tr>
<tr>
<td>A_REVERSE</td>
<td>Reverse background and foreground colors.</td>
</tr>
<tr>
<td>A_STANDOUT</td>
<td>Standout mode.</td>
</tr>
<tr>
<td>A_UNDERLINE</td>
<td>Underline mode.</td>
</tr>
</tbody>
</table>
Keys are referred to by integer constants with names starting with `KEY_`. The exact keycaps available are system dependent.

<table>
<thead>
<tr>
<th>Key constant</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>KEY_MIN</td>
<td>Minimum key value</td>
</tr>
<tr>
<td>KEY_BREAK</td>
<td>Break key (unreliable)</td>
</tr>
<tr>
<td>KEY_DOWN</td>
<td>Down-arrow</td>
</tr>
<tr>
<td>KEY_UP</td>
<td>Up-arrow</td>
</tr>
<tr>
<td>KEY_LEFT</td>
<td>Left-arrow</td>
</tr>
<tr>
<td>KEY_RIGHT</td>
<td>Right-arrow</td>
</tr>
<tr>
<td>KEY_HOME</td>
<td>Home key (upward+left arrow)</td>
</tr>
<tr>
<td>KEY_BACKSPACE</td>
<td>Backspace (unreliable)</td>
</tr>
<tr>
<td>KEY_F0</td>
<td>Function keys. Up to 64 function keys are supported.</td>
</tr>
<tr>
<td>KEY_Fn</td>
<td>Value of function key $n$</td>
</tr>
<tr>
<td>KEY_DL</td>
<td>Delete line</td>
</tr>
<tr>
<td>KEY_IL</td>
<td>Insert line</td>
</tr>
<tr>
<td>KEY_DC</td>
<td>Delete character</td>
</tr>
<tr>
<td>KEY_IC</td>
<td>Insert char or enter insert mode</td>
</tr>
<tr>
<td>KEY_EIC</td>
<td>Exit insert char mode</td>
</tr>
<tr>
<td>KEY_CLEAR</td>
<td>Clear screen</td>
</tr>
<tr>
<td>KEY_EOS</td>
<td>Clear to end of screen</td>
</tr>
<tr>
<td>KEY_EOL</td>
<td>Clear to end of line</td>
</tr>
<tr>
<td>KEY_SF</td>
<td>Scroll 1 line forward</td>
</tr>
<tr>
<td>KEY_SR</td>
<td>Scroll 1 line backward (reverse)</td>
</tr>
<tr>
<td>KEY_NPAGE</td>
<td>Next page</td>
</tr>
<tr>
<td>Function</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>KEY_PPAGE</td>
<td>Previous page</td>
</tr>
<tr>
<td>KEY_STAB</td>
<td>Set tab</td>
</tr>
<tr>
<td>KEY_CTAB</td>
<td>Clear tab</td>
</tr>
<tr>
<td>KEY_CATAB</td>
<td>Clear all tabs</td>
</tr>
<tr>
<td>KEY_ENTER</td>
<td>Enter or send (unreliable)</td>
</tr>
<tr>
<td>KEY_SRESET</td>
<td>Soft (partial) reset (unreliable)</td>
</tr>
<tr>
<td>KEY_RESET</td>
<td>Reset or hard reset (unreliable)</td>
</tr>
<tr>
<td>KEY_PRINT</td>
<td>Print</td>
</tr>
<tr>
<td>KEY_LL</td>
<td>Home down or bottom (lower left)</td>
</tr>
<tr>
<td>KEY_A1</td>
<td>Upper left of keypad</td>
</tr>
<tr>
<td>KEY_A3</td>
<td>Upper right of keypad</td>
</tr>
<tr>
<td>KEY_B2</td>
<td>Center of keypad</td>
</tr>
<tr>
<td>KEY_C1</td>
<td>Lower left of keypad</td>
</tr>
<tr>
<td>KEY_C3</td>
<td>Lower right of keypad</td>
</tr>
<tr>
<td>KEY_BTAB</td>
<td>Back tab</td>
</tr>
<tr>
<td>KEY_BEG</td>
<td>Beg (beginning)</td>
</tr>
<tr>
<td>KEY_CANCEL</td>
<td>Cancel</td>
</tr>
<tr>
<td>KEY_CLOSE</td>
<td>Close</td>
</tr>
<tr>
<td>KEY_COMMAND</td>
<td>Cmd (command)</td>
</tr>
<tr>
<td>KEY_COPY</td>
<td>Copy</td>
</tr>
<tr>
<td>KEY_CREATE</td>
<td>Create</td>
</tr>
<tr>
<td>KEY_END</td>
<td>End</td>
</tr>
<tr>
<td>KEY_EXIT</td>
<td>Exit</td>
</tr>
<tr>
<td>KEY_FIND</td>
<td>Find</td>
</tr>
<tr>
<td>KEY_HELP</td>
<td>Help</td>
</tr>
<tr>
<td>KEY</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>KEY_MARK</td>
<td>Mark</td>
</tr>
<tr>
<td>KEY_MESSAGE</td>
<td>Message</td>
</tr>
<tr>
<td>KEY_MOVE</td>
<td>Move</td>
</tr>
<tr>
<td>KEY_NEXT</td>
<td>Next</td>
</tr>
<tr>
<td>KEY_OPEN</td>
<td>Open</td>
</tr>
<tr>
<td>KEY_OPTIONS</td>
<td>Options</td>
</tr>
<tr>
<td>KEY_PREVIOUS</td>
<td>Prev (previous)</td>
</tr>
<tr>
<td>KEY_REDO</td>
<td>Redo</td>
</tr>
<tr>
<td>KEY_REFERENCE</td>
<td>Ref (reference)</td>
</tr>
<tr>
<td>KEY_REFRESH</td>
<td>Refresh</td>
</tr>
<tr>
<td>KEY_REPLACE</td>
<td>Replace</td>
</tr>
<tr>
<td>KEY_RESTART</td>
<td>Restart</td>
</tr>
<tr>
<td>KEY_RESUME</td>
<td>Resume</td>
</tr>
<tr>
<td>KEY_SAVE</td>
<td>Save</td>
</tr>
<tr>
<td>KEY_SBEG</td>
<td>Shifted Beg (beginning)</td>
</tr>
<tr>
<td>KEY_SCANCEL</td>
<td>Shifted Cancel</td>
</tr>
<tr>
<td>KEY_SCOMMAND</td>
<td>Shifted Command</td>
</tr>
<tr>
<td>KEY_SCOPY</td>
<td>Shifted Copy</td>
</tr>
<tr>
<td>KEY_SCREATE</td>
<td>Shifted Create</td>
</tr>
<tr>
<td>KEY_SDC</td>
<td>Shifted Delete char</td>
</tr>
<tr>
<td>KEY(SDL)</td>
<td>Shifted Delete line</td>
</tr>
<tr>
<td>KEY_SELECT</td>
<td>Select</td>
</tr>
<tr>
<td>KEY_SEND</td>
<td>Shifted End</td>
</tr>
<tr>
<td>KEY_SEOL</td>
<td>Shifted Clear line</td>
</tr>
<tr>
<td>KEY_SEXIT</td>
<td>Shifted Dxit</td>
</tr>
<tr>
<td>Key</td>
<td>Function</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>KEY_SFIN</td>
<td>Shifted Find</td>
</tr>
<tr>
<td>KEY_SHELP</td>
<td>Shifted Help</td>
</tr>
<tr>
<td>KEY_SHOME</td>
<td>Shifted Home</td>
</tr>
<tr>
<td>KEY_SIC</td>
<td>Shifted Input</td>
</tr>
<tr>
<td>KEY_SLEFT</td>
<td>Shifted Left arrow</td>
</tr>
<tr>
<td>KEY_SMES</td>
<td>Shifted Message</td>
</tr>
<tr>
<td>KEY_SMOVE</td>
<td>Shifted Move</td>
</tr>
<tr>
<td>KEY_SNEXT</td>
<td>Shifted Next</td>
</tr>
<tr>
<td>KEY_SOPT</td>
<td>Shifted Options</td>
</tr>
<tr>
<td>KEY_SPREV</td>
<td>Shifted Prev</td>
</tr>
<tr>
<td>KEY_SPRINT</td>
<td>Shifted Print</td>
</tr>
<tr>
<td>KEY_SREDO</td>
<td>Shifted Redo</td>
</tr>
<tr>
<td>KEY_SREPL</td>
<td>Shifted Replace</td>
</tr>
<tr>
<td>KEY_SRIG</td>
<td>Shifted Right arrow</td>
</tr>
<tr>
<td>KEY_SRSUM</td>
<td>Shifted Resume</td>
</tr>
<tr>
<td>KEY_SSAVE</td>
<td>Shifted Save</td>
</tr>
<tr>
<td>KEY_SSUSP</td>
<td>Shifted Suspend</td>
</tr>
<tr>
<td>KEY_SUND</td>
<td>Shifted Undo</td>
</tr>
<tr>
<td>KEY_SUSP</td>
<td>Suspend</td>
</tr>
<tr>
<td>KEY_UNDO</td>
<td>Undo</td>
</tr>
<tr>
<td>KEY_MOUSE</td>
<td>Mouse event has occurred</td>
</tr>
<tr>
<td>KEY_RESIZE</td>
<td>Terminal resize event</td>
</tr>
<tr>
<td>KEY_MAX</td>
<td>Maximum key value</td>
</tr>
</tbody>
</table>

On VT100s and their software emulations, such as X terminal emulators, there are normally at least four function keys (KEY_F1,
KEY_F2, KEY_F3, KEY_F4) available, and the arrow keys mapped to KEY_UP, KEY_DOWN, KEY_LEFT and KEY_RIGHT in the obvious way. If your machine has a PC keyboard, it is safe to expect arrow keys and twelve function keys (older PC keyboards may have only ten function keys); also, the following keypad mappings are standard:

<table>
<thead>
<tr>
<th>Keycap</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insert</td>
<td>KEY_IC</td>
</tr>
<tr>
<td>Delete</td>
<td>KEY_DC</td>
</tr>
<tr>
<td>Home</td>
<td>KEY_HOME</td>
</tr>
<tr>
<td>End</td>
<td>KEY_END</td>
</tr>
<tr>
<td>Page Up</td>
<td>KEY_NPAGE</td>
</tr>
<tr>
<td>Page Down</td>
<td>KEY_PPAGE</td>
</tr>
</tbody>
</table>

The following table lists characters from the alternate character set. These are inherited from the VT100 terminal, and will generally be available on software emulations such as X terminals. When there is no graphic available, curses falls back on a crude printable ASCII approximation.

**Note:** These are available only after `initscr()` has been called.

<table>
<thead>
<tr>
<th>ACS code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS_BBSS</td>
<td>alternate name for upper right corner</td>
</tr>
<tr>
<td>ACS_BLOCK</td>
<td>solid square block</td>
</tr>
<tr>
<td>ACS_BOARD</td>
<td>board of squares</td>
</tr>
<tr>
<td>ACS_BSBS</td>
<td>alternate name for horizontal line</td>
</tr>
<tr>
<td>ACS_BSSB</td>
<td>alternate name for upper left corner</td>
</tr>
<tr>
<td>ACS_BSSS</td>
<td>alternate name for top tee</td>
</tr>
<tr>
<td>ACS_BTEE</td>
<td>bottom tee</td>
</tr>
<tr>
<td>-------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>ACS_BULLET</td>
<td>bullet</td>
</tr>
<tr>
<td>ACS_CKBOARD</td>
<td>checker board (stipple)</td>
</tr>
<tr>
<td>ACS_DARROW</td>
<td>arrow pointing down</td>
</tr>
<tr>
<td>ACS_DEGREE</td>
<td>degree symbol</td>
</tr>
<tr>
<td>ACS_DIAMOND</td>
<td>diamond</td>
</tr>
<tr>
<td>ACS_GEQUAL</td>
<td>greater-than-or-equal-to</td>
</tr>
<tr>
<td>ACS_HLINE</td>
<td>horizontal line</td>
</tr>
<tr>
<td>ACS_LANTERN</td>
<td>lantern symbol</td>
</tr>
<tr>
<td>ACS_LARROW</td>
<td>left arrow</td>
</tr>
<tr>
<td>ACS_LEQUAL</td>
<td>less-than-or-equal-to</td>
</tr>
<tr>
<td>ACS_LLCORNER</td>
<td>lower left-hand corner</td>
</tr>
<tr>
<td>ACS_LRCORNER</td>
<td>lower right-hand corner</td>
</tr>
<tr>
<td>ACS_LTEE</td>
<td>left tee</td>
</tr>
<tr>
<td>ACS_NEQUAL</td>
<td>not-equal sign</td>
</tr>
<tr>
<td>ACS_PI</td>
<td>letter pi</td>
</tr>
<tr>
<td>ACS_PLMINUS</td>
<td>plus-or-minus sign</td>
</tr>
<tr>
<td>ACS_PLUS</td>
<td>big plus sign</td>
</tr>
<tr>
<td>ACS_RARROW</td>
<td>right arrow</td>
</tr>
<tr>
<td>ACS_RTEE</td>
<td>right tee</td>
</tr>
<tr>
<td>ACS_S1</td>
<td>scan line 1</td>
</tr>
<tr>
<td>ACS_S3</td>
<td>scan line 3</td>
</tr>
<tr>
<td>ACS_S7</td>
<td>scan line 7</td>
</tr>
<tr>
<td>ACS_S9</td>
<td>scan line 9</td>
</tr>
<tr>
<td>ACS_SBBS</td>
<td>alternate name for lower right corner</td>
</tr>
</tbody>
</table>
The following table lists the predefined colors:

<table>
<thead>
<tr>
<th>Constant</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLOR_BLACK</td>
<td>Black</td>
</tr>
<tr>
<td>COLOR_BLUE</td>
<td>Blue</td>
</tr>
<tr>
<td>COLOR_CYAN</td>
<td>Cyan (light greenish blue)</td>
</tr>
<tr>
<td>COLOR_GREEN</td>
<td>Green</td>
</tr>
<tr>
<td>COLOR_MAGENTA</td>
<td>Magenta (purplish red)</td>
</tr>
<tr>
<td>COLOR_RED</td>
<td>Red</td>
</tr>
<tr>
<td>COLOR_WHITE</td>
<td>White</td>
</tr>
<tr>
<td>COLOR_YELLOW</td>
<td>Yellow</td>
</tr>
</tbody>
</table>
16.11. `curses.textpad` — Text input widget for curses programs

The `curses.textpad` module provides a `Textbox` class that handles elementary text editing in a curses window, supporting a set of keybindings resembling those of Emacs (thus, also of Netscape Navigator, BBedit 6.x, FrameMaker, and many other programs). The module also provides a rectangle-drawing function useful for framing text boxes or for other purposes.

The module `curses.textpad` defines the following function:

```
curses.textpad.rectangle(win, uly, ulx, lry, lrx)
```

Draw a rectangle. The first argument must be a window object; the remaining arguments are coordinates relative to that window. The second and third arguments are the y and x coordinates of the upper left hand corner of the rectangle to be drawn; the fourth and fifth arguments are the y and x coordinates of the lower right hand corner. The rectangle will be drawn using VT100/IBM PC forms characters on terminals that make this possible (including xterm and most other software terminal emulators). Otherwise it will be drawn with ASCII dashes, vertical bars, and plus signs.
16.11.1. Textbox objects

You can instantiate a `Textbox` object as follows:

```
class curses.textpad.Textbox(win)
```

Return a textbox widget object. The `win` argument should be a `curses.WindowObject` in which the textbox is to be contained. The edit cursor of the textbox is initially located at the upper left hand corner of the containing window, with coordinates (0, 0). The instance's `stripspaces` flag is initially on.

`Textbox` objects have the following methods:

```
edit([validator])
```

This is the entry point you will normally use. It accepts editing keystrokes until one of the termination keystrokes is entered. If `validator` is supplied, it must be a function. It will be called for each keystroke entered with the keystroke as a parameter; command dispatch is done on the result. This method returns the window contents as a string; whether blanks in the window are included is affected by the `stripspaces` attribute.

```
do_command(ch)
```

Process a single command keystroke. Here are the supported special keystrokes:

<table>
<thead>
<tr>
<th>Keystroke</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-A</td>
<td>Go to left edge of window.</td>
</tr>
<tr>
<td>Control-B</td>
<td>Cursor left, wrapping to previous line if appropriate.</td>
</tr>
<tr>
<td>Control-D</td>
<td>Delete character under cursor.</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Control-E</td>
<td>Go to right edge (stripspaces off) or end of line (stripspaces on).</td>
</tr>
<tr>
<td>Control-F</td>
<td>Cursor right, wrapping to next line when appropriate.</td>
</tr>
<tr>
<td>Control-G</td>
<td>Terminate, returning the window contents.</td>
</tr>
<tr>
<td>Control-H</td>
<td>Delete character backward.</td>
</tr>
<tr>
<td>Control-J</td>
<td>Terminate if the window is 1 line, otherwise insert newline.</td>
</tr>
<tr>
<td>Control-K</td>
<td>If line is blank, delete it, otherwise clear to end of line.</td>
</tr>
<tr>
<td>Control-L</td>
<td>Refresh screen.</td>
</tr>
<tr>
<td>Control-N</td>
<td>Cursor down; move down one line.</td>
</tr>
<tr>
<td>Control-O</td>
<td>Insert a blank line at cursor location.</td>
</tr>
<tr>
<td>Control-P</td>
<td>Cursor up; move up one line.</td>
</tr>
</tbody>
</table>

Move operations do nothing if the cursor is at an edge where the movement is not possible. The following synonyms are supported where possible:

<table>
<thead>
<tr>
<th>Constant</th>
<th>Keystroke</th>
</tr>
</thead>
<tbody>
<tr>
<td>KEY_LEFT</td>
<td>Control-B</td>
</tr>
<tr>
<td>KEY_RIGHT</td>
<td>Control-F</td>
</tr>
<tr>
<td>KEY_UP</td>
<td>Control-P</td>
</tr>
<tr>
<td>KEY_DOWN</td>
<td>Control-N</td>
</tr>
<tr>
<td>KEY_BACKSPACE</td>
<td>Control-h</td>
</tr>
</tbody>
</table>

All other keystrokes are treated as a command to insert the given character and move right (with line wrapping).
gather()

Return the window contents as a string; whether blanks in the window are included is affected by the `stripspaces` member.

stripspaces

This attribute is a flag which controls the interpretation of blanks in the window. When it is on, trailing blanks on each line are ignored; any cursor motion that would land the cursor on a trailing blank goes to the end of that line instead, and trailing blanks are stripped when the window contents are gathered.
16.12. *curses.ascii* — Utilities for ASCII characters

The *curses.ascii* module supplies name constants for ASCII characters and functions to test membership in various ASCII character classes. The constants supplied are names for control characters as follows:

<table>
<thead>
<tr>
<th>Name</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUL</td>
<td></td>
</tr>
<tr>
<td>SOH</td>
<td>Start of heading, console interrupt</td>
</tr>
<tr>
<td>STX</td>
<td>Start of text</td>
</tr>
<tr>
<td>ETX</td>
<td>End of text</td>
</tr>
<tr>
<td>EOT</td>
<td>End of transmission</td>
</tr>
<tr>
<td>ENQ</td>
<td>Enquiry, goes with ACK flow control</td>
</tr>
<tr>
<td>ACK</td>
<td>Acknowledgement</td>
</tr>
<tr>
<td>BEL</td>
<td>Bell</td>
</tr>
<tr>
<td>BS</td>
<td>Backspace</td>
</tr>
<tr>
<td>TAB</td>
<td>Tab</td>
</tr>
<tr>
<td>HT</td>
<td>Alias for TAB: “Horizontal tab”</td>
</tr>
<tr>
<td>LF</td>
<td>Line feed</td>
</tr>
<tr>
<td>NL</td>
<td>Alias for LF: “New line”</td>
</tr>
<tr>
<td>VT</td>
<td>Vertical tab</td>
</tr>
<tr>
<td>FF</td>
<td>Form feed</td>
</tr>
<tr>
<td>CR</td>
<td>Carriage return</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------------------------------------------</td>
</tr>
<tr>
<td>SO</td>
<td>Shift-out, begin alternate character set</td>
</tr>
<tr>
<td>SI</td>
<td>Shift-in, resume default character set</td>
</tr>
<tr>
<td>DLE</td>
<td>Data-link escape</td>
</tr>
<tr>
<td>DC1</td>
<td>XON, for flow control</td>
</tr>
<tr>
<td>DC2</td>
<td>Device control 2, block-mode flow control</td>
</tr>
<tr>
<td>DC3</td>
<td>XOFF, for flow control</td>
</tr>
<tr>
<td>DC4</td>
<td>Device control 4</td>
</tr>
<tr>
<td>NAK</td>
<td>Negative acknowledgement</td>
</tr>
<tr>
<td>SYN</td>
<td>Synchronous idle</td>
</tr>
<tr>
<td>ETB</td>
<td>End transmission block</td>
</tr>
<tr>
<td>CAN</td>
<td>Cancel</td>
</tr>
<tr>
<td>EM</td>
<td>End of medium</td>
</tr>
<tr>
<td>SUB</td>
<td>Substitute</td>
</tr>
<tr>
<td>ESC</td>
<td>Escape</td>
</tr>
<tr>
<td>FS</td>
<td>File separator</td>
</tr>
<tr>
<td>GS</td>
<td>Group separator</td>
</tr>
<tr>
<td>RS</td>
<td>Record separator, block-mode terminator</td>
</tr>
<tr>
<td>US</td>
<td>Unit separator</td>
</tr>
<tr>
<td>SP</td>
<td>Space</td>
</tr>
<tr>
<td>DEL</td>
<td>Delete</td>
</tr>
</tbody>
</table>

Note that many of these have little practical significance in modern usage. The mnemonics derive from teleprinter conventions that predate digital computers.

The module supplies the following functions, patterned on those in the
standard C library:

curses.ascii.isalnum(c)
   Checks for an ASCII alphanumeric character; it is equivalent to isalpha(c) or isdigit(c).

curses.ascii.isalpha(c)
   Checks for an ASCII alphabetic character; it is equivalent to isupper(c) or islower(c).

curses.ascii.isascii(c)
   Checks for a character value that fits in the 7-bit ASCII set.

curses.ascii.isblank(c)
   Checks for an ASCII whitespace character.

curses.ascii.iscntrl(c)
   Checks for an ASCII control character (in the range 0x00 to 0x1f).

curses.ascii.isdigit(c)
   Checks for an ASCII decimal digit, '0' through '9'. This is equivalent to c in string.digits.

curses.ascii.isgraph(c)
   Checks for ASCII any printable character except space.

curses.ascii.islower(c)
   Checks for an ASCII lower-case character.

curses.ascii.isprint(c)
   Checks for any ASCII printable character including space.

curses.ascii.ispunct(c)
Checks for any printable ASCII character which is not a space or an alphanumeric character.

```
curses.ascii.isspace(c)
```
Checks for ASCII white-space characters; space, line feed, carriage return, form feed, horizontal tab, vertical tab.

```
curses.ascii.isupper(c)
```
Checks for an ASCII uppercase letter.

```
curses.ascii.isxdigit(c)
```
Checks for an ASCII hexadecimal digit. This is equivalent to `c` in `string.hexdigits`.

```
curses.ascii.isctrl(c)
```
Checks for an ASCII control character (ordinal values 0 to 31).

```
curses.ascii.ismeta(c)
```
Checks for a non-ASCII character (ordinal values 0x80 and above).

These functions accept either integers or strings; when the argument is a string, it is first converted using the built-in function `ord()`.

Note that all these functions check ordinal bit values derived from the first character of the string you pass in; they do not actually know anything about the host machine's character encoding. For functions that know about the character encoding (and handle internationalization properly) see the `string` module.

The following two functions take either a single-character string or integer byte value; they return a value of the same type.

```
curses.ascii.ascii(c)
```
Return the ASCII value corresponding to the low 7 bits of \( c \).

\texttt{curses.ascii.\texttt{ctrl}(c)}

Return the control character corresponding to the given character (the character bit value is bitwise-anded with 0x1f).

\texttt{curses.ascii.\texttt{alt}(c)}

Return the 8-bit character corresponding to the given ASCII character (the character bit value is bitwise-ored with 0x80).

The following function takes either a single-character string or integer value; it returns a string.

\texttt{curses.ascii.\texttt{unctrl}(c)}

Return a string representation of the ASCII character \( c \). If \( c \) is printable, this string is the character itself. If the character is a control character (0x00-0x1f) the string consists of a caret ('\(^{\wedge}\)') followed by the corresponding uppercase letter. If the character is an ASCII delete (0x7f) the string is '\(^{\wedge}\text{?}\)'. If the character has its meta bit (0x80) set, the meta bit is stripped, the preceding rules applied, and '\(!\)' prepended to the result.

\texttt{curses.ascii.\texttt{controlnames}}

A 33-element string array that contains the ASCII mnemonics for the thirty-two ASCII control characters from 0 (NUL) to 0x1f (US), in order, plus the mnemonic SP for the space character.
Panels are windows with the added feature of depth, so they can be stacked on top of each other, and only the visible portions of each window will be displayed. Panels can be added, moved up or down in the stack, and removed.
16.13.1. Functions

The module `curses.panel` defines the following functions:

`curses.panel.bottom_panel()`

Returns the bottom panel in the panel stack.

`curses.panel.new_panel(win)`

Returns a panel object, associating it with the given window `win`. Be aware that you need to keep the returned panel object referenced explicitly. If you don’t, the panel object is garbage collected and removed from the panel stack.

`curses.panel.top_panel()`

Returns the top panel in the panel stack.

`curses.panel.update_panels()`

Updates the virtual screen after changes in the panel stack. This does not call `curses.doupdate()`, so you'll have to do this yourself.
16.13.2. Panel Objects

Panel objects, as returned by `new_panel()` above, are windows with a stacking order. There’s always a window associated with a panel which determines the content, while the panel methods are responsible for the window’s depth in the panel stack.

Panel objects have the following methods:

Panel.**above**()

    Returns the panel above the current panel.

Panel.**below**()

    Returns the panel below the current panel.

Panel.**bottom**()

    Push the panel to the bottom of the stack.

Panel.**hidden**()

    Returns true if the panel is hidden (not visible), false otherwise.

Panel.**hide**()

    Hide the panel. This does not delete the object, it just makes the window on screen invisible.

Panel.**move**(y, x)

    Move the panel to the screen coordinates (y, x).

Panel.**replace**(win)

    Change the window associated with the panel to the window win.

Panel.**set_userptr**(obj)
Set the panel's user pointer to `obj`. This is used to associate an arbitrary piece of data with the panel, and can be any Python object.

`Panel.show()`  
Display the panel (which might have been hidden).

`Panel.top()`  
Push panel to the top of the stack.

`Panel.userptr()`  
Returns the user pointer for the panel. This might be any Python object.

`Panel.window()`  
Returns the window object associated with the panel.
16.14. **platform** — Access to underlying platform’s identifying data

**Source code**: `Lib/platform.py`

**Note**: Specific platforms listed alphabetically, with Linux included in the Unix section.

platform.architecture(executable=sys.executable, bits='', linkage="")

Queries the given executable (defaults to the Python interpreter binary) for various architecture information.

Returns a tuple (bits, linkage) which contain information about the bit architecture and the linkage format used for the executable. Both values are returned as strings.

Values that cannot be determined are returned as given by the parameter presets. If bits is given as '', the sizeof(pointer) (or sizeof(long) on Python version < 1.5.2) is used as indicator for the supported pointer size.

The function relies on the system's file command to do the actual work. This is available on most if not all Unix platforms and some non-Unix platforms and then only if the executable points to the Python interpreter. Reasonable defaults are used when the above needs are not met.

**Note:** On Mac OS X (and perhaps other platforms), executable files may be universal files containing multiple architectures. To get at the “64-bitness” of the current interpreter, it is more reliable to query the `sys.maxsize` attribute:

```
is_64bits = sys.maxsize > 2**32
```

platform.machine()

Returns the machine type, e.g. 'i386'. An empty string is
returned if the value cannot be determined.

**platform.node()**

Returns the computer’s network name (may not be fully qualified!). An empty string is returned if the value cannot be determined.

**platform.platform(aliased=0, terse=0)**

Returns a single string identifying the underlying platform with as much useful information as possible.

The output is intended to be *human readable* rather than machine parseable. It may look different on different platforms and this is intended.

If `aliased` is true, the function will use aliases for various platforms that report system names which differ from their common names, for example SunOS will be reported as Solaris. The `system_alias()` function is used to implement this.

Setting `terse` to true causes the function to return only the absolute minimum information needed to identify the platform.

**platform.processor()**

Returns the (real) processor name, e.g. 'amdk6'.

An empty string is returned if the value cannot be determined. Note that many platforms do not provide this information or simply return the same value as for `machine()`. NetBSD does this.

**platform.python_build()**

Returns a tuple `(buildno, builddate)` stating the Python build number and date as strings.
platform.python_compiler()
Returns a string identifying the compiler used for compiling Python.

platform.python_branch()
Returns a string identifying the Python implementation SCM branch.

platform.python_implementation()
Returns a string identifying the Python implementation. Possible return values are: 'CPython', 'IronPython', 'Jython', 'PyPy'.

platform.python_revision()
Returns a string identifying the Python implementation SCM revision.

platform.python_version()
Returns the Python version as string 'major.minor.patchlevel'.

Note that unlike the Python sys.version, the returned value will always include the patchlevel (it defaults to 0).

platform.python_version_tuple()
Returns the Python version as tuple (major, minor, patchlevel) of strings.

Note that unlike the Python sys.version, the returned value will always include the patchlevel (it defaults to '0').

platform.release()
Returns the system's release, e.g. '2.2.0' or 'NT' An empty string is returned if the value cannot be determined.
platform.\texttt{system()}  
Returns the system/OS name, e.g. 'Linux', 'Windows', or 'Java'. An empty string is returned if the value cannot be determined.

platform.\texttt{system\_alias}(\textit{system, release, version})  
Returns (system, release, version) aliased to common marketing names used for some systems. It also does some reordering of the information in some cases where it would otherwise cause confusion.

platform.\texttt{version()}  
Returns the system's release version, e.g. '#3 on degas'. An empty string is returned if the value cannot be determined.

platform.\texttt{uname()}  
Fairly portable uname interface. Returns a \texttt{namedtuple()} containing six attributes: \texttt{system}, \texttt{node}, \texttt{release}, \texttt{version}, \texttt{machine}, and \texttt{processor}.

Note that this adds a sixth attribute (\texttt{processor}) not present in the \texttt{os.uname()} result. Also, the attribute names are different for the first two attributes; \texttt{os.uname()} names them sysname and nodename.

Entries which cannot be determined are set to ''.  

\textit{Changed in version 3.3}: Result changed from a tuple to a namedtuple.
16.14.2. Java Platform

platform.java_ver(release='', vendor='', vminfo=('','',''), osinfo=('','',''))

    Version interface for Jython.

    Returns a tuple (release, vendor, vminfo, osinfo) with vminfo being a tuple (vm_name, vm_release, vm_vendor) and osinfo being a tuple (os_name, os_version, os_arch). Values which cannot be determined are set to the defaults given as parameters (which all default to '').
16.14.3. Windows Platform

platform.win32_ver(release='', version='', csd='', ptype='')

Get additional version information from the Windows Registry and return a tuple (release, version, csd, ptype) referring to OS release, version number, CSD level (service pack) and OS type (multi/single processor).

As a hint: ptype is 'Uniprocessor Free' on single processor NT machines and 'Multiprocessor Free' on multi processor machines. The 'Free' refers to the OS version being free of debugging code. It could also state 'Checked' which means the OS version uses debugging code, i.e. code that checks arguments, ranges, etc.

**Note:** This function works best with Mark Hammond's win32all package installed, but also on Python 2.3 and later (support for this was added in Python 2.6). It obviously only runs on Win32 compatible platforms.

16.14.3.1. Win95/98 specific

platform.popen(cmd, mode='r', bufsize=-1)

Portable popen() interface. Find a working popen implementation preferring win32pipe.popen(). On Windows NT, win32pipe.popen() should work; on Windows 9x it hangs due to bugs in the MS C library.

*Deprecated since version 3.3:* This function is obsolete. Use the subprocess module. Check especially the Replacing Older
Functions with the subprocess Module section.
16.14.4. Mac OS Platform

```
platform.mac_ver(release='', versioninfo=(' ', ', '), machine='')
```

Get Mac OS version information and return it as tuple (release, versioninfo, machine) with versioninfo being a tuple (version, dev_stage, non_release_version).

Entries which cannot be determined are set to ' '. All tuple entries are strings.
16.14.5. Unix Platforms

platform.dist(distname='', version='', id='', supported_dists=('SuSE', 'debian', 'redhat', 'mandrake', ...))

This is another name for linux_distribution().

Deprecated since version 3.5, will be removed in version 3.7.

platform.linux_distribution(distname='', version='', id='', supported_dists=('SuSE', 'debian', 'redhat', 'mandrake', ...), full_distribution_name=1)

Tries to determine the name of the Linux OS distribution name.

supported_dists may be given to define the set of Linux distributions to look for. It defaults to a list of currently supported Linux distributions identified by their release file name.

If full_distribution_name is true (default), the full distribution read from the OS is returned. Otherwise the short name taken from supported_dists is used.

Returns a tuple (distname,version,id) which defaults to the args given as parameters. id is the item in parentheses after the version number. It is usually the version codename.

Deprecated since version 3.5, will be removed in version 3.7.

platform.libc_ver(executable=sys.executable, lib='', version='', chunksize=2048)

Tries to determine the libc version against which the file executable (defaults to the Python interpreter) is linked. Returns a tuple of strings (lib, version) which default to the given parameters in
case the lookup fails.

Note that this function has intimate knowledge of how different libc versions add symbols to the executable is probably only usable for executables compiled using gcc.

The file is read and scanned in chunks of chunksize bytes.
16.15. **errno — Standard errno system symbols**

This module makes available standard errno system symbols. The value of each symbol is the corresponding integer value. The names and descriptions are borrowed from `linux/include/errno.h`, which should be pretty all-inclusive.

**errno.errorcode**

Dictionary providing a mapping from the errno value to the string name in the underlying system. For instance, `errno.errorcode[errno.EPERM]` maps to 'EPERM'.

To translate a numeric error code to an error message, use `os.strerror()`.

Of the following list, symbols that are not used on the current platform are not defined by the module. The specific list of defined symbols is available as `errno.errorcode.keys()`. Symbols available can include:

**errno.EPERM**

Operation not permitted

**errno.ENOENT**

No such file or directory

**errno.ESRCH**

No such process

**errno.EINTR**
Interrupted system call.

**See also:** This error is mapped to the exception `InterruptedError`.

erro.**EIO**
I/O error

erro.**ENXIO**
No such device or address

erro.**E2BIG**
Arg list too long

erro.**ENOEXEC**
Exec format error

erro.**EBADF**
Bad file number

erro.**ECHILD**
No child processes

erro.**EAGAIN**
Try again

erro.**ENOMEM**
Out of memory

erro.**EACCES**
Permission denied

erro.**EFAULT**
Bad address

errno.**ENOTBLK**
Block device required

errno.**EBUSY**
Device or resource busy

errno.**EEXIST**
File exists

errno.**EXDEV**
Cross-device link

errno.**ENODEV**
No such device

errno.**ENOTDIR**
Not a directory

errno.**EISDIR**
Is a directory

errno.**EINVAL**
Invalid argument

errno.**ENFILE**
File table overflow

errno.**EMFILE**
Too many open files

errno.**ENOTTY**
Not a typewriter
errno.**ETXTBSY**
   Text file busy

errno.**EFBIG**
   File too large

errno.**ENOSPC**
   No space left on device

errno.**ESPIPE**
   Illegal seek

errno.**EROFS**
   Read-only file system

errno.**EMLINK**
   Too many links

errno.**EPIPE**
   Broken pipe

errno.**EDOM**
   Math argument out of domain of func

errno.**ERANGE**
   Math result not representable

errno.**EDEADLK**
   Resource deadlock would occur

errno.**ENAMETOOLONG**
   File name too long

errno.**ENOLCK**
No record locks available

errno.ENOSYS
   Function not implemented

errno.ENOTEMPTY
   Directory not empty

errno.ELoop
   Too many symbolic links encountered

errno.EWOULDBLOCK
   Operation would block

errno.ENOMSG
   No message of desired type

errno.EIDRM
   Identifier removed

errno.ECHRNG
   Channel number out of range

errno.EL2NSYNC
   Level 2 not synchronized

errno.EL3HLT
   Level 3 halted

errno.EL3RST
   Level 3 reset

errno.ELNRNG
   Link number out of range
errno. **EUNATCH**
Protocol driver not attached

errno. **ENOCSI**
No CSI structure available

errno. **EL2HLT**
Level 2 halted

errno. **EBADE**
Invalid exchange

errno. **EBADR**
Invalid request descriptor

errno. **EXFULL**
Exchange full

errno. **ENOANO**
No anode

errno. **EBADRQC**
Invalid request code

errno. **EBADSLT**
Invalid slot

errno. **EDEADLOCK**
File locking deadlock error

errno. **EBFONT**
Bad font file format

errno. **ENOSTR**
Device not a stream

errno.\texttt{ENODATA}
No data available

errno.\texttt{ETIME}
Timer expired

errno.\texttt{ENOSR}
Out of streams resources

errno.\texttt{ENONET}
Machine is not on the network

errno.\texttt{ENOPKG}
Package not installed

errno.\texttt{EREMOTE}
Object is remote

errno.\texttt{ENOLINK}
Link has been severed

errno.\texttt{EADV}
Advertise error

errno.\texttt{ESRMNT}
Srmount error

errno.\texttt{ECOMM}
Communication error on send

errno.\texttt{EPROTO}
Protocol error
errno.**EMULTIHOP**
Multihop attempted

errno.**EDOTDOT**
RFS specific error

errno.**EBADMSG**
Not a data message

errno.**EOVERFLOW**
Value too large for defined data type

errno.**ENOTUNIQ**
Name not unique on network

errno.**EBADFD**
File descriptor in bad state

errno.**EREMCHG**
Remote address changed

errno.**ELIBACC**
Can not access a needed shared library

errno.**ELIBBAD**
Accessing a corrupted shared library

errno.**ELIBSCN**
.lib section in a.out corrupted

errno.**ELIBMAX**
Attempting to link in too many shared libraries

errno.**ELIBEXEC**
Cannot exec a shared library directly

errno. **EILSEQ**
Illegal byte sequence

errno. **ERESTART**
Interrupted system call should be restarted

errno. **ESTRPIPE**
Streams pipe error

errno. **EUSERS**
Too many users

errno. **ENOTSOCK**
Socket operation on non-socket

errno. **EDESTADDRREQ**
Destination address required

errno. **EMSGSIZE**
Message too long

errno. **EPROTOTYPE**
Protocol wrong type for socket

errno. **ENOPROTOOPT**
Protocol not available

errno. **EPROTONOSUPPORT**
Protocol not supported

errno. **ESOCKTNOSUPPORT**
Socket type not supported
errno. **EOPNOTSUPP**  
Operation not supported on transport endpoint

errno. **EPFNOSUPPORT**  
Protocol family not supported

errno. **EAFNOSUPPORT**  
Address family not supported by protocol

errno. **EADDRINUSE**  
Address already in use

errno. **EADDRNOTAVAIL**  
Cannot assign requested address

errno. **ENETDOWN**  
Network is down

errno. **ENETUNREACH**  
Network is unreachable

errno. **ENETRESET**  
Network dropped connection because of reset

errno. **ECONNABORTED**  
Software caused connection abort

errno. **ECONNRESET**  
Connection reset by peer

errno. **ENOBUSFS**  
No buffer space available

errno. **EISCONN**
Transport endpoint is already connected

errno.\texttt{ENOTCONN}
Transport endpoint is not connected

errno.\texttt{ESHUTDOWN}
Cannot send after transport endpoint shutdown

errno.\texttt{ETOOMANYREFS}
Too many references: cannot splice

errno.\texttt{ETIMEDOUT}
Connection timed out

errno.\texttt{ECONNREFUSED}
Connection refused

errno.\texttt{EHOSTDOWN}
Host is down

errno.\texttt{EHOSTUNREACH}
No route to host

errno.\texttt{EALREADY}
Operation already in progress

errno.\texttt{EINPROGRESS}
Operation now in progress

errno.\texttt{ESTALE}
Stale NFS file handle

errno.\texttt{EUCLEAN}
Structure needs cleaning
errno. **ENOTNAM**
Not a XENIX named type file

errno. **ENAVAIL**
No XENIX semaphores available

errno. **EISNAM**
Is a named type file

errno. **EREMOTEIO**
Remote I/O error

errno. **EDQUOT**
Quota exceeded
16.16. **ctypes** — A foreign function library for Python

**ctypes** is a foreign function library for Python. It provides C compatible data types, and allows calling functions in DLLs or shared libraries. It can be used to wrap these libraries in pure Python.
16.16.1. ctypes tutorial

Note: The code samples in this tutorial use doctest to make sure that they actually work. Since some code samples behave differently under Linux, Windows, or Mac OS X, they contain doctest directives in comments.

Note: Some code samples reference the ctypes c_int type. This type is an alias for the c_long type on 32-bit systems. So, you should not be confused if c_long is printed if you would expect c_int — they are actually the same type.

16.16.1.1. Loading dynamic link libraries

ctypes exports the cdll, and on Windows windll and oledll objects, for loading dynamic link libraries.

You load libraries by accessing them as attributes of these objects. cdll loads libraries which export functions using the standard cdecl calling convention, while windll libraries call functions using the stdcall calling convention. oledll also uses the stdcall calling convention, and assumes the functions return a Windows HRESULT error code. The error code is used to automatically raise an OSError exception when the function call fails.

Changed in version 3.3: Windows errors used to raise WindowsError, which is now an alias of OSError.

Here are some examples for Windows. Note that msvcrt is the MS standard C library containing most standard C functions, and uses the cdecl calling convention:
Windows appends the usual .dll file suffix automatically.

On Linux, it is required to specify the filename *including* the extension to load a library, so attribute access can not be used to load libraries. Either the LoadLibrary() method of the dll loaders should be used, or you should load the library by creating an instance of CDLL by calling the constructor:

```python
>>> cdll.LoadLibrary("libc.so.6")
<CDLL 'libc.so.6', handle ... at ...>
>>> libc = CDLL("libc.so.6")
>>> libc
<CDLL 'libc.so.6', handle ... at ...>
```

16.16.1.2. Accessing functions from loaded dlls

Functions are accessed as attributes of dll objects:

```python
>>> from ctypes import *
>>> libc.printf
<_FuncPtr object at 0x...>
>>> print(windll.kernel32.GetModuleHandleA)
<_FuncPtr object at 0x...>
>>> print(windll.kernel32.MyOwnFunction)
Traceback (most recent call last):
```
File "<stdin>", line 1, in ?
File "ctypes.py", line 239, in __getattr__
    func = _StdcallFuncPtr(name, self)
AttributeError: function 'MyOwnFunction' not found

Note that win32 system dlls like kernel32 and user32 often export ANSI as well as UNICODE versions of a function. The UNICODE version is exported with an W appended to the name, while the ANSI version is exported with an A appended to the name. The win32 GetModuleHandle function, which returns a module handle for a given module name, has the following C prototype, and a macro is used to expose one of them as GetModuleHandle depending on whether UNICODE is defined or not:

```c
/* ANSI version */
HMODULE GetModuleHandleA(LPCSTR lpModuleName);
/* UNICODE version */
HMODULE GetModuleHandleW(LPCWSTR lpModuleName);
```

`windll` does not try to select one of them by magic, you must access the version you need by specifying GetModuleHandleA or GetModuleHandleW explicitly, and then call it with bytes or string objects respectively.

Sometimes, dlls export functions with names which aren't valid Python identifiers, like "??2@YAPAXI@Z". In this case you have to use `getattr()` to retrieve the function:

```python
>>> getattr(cdll.msvcrt, "??2@YAPAXI@Z")
<_FuncPtr object at 0x...>  
```
On Windows, some dlls export functions not by name but by ordinal. These functions can be accessed by indexing the dll object with the ordinal number:

```python
>>> cdll.kernel32[1]
<_FuncPtr object at 0x...>
>>> cdll.kernel32[0]
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "ctypes.py", line 310, in __getitem__
    func = _StdcallFuncPtr(name, self)
AttributeError: function ordinal 0 not found
```
the function returns, so although an error is raised the function has been called:

```python
>>> windll.kernel32.GetModuleHandleA()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: Procedure probably called with not enough arguments (4 bytes missing)
```

The same exception is raised when you call an stdcall function with the cdecl calling convention, or vice versa:

```python
>>> cdll.kernel32.GetModuleHandleA(None)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: Procedure probably called with not enough arguments
```

```python
>>> windll.msvcrt.printf(b"spam")
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: Procedure probably called with too many arguments (4 bytes in excess)
```

To find out the correct calling convention you have to look into the C header file or the documentation for the function you want to call.

On Windows, `ctypes` uses win32 structured exception handling to prevent crashes from general protection faults when functions are called with invalid argument values:
There are, however, enough ways to crash Python with \texttt{ctypes}, so you should be careful anyway. The \texttt{faulthandler} module can be helpful in debugging crashes (e.g. from segmentation faults produced by erroneous C library calls).

None, integers, bytes objects and (unicode) strings are the only native Python objects that can directly be used as parameters in these function calls. None is passed as a C NULL pointer, bytes objects and strings are passed as pointer to the memory block that contains their data (\texttt{char} * or \texttt{wchar_t} *). Python integers are passed as the platforms default C int type, their value is masked to fit into the C type.

Before we move on calling functions with other parameter types, we have to learn more about \texttt{ctypes} data types.

\textbf{16.16.1.4. Fundamental data types}

\texttt{ctypes} defines a number of primitive C compatible data types:

<table>
<thead>
<tr>
<th>ctypes type</th>
<th>C type</th>
<th>Python type</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{c_bool}</td>
<td>_Bool</td>
<td>bool (1)</td>
</tr>
<tr>
<td>\texttt{c_char}</td>
<td>char</td>
<td>1-character bytes object</td>
</tr>
<tr>
<td>\texttt{c_wchar}</td>
<td>wchar_t</td>
<td>1-character string</td>
</tr>
<tr>
<td>c_byte</td>
<td>char</td>
<td>int</td>
</tr>
<tr>
<td>---------</td>
<td>---------------</td>
<td>------</td>
</tr>
<tr>
<td>c_ubyte</td>
<td>unsigned char</td>
<td>int</td>
</tr>
<tr>
<td>c_short</td>
<td>short</td>
<td>int</td>
</tr>
<tr>
<td>c_ushort</td>
<td>unsigned short</td>
<td>int</td>
</tr>
<tr>
<td>c_int</td>
<td>int</td>
<td>int</td>
</tr>
<tr>
<td>c_uint</td>
<td>unsigned int</td>
<td>int</td>
</tr>
<tr>
<td>c_long</td>
<td>long int</td>
<td>int</td>
</tr>
<tr>
<td>c_ulong</td>
<td>unsigned long</td>
<td>int</td>
</tr>
<tr>
<td>c_longlong</td>
<td>__int64 or long long</td>
<td>int</td>
</tr>
<tr>
<td>c_ulonglong</td>
<td>unsigned __int64 or unsigned long long</td>
<td>int</td>
</tr>
<tr>
<td>c_size_t</td>
<td>size_t</td>
<td>int</td>
</tr>
<tr>
<td>c_ssize_t</td>
<td>ssize_t or Py_ssize_t</td>
<td>int</td>
</tr>
<tr>
<td>c_float</td>
<td>float</td>
<td>float</td>
</tr>
<tr>
<td>c_double</td>
<td>double</td>
<td>float</td>
</tr>
<tr>
<td>c_longdouble</td>
<td>long double</td>
<td>float</td>
</tr>
<tr>
<td>c_char_p</td>
<td>char *(NUL terminated)</td>
<td>bytes object or None</td>
</tr>
<tr>
<td>c_wchar_p</td>
<td>wchar_t *(NUL terminated)</td>
<td>string or None</td>
</tr>
<tr>
<td>c_void_p</td>
<td>void *</td>
<td>int or None</td>
</tr>
</tbody>
</table>

1. The constructor accepts any object with a truth value.

All these types can be created by calling them with an optional initializer of the correct type and value:

```python
>>> c_int()
```
c_long(0)
>>> c_wchar_p("Hello, World")
c_wchar_p('Hello, World')
>>> c_ushort(-3)
c_ushort(65533)

Since these types are mutable, their value can also be changed afterwards:

>>> i = c_int(42)
>>> print(i)
c_long(42)
>>> print(i.value)
42
>>> i.value = -99
>>> print(i.value)
-99

Assigning a new value to instances of the pointer types c_char_p, c_wchar_p, and c_void_p changes the memory location they point to, not the contents of the memory block (of course not, because Python bytes objects are immutable):

>>> s = "Hello, World"
>>> c_s = c_wchar_p(s)
>>> print(c_s)
c_wchar_p('Hello, World')
>>> c_s.value = "Hi, there"
>>> print(c_s)
c_wchar_p('Hi, there')
>>> print(s) # first object is unchanged
Hello, World

>>>
You should be careful, however, not to pass them to functions expecting pointers to mutable memory. If you need mutable memory blocks, ctypes has a `create_string_buffer()` function which creates these in various ways. The current memory block contents can be accessed (or changed) with the raw property; if you want to access it as NUL terminated string, use the value property:

```python
>>> from ctypes import *
>>> p = create_string_buffer(3)  # create
3 b'\x00\x00\x00'
>>> p = create_string_buffer(b"Hello")  # create
6 b'Hello\x00'
>>> print(repr(p.value))
b'Hello'
>>> p = create_string_buffer(b"Hello", 10)  # create
10 b'Hello\x00\x00\x00\x00\x00'
>>> p.value = b"Hi"
>>> print(repr(p.value))
10 b'Hi\x00lo\x00\x00\x00\x00\x00'
```

The `create_string_buffer()` function replaces the `c_buffer()` function (which is still available as an alias), as well as the `c_string()` function from earlier ctypes releases. To create a mutable memory block containing unicode characters of the C type `wchar_t` use the `create_unicode_buffer()` function.

16.16.1.5. Calling functions, continued

Note that printf prints to the real standard output channel, not to
sys.stdout, so these examples will only work at the console prompt, not from within IDLE or PythonWin:

```python
>>> printf = libc.printf
>>> printf(b"Hello, %s\n", b"World!")
Hello, World!
14
>>> printf(b"Hello, %S\n", "World!")
Hello, World!
14
>>> printf(b"%d bottles of beer\n", 42)
42 bottles of beer
19
>>> printf(b"%f bottles of beer\n", 42.5)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ArgumentError: argument 2: exceptions.TypeError: Don
```

As has been mentioned before, all Python types except integers, strings, and bytes objects have to be wrapped in their corresponding ctypes type, so that they can be converted to the required C data type:

```python
>>> printf(b"An int %d, a double %f\n", 1234, c_double(3.14))
An int 1234, a double 3.140000
31
```

16.16.1.6. Calling functions with your own custom data types

You can also customize ctypes argument conversion to allow
instances of your own classes be used as function arguments. `ctypes` looks for an `_as_parameter_` attribute and uses this as the function argument. Of course, it must be one of integer, string, or bytes:

```python
>>> class Bottles:
...     def __init__(self, number):
...         self._as_parameter_ = number
... >>> bottles = Bottles(42)
>>> printf(b"%d bottles of beer\n", bottles)
42 bottles of beer
19
>>> 
```

If you don't want to store the instance's data in the `_as_parameter_` instance variable, you could define a `property` which makes the attribute available on request.

### 16.16.1.7. Specifying the required argument types (function prototypes)

It is possible to specify the required argument types of functions exported from DLLs by setting the `argtypes` attribute.

`argtypes` must be a sequence of C data types (the `printf` function is probably not a good example here, because it takes a variable number and different types of parameters depending on the format string, on the other hand this is quite handy to experiment with this feature):

```python
>>> printf.argtypes = [c_char_p, c_char_p, c_int, c_
>>> printf(b"String '%%s', Int %d, Double %f\n", b"Hi
```
Specifying a format protects against incompatible argument types (just as a prototype for a C function), and tries to convert the arguments to valid types:

```
>>> printf(b"%d %d %d", 1, 2, 3)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ArgumentError: argument 2: exceptions.TypeError: wrong type
```

```
>>> printf(b"%s %d %f\n", b"X", 2, 3)
X 2 3.000000
```

If you have defined your own classes which you pass to function calls, you have to implement a `from_param()` class method for them to be able to use them in the argtypes sequence. The `from_param()` class method receives the Python object passed to the function call, it should do a typecheck or whatever is needed to make sure this object is acceptable, and then return the object itself, its `_as_parameter_` attribute, or whatever you want to pass as the C function argument in this case. Again, the result should be an integer, string, bytes, a `ctypes` instance, or an object with an `_as_parameter_` attribute.

**16.16.1.8. Return types**

By default functions are assumed to return the C `int` type. Other return types can be specified by setting the `restype` attribute of the function object.
Here is a more advanced example, it uses the `strchr` function, which expects a string pointer and a char, and returns a pointer to a string:

```python
>>> strchr = libc.strchr
>>> strchr(b"abcdef", ord("d"))
8059983
>>> strchr.restype = c_char_p  # c_char_p is a pointer to a string
>>> strchr(b"abcdef", ord("d"))
'b'def'
>>> print(strchr(b"abcdef", ord("x")))
None
```

If you want to avoid the `ord("x")` calls above, you can set the `argtypes` attribute, and the second argument will be converted from a single character Python bytes object into a C char:

```python
>>> strchr.restype = c_char_p
>>> strchr.argtypes = [c_char_p, c_char]
>>> strchr(b"abcdef", b"d")
'def'
>>> strchr(b"abcdef", b"def")
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ArgumentError: argument 2: exceptions.TypeError: one character string expected
```

You can also use a callable Python object (a function or a class for example) as the restype attribute, if the foreign function returns an integer. The callable will be called with the integer the C function
returns, and the result of this call will be used as the result of your function call. This is useful to check for error return values and automatically raise an exception:

```python
>>> GetModuleHandle = windll.kernel32.GetModuleHandle
>>> def ValidHandle(value):
...     if value == 0:
...         raise WinError()
...     return value
...
>>> GetModuleHandle.retype = ValidHandle
>>> GetModuleHandle(None)
486539264
>>> GetModuleHandle("something silly")
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "<stdin>", line 3, in ValidHandle
OSError: [Errno 126] The specified module could not
```

WinError is a function which will call Windows FormatMessage() api to get the string representation of an error code, and returns an exception. WinError takes an optional error code parameter, if no one is used, it calls GetLastError() to retrieve it.

Please note that a much more powerful error checking mechanism is available through the errcheck attribute; see the reference manual for details.

16.16.1.9. Passing pointers (or: passing parameters by reference)
Sometimes a C api function expects a *pointer* to a data type as parameter, probably to write into the corresponding location, or if the data is too large to be passed by value. This is also known as *passing parameters by reference*.

`ctypes` exports the `byref()` function which is used to pass parameters by reference. The same effect can be achieved with the `pointer()` function, although `pointer()` does a lot more work since it constructs a real pointer object, so it is faster to use `byref()` if you don’t need the pointer object in Python itself:

```python
>>> i = c_int()
>>> f = c_float()
>>> s = create_string_buffer(b'\000' * 32)
>>> print(i.value, f.value, repr(s.value))
0 0.0 b''
>>> libc sscanf(b"1 3.14 Hello", b"%d %f %s", ... byref(i), byref(f), s)
3
>>> print(i.value, f.value, repr(s.value))
1 3.1400001049 b'Hello'
```

**16.16.1.10. Structures and unions**

Structures and unions must derive from the `Structure` and `Union` base classes which are defined in the `ctypes` module. Each subclass must define a `_fields_` attribute. `_fields_` must be a list of 2-tuples, containing a *field name* and a *field type*.

The field type must be a `ctypes` type like `c_int`, or any other derived `ctypes` type: structure, union, array, pointer.
Here is a simple example of a POINT structure, which contains two integers named x and y, and also shows how to initialize a structure in the constructor:

```python
>>> from ctypes import *
>>> class POINT(Structure):
...     _fields_ = ["x", c_int],
...     ("y", c_int)]
...
>>> point = POINT(10, 20)
>>> print(point.x, point.y)
10 20
>>> point = POINT(y=5)
>>> print(point.x, point.y)
0 5
>>> POINT(1, 2, 3)
Traceback (most recent call last):
  File "<stdin>" , line 1, in ?
ValueError: too many initializers
```

You can, however, build much more complicated structures. A structure can itself contain other structures by using a structure as a field type.

Here is a RECT structure which contains two POINTs named upperleft and lowerright:

```python
>>> class RECT(Structure):
...     _fields_ = ["upperleft", POINT),
...             ("lowerright", POINT)]
...
>>> rc = RECT(point)
>>> print(rc.upperleft.x, rc.upperleft.y)
0 5
>>> print(rc.lowerright.x, rc.lowerright.y)
```

Nested structures can also be initialized in the constructor in several ways:

```python
>>> r = RECT(POINT(1, 2), POINT(3, 4))
>>> r = RECT((1, 2), (3, 4))
```

Field descriptors can be retrieved from the class, they are useful for debugging because they can provide useful information:

```python
>>> print(POINT.x)
<Field type=c_long, ofs=0, size=4>
>>> print(POINT.y)
<Field type=c_long, ofs=4, size=4>
```

**Warning:** ctypes does not support passing unions or structures with bit-fields to functions by value. While this may work on 32-bit x86, it’s not guaranteed by the library to work in the general case. Unions and structures with bit-fields should always be passed to functions by pointer.

### 16.16.1.11. Structure/union alignment and byte order

By default, Structure and Union fields are aligned in the same way the C compiler does it. It is possible to override this behavior by specifying a `_pack_` class attribute in the subclass definition. This must be set to a positive integer and specifies the maximum alignment for the fields. This is what `#pragma pack(n)` also does in MSVC.
ctypes uses the native byte order for Structures and Unions. To build structures with non-native byte order, you can use one of the BigEndianStructure, LittleEndianStructure, BigEndianUnion, and LittleEndianUnion base classes. These classes cannot contain pointer fields.

16.16.1.12. Bit fields in structures and unions

It is possible to create structures and unions containing bit fields. Bit fields are only possible for integer fields, the bit width is specified as the third item in the _fields_ tuples:

```python
>>> class Int(Structure):
...     _fields_ = ["first_16", c_int, 16],
...             ("second_16", c_int, 16)]
... >>> print(Int.first_16)
<Field type=c_long, ofs=0:0, bits=16>
>>> print(Int.second_16)
<Field type=c_long, ofs=0:16, bits=16>
```

16.16.1.13. Arrays

Arrays are sequences, containing a fixed number of instances of the same type.

The recommended way to create array types is by multiplying a data type with a positive integer:

```python
TenPointsArrayType = POINT * 10
```

Here is an example of an somewhat artificial data type, a structure
containing 4 POINTs among other stuff:

```python
from ctypes import *

class POINT(Structure):
    _fields_ = ("x", c_int), ("y", c_int)

class MyStruct(Structure):
    _fields_ = [("a", c_int),
                ("b", c_float),
                ("point_array", POINT * 4)]

print(len(MyStruct().point_array))
4
```

Instances are created in the usual way, by calling the class:

```python
arr = TenPointsArrayType()
for pt in arr:
    print(pt.x, pt.y)
```

The above code print a series of 0 0 lines, because the array contents is initialized to zeros.

Initializers of the correct type can also be specified:

```python
from ctypes import *
TenIntegers = c_int * 10
ii = TenIntegers(1, 2, 3, 4, 5, 6, 7, 8, 9, 10)
print(ii)
for i in ii: print(i, end=" ")
... 1 2 3 4 5 6 7 8 9 10
```

Pointer instances are created by calling the `pointer()` function on a `ctypes` type:

```python
>>> from ctypes import *
>>> i = c_int(42)
>>> pi = pointer(i)

>>> pi
<__pointer__ object at 0x7f81a30b09a0>
```

Pointer instances have a `contents` attribute which returns the object to which the pointer points, the `i` object above:

```python
>>> pi.contents
<__c_int object at 0x7f81a30b09a0>
```

Note that `ctypes` does not have OOR (original object return), it constructs a new, equivalent object each time you retrieve an attribute:

```python
>>> pi.contents is i
False
>>> pi.contents is pi.contents
False

>>> pi = pointer(i)
```

Assigning another `c_int` instance to the pointer’s `contents` attribute would cause the pointer to point to the memory location where this is stored:

```python
>>> i = c_int(99)
>>> pi.contents = i
>>> pi.contents
<__c_int object at 0x7f81a30b09a0>
```

```python
>>> pi = pointer(i)
```
Pointer instances can also be indexed with integers:

```python
>>> pi[0]
99
```

Assigning to an integer index changes the pointed to value:

```python
>>> print(i)
c_long(99)
>>> pi[0] = 22
>>> print(i)
c_long(22)
```

It is also possible to use indexes different from 0, but you must know what you're doing, just as in C: You can access or change arbitrary memory locations. Generally you only use this feature if you receive a pointer from a C function, and you know that the pointer actually points to an array instead of a single item.

Behind the scenes, the `pointer()` function does more than simply create pointer instances, it has to create pointer types first. This is done with the `POINTER()` function, which accepts any `ctypes` type, and returns a new type:

```python
>>> PI = POINTER(c_int)
>>> PI
<class 'ctypes.LP_c_long'>
>>> PI(42)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: expected c_long instead of int
Calling the pointer type without an argument creates a NULL pointer. NULL pointers have a False boolean value:

```python
>>> null_ptr = POINTER(c_int)()
>>> print(bool(null_ptr))
False
```

ctypes checks for NULL when dereferencing pointers (but dereferencing invalid non-NULI pointers would crash Python):

```python
>>> null_ptr[0]
ValueError: NULL pointer access
```

```python
>>> null_ptr[0] = 1234
ValueError: NULL pointer access
```

16.16.1.15. Type conversions

Usually, ctypes does strict type checking. This means, if you have POINTER(c_int) in the argtypes list of a function or as the type of a member field in a structure definition, only instances of exactly the same type are accepted. There are some exceptions to this rule, where ctypes accepts other objects. For example, you can pass
compatible array instances instead of pointer types. So, for
POINTER(c_int), ctypes accepts an array of c_int:

```python
>>> class Bar(Structure):
...     _fields_ = [("count", c_int), ("values", POINTER(c_int))]
...     count = 3
...     values = (c_int * 3)(1, 2, 3)
>>> for i in range(bar.count):
...     print(bar.values[i])
1
2
3
```

In addition, if a function argument is explicitly declared to be a pointer
type (such as POINTER(c_int)) in argtypes, an object of the
pointed type (c_int in this case) can be passed to the function.
ctypes will apply the required `byref()` conversion in this case
automatically.

To set a POINTER type field to NULL, you can assign None:

```python
>>> bar.values = None
```

Sometimes you have instances of incompatible types. In C, you can
cast one type into another type. ctypes provides a `cast()` function
which can be used in the same way. The Bar structure defined above
accepts POINTER(c_int) pointers or c_int arrays for its values
field, but not instances of other types:
For these cases, the `cast()` function is handy.

The `cast()` function can be used to cast a ctypes instance into a pointer to a different ctypes data type. `cast()` takes two parameters, a ctypes object that is or can be converted to a pointer of some kind, and a ctypes pointer type. It returns an instance of the second argument, which references the same memory block as the first argument:

```python
>>> a = (c_byte * 4)()
>>> cast(a, POINTER(c_int))
<ctypes.LP_c_long object at ...>
```

So, `cast()` can be used to assign to the values field of Bar the structure:

```python
>>> bar = Bar()
>>> bar.values = cast((c_byte * 4)(), POINTER(c_int))
>>> print(bar.values[0])
0
```

16.16.1.16. Incomplete Types

Incomplete Types are structures, unions or arrays whose members are
not yet specified. In C, they are specified by forward declarations, which are defined later:

```c
struct cell; /* forward declaration */

struct cell {
    char *name;
    struct cell *next;
};
```

The straightforward translation into ctypes code would be this, but it does not work:

```python
>>> class cell(Structure):
...     _fields_ = [(
...         "name", c_char_p),
...         ("next", POINTER(cell))]
...
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "<stdin>", line 2, in cell
NameError: name 'cell' is not defined
```
Lets try it. We create two instances of `cell`, and let them point to each other, and finally follow the pointer chain a few times:

```python
>>> c1 = cell()
>>> c1.name = "foo"
>>> c2 = cell()
>>> c2.name = "bar"
>>> c1.next = pointer(c2)
>>> c2.next = pointer(c1)
>>> p = c1
>>> for i in range(8):
...   print(p.name, end=" ")
...   p = p.next[0]
...
foo bar foo bar foo bar foo bar
```

16.16.1.17. Callback functions

`ctypes` allows to create C callable function pointers from Python callables. These are sometimes called `callback functions`.

First, you must create a class for the callback function. The class knows the calling convention, the return type, and the number and types of arguments this function will receive.

The `CFUNCTYPE()` factory function creates types for callback functions using the cdecl calling convention. On Windows, the `WINFUNCTYPE()` factory function creates types for callback functions using the stdcall calling convention.

Both of these factory functions are called with the result type as first argument, and the callback functions expected argument types as the remaining arguments.
I will present an example here which uses the standard C library’s `qsort()` function, that is used to sort items with the help of a callback function. `qsort()` will be used to sort an array of integers:

```python
>>> IntArray5 = c_int * 5
>>> ia = IntArray5(5, 1, 7, 33, 99)
>>> qsort = libc.qsort
>>> qsort.restype = None
>>> qsort()
```

`qsort()` must be called with a pointer to the data to sort, the number of items in the data array, the size of one item, and a pointer to the comparison function, the callback. The callback will then be called with two pointers to items, and it must return a negative integer if the first item is smaller than the second, a zero if they are equal, and a positive integer otherwise.

So our callback function receives pointers to integers, and must return an integer. First we create the type for the callback function:

```python
>>> CMPFUNC = CFUNCTYPE(c_int, POINTER(c_int), POINTER(c_int))
```

To get started, here is a simple callback that shows the values it gets passed:

```python
>>> def py_cmp_func(a, b):
...     print("py_cmp_func", a[0], b[0])
...     return 0
...
>>> cmp_func = CMPFUNC(py_cmp_func)
```
The result:

```python
>>> qsort(ia, len(ia), sizeof(c_int), cmp_func)
py_cmp_func 5 1
py_cmp_func 33 99
py_cmp_func 7 33
py_cmp_func 5 7
py_cmp_func 1 7
```

Now we can actually compare the two items and return a useful result:

```python
>>> def py_cmp_func(a, b):
...     print("py_cmp_func", a[0], b[0])
...     return a[0] - b[0]
...
```

As we can easily check, our array is sorted now:

```python
>>> qsort(ia, len(ia), sizeof(c_int), CMPFUNC(py_cmp_func)
py_cmp_func 5 1
py_cmp_func 33 99
py_cmp_func 7 33
py_cmp_func 1 7
py_cmp_func 5 7
```

```python
>>> for i in ia: print(i, end=" ")
...
1 5 7 33 99
```

**Note:** Make sure you keep references to `CFUNCTYPE()` objects as long as they are used from C code. `ctypes` doesn't, and if you
don’t, they may be garbage collected, crashing your program when a callback is made.

Also, note that if the callback function is called in a thread created outside of Python’s control (e.g. by the foreign code that calls the callback), ctypes creates a new dummy Python thread on every invocation. This behavior is correct for most purposes, but it means that values stored with `threading.local` will not survive across different callbacks, even when those calls are made from the same C thread.

16.16.1.18. Accessing values exported from dlls

Some shared libraries not only export functions, they also export variables. An example in the Python library itself is the `Py_OptimizeFlag`, an integer set to 0, 1, or 2, depending on the `-O` or `-00` flag given on startup.

`ctypes` can access values like this with the `in_dll()` class methods of the type. `pythonapi` is a predefined symbol giving access to the Python C api:

```python
>>> opt_flag = c_int.in_dll(pythonapi, "Py_OptimizeFlag")
>>> print(opt_flag)
c_long(0)
```

If the interpreter would have been started with `-O`, the sample would have printed `c_long(1)`, or `c_long(2)` if `-00` would have been specified.

An extended example which also demonstrates the use of pointers...
accesses the `PyImport_FrozenModules` pointer exported by Python.

Quoting the docs for that value:

This pointer is initialized to point to an array of `struct _frozen` records, terminated by one whose members are all `NULL` or zero. When a frozen module is imported, it is searched in this table. Third-party code could play tricks with this to provide a dynamically created collection of frozen modules.

So manipulating this pointer could even prove useful. To restrict the example size, we show only how this table can be read with `ctypes`:

```python
>>> from ctypes import *

>>> class struct_frozen(Structure):
...    _fields_ = ["name", c_char_p],
...               ["code", POINTER(c_ubyte)],
...               ["size", c_int]

>>> FrozenTable = POINTER(struct_frozen)
>>> table = FrozenTable.in_dll(pythonapi, "PyImport_"
```

We have defined the `struct _frozen` data type, so we can get the pointer to the table:

```python
>>> FrozenTable = POINTER(struct_frozen)
>>> table = FrozenTable.in_dll(pythonapi, "PyImport_"
```

Since `table` is a pointer to the array of `struct_frozen` records, we can iterate over it, but we just have to make sure that our loop terminates, because pointers have no size. Sooner or later it would probably crash with an access violation or whatever, so it’s better to
break out of the loop when we hit the NULL entry:

```python
>>> for item in table:
...    print(item.name, item.size)
...    if item.name is None:
...        break
...
__hello__ 104
__phello__ -104
__phello__.spam 104
None 0

>>> 
```

The fact that standard Python has a frozen module and a frozen package (indicated by the negative size member) is not well known, it is only used for testing. Try it out with `import __hello__` for example.

16.16.1.19. Surprises

There are some edges in `ctypes` where you might expect something other than what actually happens.

Consider the following example:

```python
>>> from ctypes import *
>>> class POINT(Structure):
...    _fields_ = ("x", c_int), ("y", c_int)
...>>> class RECT(Structure):
...    _fields_ = ("a", POINT), ("b", POINT)
...>>> p1 = POINT(1, 2)
>>> p2 = POINT(3, 4)
>>> rc = RECT(p1, p2)
```
Hm. We certainly expected the last statement to print 3 4 1 2. What happened? Here are the steps of the `rc.a, rc.b = rc.b, rc.a` line above:

```python
>>> temp0, temp1 = rc.b, rc.a
>>> rc.a = temp0
>>> rc.b = temp1
``` 

Note that `temp0` and `temp1` are objects still using the internal buffer of the `rc` object above. So executing `rc.a = temp0` copies the buffer contents of `temp0` into `rc`'s buffer. This, in turn, changes the contents of `temp1`. So, the last assignment `rc.b = temp1`, doesn't have the expected effect.

Keep in mind that retrieving sub-objects from Structure, Unions, and Arrays doesn't *copy* the sub-object, instead it retrieves a wrapper object accessing the root-object's underlying buffer.

Another example that may behave different from what one would expect is this:

```python
>>> s = c_char_p()
>>> s.value = "abc def ghi"
>>> s.value
'abc def ghi'
```
Why is it printing False? ctypes instances are objects containing a memory block plus some descriptors accessing the contents of the memory. Storing a Python object in the memory block does not store the object itself, instead the contents of the object is stored. Accessing the contents again constructs a new Python object each time!

16.16.1.20. Variable-sized data types

ctypes provides some support for variable-sized arrays and structures.

The resize() function can be used to resize the memory buffer of an existing ctypes object. The function takes the object as first argument, and the requested size in bytes as the second argument. The memory block cannot be made smaller than the natural memory block specified by the objects type, a ValueError is raised if this is tried:

```python
>>> short_array = (c_short * 4)()
>>> print(sizeof(short_array))
8
>>> resize(short_array, 4)
Traceback (most recent call last):
  ... ValueError: minimum size is 8
>>> resize(short_array, 32)
>>> sizeof(short_array)
32
>>> sizeof(type(short_array))
8
```
This is nice and fine, but how would one access the additional elements contained in this array? Since the type still only knows about 4 elements, we get errors accessing other elements:

```python
>>> short_array[:]
[0, 0, 0, 0]
>>> short_array[7]
Traceback (most recent call last):
  ...  
IndexError: invalid index
```

Another way to use variable-sized data types with `ctypes` is to use the dynamic nature of Python, and (re-)define the data type after the required size is already known, on a case by case basis.
16.16.2. ctypes reference

16.16.2.1. Finding shared libraries

When programming in a compiled language, shared libraries are accessed when compiling/linking a program, and when the program is run.

The purpose of the `find_library()` function is to locate a library in a way similar to what the compiler does (on platforms with several versions of a shared library the most recent should be loaded), while the ctypes library loaders act like when a program is run, and call the runtime loader directly.

The `ctypes.util` module provides a function which can help to determine the library to load.

`ctypes.util.find_library(name)`

Try to find a library and return a pathname. `name` is the library name without any prefix like `lib`, suffix like `.so`, `.dylib` or version number (this is the form used for the posix linker option `-l`). If no library can be found, returns `None`.

The exact functionality is system dependent.

On Linux, `find_library()` tries to run external programs (`/sbin/ldconfig`, `gcc`, and `objdump`) to find the library file. It returns the filename of the library file. Here are some examples:

```python
>>> from ctypes.util import find_library
>>> find_library("m")
'libm.so.6'
```
On OS X, `find_library()` tries several predefined naming schemes and paths to locate the library, and returns a full pathname if successful:

```python
>>> from ctypes.util import find_library
>>> find_library("c")
'/usr/lib/libc.dylib'
>>> find_library("m")
'/usr/lib/libm.dylib'
>>> find_library("bz2")
'/usr/lib/libbz2.dylib'
>>> find_library("AGL")
'/System/Library/Frameworks/AGL.framework/AGL'
```

On Windows, `find_library()` searches along the system search path, and returns the full pathname, but since there is no predefined naming scheme a call like `find_library("c")` will fail and return None.

If wrapping a shared library with `ctypes`, it *may* be better to determine the shared library name at development time, and hardcode that into the wrapper module instead of using `find_library()` to locate the library at runtime.

**16.16.2.2. Loading shared libraries**

There are several ways to loaded shared libraries into the Python
process. One way is to instantiate one of the following classes:

```python
class ctypes.CDLL(name, mode=DEFAULT_MODE, handle=None, use_errno=False, use_last_error=False)
```

Instances of this class represent loaded shared libraries. Functions in these libraries use the standard C calling convention, and are assumed to return int.

```python
class ctypes.OleDLL(name, mode=DEFAULT_MODE, handle=None, use_errno=False, use_last_error=False)
```

Windows only: Instances of this class represent loaded shared libraries, functions in these libraries use the stdcall calling convention, and are assumed to return the windows specific HRESULT code. HRESULT values contain information specifying whether the function call failed or succeeded, together with additional error code. If the return value signals a failure, an OSError is automatically raised.

*Changed in version 3.3:* WindowsError used to be raised.

```python
class ctypes.WinDLL(name, mode=DEFAULT_MODE, handle=None, use_errno=False, use_last_error=False)
```

Windows only: Instances of this class represent loaded shared libraries, functions in these libraries use the stdcall calling convention, and are assumed to return int by default.

On Windows CE only the standard calling convention is used, for convenience the WinDLL and OleDLL use the standard calling convention on this platform.

The Python global interpreter lock is released before calling any function exported by these libraries, and reacquired afterwards.
class ctypes.PyDLL(name, mode=DEFAULT_MODE, handle=None)

Instances of this class behave like CDLL instances, except that the Python GIL is *not* released during the function call, and after the function execution the Python error flag is checked. If the error flag is set, a Python exception is raised.

Thus, this is only useful to call Python C api functions directly.

All these classes can be instantiated by calling them with at least one argument, the pathname of the shared library. If you have an existing handle to an already loaded shared library, it can be passed as the handle named parameter, otherwise the underlying platforms dlopen or LoadLibrary function is used to load the library into the process, and to get a handle to it.

The *mode* parameter can be used to specify how the library is loaded. For details, consult the *dlopen*(3) manpage, on Windows, *mode* is ignored.

The *use_errno* parameter, when set to True, enables a ctypes mechanism that allows to access the system *errno* error number in a safe way. ctypes maintains a thread-local copy of the systems *errno* variable; if you call foreign functions created with *use_errno=True* then the *errno* value before the function call is swapped with the ctypes private copy, the same happens immediately after the function call.

The function ctypes.get_errno() returns the value of the ctypes private copy, and the function ctypes.set_errno() changes the ctypes private copy to a new value and returns the former value.

The *use_last_error* parameter, when set to True, enables the same
mechanism for the Windows error code which is managed by the GetLastErrorCode() and SetLastError() Windows API functions; ctypes.get_last_error() and ctypes.set_last_error() are used to request and change the ctypes private copy of the windows error code.

c ctypes.\texttt{RTLD\_GLOBAL}  
Flag to use as \texttt{mode} parameter. On platforms where this flag is not available, it is defined as the integer zero.

c ctypes.\texttt{RTLD\_LOCAL}  
Flag to use as \texttt{mode} parameter. On platforms where this is not available, it is the same as \texttt{RTLD\_GLOBAL}.

c ctypes.\texttt{DEFAULT\_MODE}  
The default mode which is used to load shared libraries. On OSX 10.3, this is \texttt{RTLD\_GLOBAL}, otherwise it is the same as \texttt{RTLD\_LOCAL}.

Instances of these classes have no public methods. Functions exported by the shared library can be accessed as attributes or by index. Please note that accessing the function through an attribute caches the result and therefore accessing it repeatedly returns the same object each time. On the other hand, accessing it through an index returns a new object each time:

```python
>>> libc.time == libc.time
True
>>> libc[\texttt{\textquotesingle}time\textquotesingle] == libc[\texttt{\textquotesingle}time\textquotesingle]
False
```

The following public attributes are available, their name starts with an underscore to not clash with exported function names:
PyDLL._handle

The system handle used to access the library.

PyDLL._name

The name of the library passed in the constructor.

Shared libraries can also be loaded by using one of the prefabricated objects, which are instances of the LibraryLoader class, either by calling the LoadLibrary() method, or by retrieving the library as attribute of the loader instance.

class ctypes.LibraryLoader(dlltype)

Class which loads shared libraries. dlltype should be one of the CDLL, PyDLL, WinDLL, or OleDLL types.

__getattr__() has special behavior: It allows to load a shared library by accessing it as attribute of a library loader instance. The result is cached, so repeated attribute accesses return the same library each time.

LoadLibrary(name)

Load a shared library into the process and return it. This method always returns a new instance of the library.

These prefabricated library loaders are available:

ctypes.cdll

Creates CDLL instances.

ctypes.windll

Windows only: Creates WinDLL instances.

c types.oledll
Windows only: Creates 01eDLL instances.

ctypes.\texttt{pydll}

Creates PyDLL instances.

For accessing the C Python api directly, a ready-to-use Python shared library object is available:

ctypes.\texttt{pythonapi}

An instance of PyDLL that exposes Python C API functions as attributes. Note that all these functions are assumed to return C int, which is of course not always the truth, so you have to assign the correct restype attribute to use these functions.

16.16.2.3. Foreign functions

As explained in the previous section, foreign functions can be accessed as attributes of loaded shared libraries. The function objects created in this way by default accept any number of arguments, accept any ctypes data instances as arguments, and return the default result type specified by the library loader. They are instances of a private class:

\begin{verbatim}
class ctypes._FuncPtr
    Base class for C callable foreign functions.

    Instances of foreign functions are also C compatible data types; they
    represent C function pointers.

    This behavior can be customized by assigning to special attributes
    of the foreign function object.

    \texttt{restype}
\end{verbatim}
Assign a ctypes type to specify the result type of the foreign function. Use None for `void`, a function not returning anything.

It is possible to assign a callable Python object that is not a ctypes type, in this case the function is assumed to return a C `int`, and the callable will be called with this integer, allowing to do further processing or error checking. Using this is deprecated, for more flexible post processing or error checking use a ctypes data type as `restype` and assign a callable to the `errcheck` attribute.

**argtypes**

Assign a tuple of ctypes types to specify the argument types that the function accepts. Functions using the `stdcall` calling convention can only be called with the same number of arguments as the length of this tuple; functions using the C calling convention accept additional, unspecified arguments as well.

When a foreign function is called, each actual argument is passed to the `from_param()` class method of the items in the `argtypes` tuple, this method allows to adapt the actual argument to an object that the foreign function accepts. For example, a `c_char_p` item in the `argtypes` tuple will convert a string passed as argument into a bytes object using ctypes conversion rules.

New: It is now possible to put items in argtypes which are not ctypes types, but each item must have a `from_param()` method which returns a value usable as argument (integer, string, ctypes instance). This allows to define adapters that can adapt custom objects as function parameters.
errcheck

Assign a Python function or another callable to this attribute. The callable will be called with three or more arguments:

callable(result, func, arguments)

result is what the foreign function returns, as specified by the restype attribute.

func is the foreign function object itself, this allows to reuse the same callable object to check or post process the results of several functions.

arguments is a tuple containing the parameters originally passed to the function call, this allows to specialize the behavior on the arguments used.

The object that this function returns will be returned from the foreign function call, but it can also check the result value and raise an exception if the foreign function call failed.

exception ctypes. ArgumentError

This exception is raised when a foreign function call cannot convert one of the passed arguments.

16.16.2.4. Function prototypes

Foreign functions can also be created by instantiating function prototypes. Function prototypes are similar to function prototypes in C; they describe a function (return type, argument types, calling convention) without defining an implementation. The factory functions must be called with the desired result type and the argument types of the function.
The returned function prototype creates functions that use the standard C calling convention. The function will release the GIL during the call. If use_errno is set to True, the ctypes private copy of the system errno variable is exchanged with the real errno value before and after the call; use_last_error does the same for the Windows error code.

Windows only: The returned function prototype creates functions that use the stdcall calling convention, except on Windows CE where WINFUNCTYPE() is the same as CFUNCTYPE(). The function will release the GIL during the call. use_errno and use_last_error have the same meaning as above.

The returned function prototype creates functions that use the Python calling convention. The function will not release the GIL during the call.

Function prototypes created by these factory functions can be instantiated in different ways, depending on the type and number of the parameters in the call:

**prototype(address)**

Returns a foreign function at the specified address which must be an integer.

**prototype(callable)**

Create a C callable function (a callback function) from a
Python *callable*.

**prototype**(*func_spec[, paramflags]*)

Returns a foreign function exported by a shared library. *func_spec* must be a 2-tuple (*name_or_ordinal*, *library*). The first item is the name of the exported function as string, or the ordinal of the exported function as small integer. The second item is the shared library instance.

**prototype**(*vtbl_index, name[, paramflags[, iid]]*)

Returns a foreign function that will call a COM method. *vtbl_index* is the index into the virtual function table, a small non-negative integer. *name* is name of the COM method. *iid* is an optional pointer to the interface identifier which is used in extended error reporting.

COM methods use a special calling convention: They require a pointer to the COM interface as first argument, in addition to those parameters that are specified in the *argtypes* tuple.

The optional *paramflags* parameter creates foreign function wrappers with much more functionality than the features described above.

*paramflags* must be a tuple of the same length as *argtypes*.

Each item in this tuple contains further information about a parameter, it must be a tuple containing one, two, or three items.

The first item is an integer containing a combination of direction flags for the parameter:

1
Specifies an input parameter to the function.

Output parameter. The foreign function fills in a value.

Input parameter which defaults to the integer zero.

The optional second item is the parameter name as string. If this is specified, the foreign function can be called with named parameters.

The optional third item is the default value for this parameter.

This example demonstrates how to wrap the Windows MessageBoxA function so that it supports default parameters and named arguments.

The C declaration from the windows header file is this:

```c
WINUSERAPI int WINAPI MessageBoxA(
    HWND hWnd,
    LPCSTR lpText,
    LPCSTR lpCaption,
    UINT uType);
```

Here is the wrapping with ctypes:

```python
>>> from ctypes import c_int, WINFUNCTYPE, windll
>>> from ctypes.wintypes import HWND, LPCSTR, UINT
>>> prototype = WINFUNCTYPE(c_int, HWND, LPCSTR, LPCSTR, UINT)
>>> paramflags = (1, "hwnd", 0), (1, "text", "Hi"),
>>> MessageBox = prototype("MessageBoxA", windll.user32)
```

The MessageBox foreign function can now be called in these ways:
A second example demonstrates output parameters. The win32 GetWindowRect function retrieves the dimensions of a specified window by copying them into RECT structure that the caller has to supply. Here is the C declaration:

```c
WINUSERAPI BOOL WINAPI GetWindowRect(
    HWND hwnd,
    LPRECT lpRect);
```

Here is the wrapping with `ctypes`:

```python
from ctypes import POINTER, WINFUNCTYPE, windll,
from ctypes.wintypes import BOOL, HWND, RECT
prototype = WINFUNCTYPE(BOOL, HWND, POINTER(RECT))
paramflags = (1, "hwnd"), (2, "lprect")
GetWindowRect = prototype("GetWindowRect", windll)
```

Functions with output parameters will automatically return the output parameter value if there is a single one, or a tuple containing the output parameter values when there are more than one, so the GetWindowRect function now returns a RECT instance, when called.

Output parameters can be combined with the errcheck protocol to do further output processing and error checking. The win32 GetWindowRect api function returns a BOOL to signal success or failure, so this function could do the error checking, and raises an
exception when the api call failed:

```python
>>> def errcheck(result, func, args):
...     if not result:
...         raise WinError()
...     return args
...
>>> GetWindowRect.errcheck = errcheck
```n
If the errcheck function returns the argument tuple it receives unchanged, ctypes continues the normal processing it does on the output parameters. If you want to return a tuple of window coordinates instead of a RECT instance, you can retrieve the fields in the function and return them instead, the normal processing will no longer take place:

```python
>>> def errcheck(result, func, args):
...     if not result:
...         raise WinError()
...     rc = args[1]
...     return rc.left, rc.top, rc.bottom, rc.right
...
>>> GetWindowRect.errcheck = errcheck
```n
### 16.16.2.5. Utility functions

**ctypes.addressof(obj)**

Returns the address of the memory buffer as integer. *obj* must be an instance of a ctypes type.

**ctypes.alignment(obj_or_type)**
Returns the alignment requirements of a ctypes type. `obj_or_type` must be a ctypes type or instance.

**ctypes.byref(obj[, offset])**

Returns a light-weight pointer to `obj`, which must be an instance of a ctypes type. `offset` defaults to zero, and must be an integer that will be added to the internal pointer value.

`byref(obj, offset)` corresponds to this C code:

```
((((char *)&obj) + offset)
```

The returned object can only be used as a foreign function call parameter. It behaves similar to `pointer(obj)`, but the construction is a lot faster.

**ctypes.cast(obj, type)**

This function is similar to the cast operator in C. It returns a new instance of `type` which points to the same memory block as `obj`. `type` must be a pointer type, and `obj` must be an object that can be interpreted as a pointer.

**ctypes.create_string_buffer(init_or_size, size=None)**

This function creates a mutable character buffer. The returned object is a ctypes array of `c_char`.

`init_or_size` must be an integer which specifies the size of the array, or a bytes object which will be used to initialize the array items.

If a bytes object is specified as first argument, the buffer is made one item larger than its length so that the last element in the array is a NUL termination character. An integer can be passed as
second argument which allows to specify the size of the array if the length of the bytes should not be used.

`ctypes.create_unicode_buffer(init_or_size, size=None)`

This function creates a mutable unicode character buffer. The returned object is a ctypes array of `c_wchar`.

`init_or_size` must be an integer which specifies the size of the array, or a string which will be used to initialize the array items.

If a string is specified as first argument, the buffer is made one item larger than the length of the string so that the last element in the array is a NUL termination character. An integer can be passed as second argument which allows to specify the size of the array if the length of the string should not be used.

`ctypes.DllCanUnloadNow()`

Windows only: This function is a hook which allows to implement in-process COM servers with ctypes. It is called from the DllCanUnloadNow function that the _ctypes extension dll exports.

`ctypes.DllGetClassObject()`

Windows only: This function is a hook which allows to implement in-process COM servers with ctypes. It is called from the DllGetClassObject function that the _ctypes extension dll exports.

`ctypes.util.find_library(name)`

Try to find a library and return a pathname. `name` is the library name without any prefix like lib, suffix like .so, .dylib or version number (this is the form used for the posix linker option `-l`). If no library can be found, returns None.

The exact functionality is system dependent.
**ctypes.util.find_msvcrt()**

Windows only: return the filename of the VC runtime library used by Python, and by the extension modules. If the name of the library cannot be determined, None is returned.

If you need to free memory, for example, allocated by an extension module with a call to the `free(void *)`, it is important that you use the function in the same library that allocated the memory.

**ctypes.FormatError([code])**

Windows only: Returns a textual description of the error code `code`. If no error code is specified, the last error code is used by calling the Windows api function `GetLastError`.

**ctypes.GetLastError()**

Windows only: Returns the last error code set by Windows in the calling thread. This function calls the Windows `GetLastError()` function directly, it does not return the ctypes-private copy of the error code.

**ctypes.get_errno()**

Returns the current value of the ctypes-private copy of the system `errno` variable in the calling thread.

**ctypes.get_last_error()**

Windows only: returns the current value of the ctypes-private copy of the system `LastError` variable in the calling thread.

**ctypes.memmove(dst, src, count)**

Same as the standard C memmove library function: copies `count` bytes from `src` to `dst`. `dst` and `src` must be integers or ctypes instances that can be converted to pointers.
ctypes.**memset**(\(dst, c, count\))
Same as the standard C memset library function: fills the memory block at address \(dst\) with \(count\) bytes of value \(c\). \(dst\) must be an integer specifying an address, or a ctypes instance.

ctypes.**POINTER**(\(type\))
This factory function creates and returns a new ctypes pointer type. Pointer types are cached an reused internally, so calling this function repeatedly is cheap. \(type\) must be a ctypes type.

ctypes.**pointer**(\(obj\))
This function creates a new pointer instance, pointing to \(obj\). The returned object is of the type \(POINTER(type(obj))\).

Note: If you just want to pass a pointer to an object to a foreign function call, you should use \(byref(obj)\) which is much faster.

ctypes.**resize**(\(obj, size\))
This function resizes the internal memory buffer of \(obj\), which must be an instance of a ctypes type. It is not possible to make the buffer smaller than the native size of the objects type, as given by \(sizeof(type(obj))\), but it is possible to enlarge the buffer.

ctypes.**set_errno**(\(value\))
Set the current value of the ctypes-private copy of the system \(errno\) variable in the calling thread to \(value\) and return the previous value.

ctypes.**set_last_error**(\(value\))
Windows only: set the current value of the ctypes-private copy of the system \(LastError\) variable in the calling thread to \(value\) and return the previous value.
ctypes.sizeof(obj_or_type)
Returns the size in bytes of a ctypes type or instance memory buffer. Does the same as the C sizeof operator.

c ctypes.string_at(address, size=-1)
This function returns the C string starting at memory address address as a bytes object. If size is specified, it is used as size, otherwise the string is assumed to be zero-terminated.

c ctypes.WinError(code=None, descr=None)
Windows only: this function is probably the worst-named thing in ctypes. It creates an instance of OSError. If code is not specified, GetLastError is called to determine the error code. If descr is not specified, FormatError() is called to get a textual description of the error.

    Changed in version 3.3: An instance of WindowsError used to be created.

c ctypes.wstring_at(address, size=-1)
This function returns the wide character string starting at memory address address as a string. If size is specified, it is used as the number of characters of the string, otherwise the string is assumed to be zero-terminated.

16.16.2.6. Data types

class ctypes._CData
    This non-public class is the common base class of all ctypes data types. Among other things, all ctypes type instances contain a memory block that hold C compatible data; the address of the memory block is returned by the addressof() helper function.
Another instance variable is exposed as `_objects`; this contains other Python objects that need to be kept alive in case the memory block contains pointers.

Common methods of ctypes data types, these are all class methods (to be exact, they are methods of the `metaclass`):

**from_buffer**(`source[, offset]`)

This method returns a ctypes instance that shares the buffer of the `source` object. The `source` object must support the writeable buffer interface. The optional `offset` parameter specifies an offset into the source buffer in bytes; the default is zero. If the source buffer is not large enough a `ValueError` is raised.

**from_buffer_copy**(`source[, offset]`)

This method creates a ctypes instance, copying the buffer from the `source` object buffer which must be readable. The optional `offset` parameter specifies an offset into the source buffer in bytes; the default is zero. If the source buffer is not large enough a `ValueError` is raised.

**from_address**(`address`)

This method returns a ctypes type instance using the memory specified by `address` which must be an integer.

**from_param**(`obj`)

This method adapts `obj` to a ctypes type. It is called with the actual object used in a foreign function call when the type is present in the foreign function’s `argtypes` tuple; it must return an object that can be used as a function call parameter.

All ctypes data types have a default implementation of this
classmethod that normally returns \( \text{obj} \) if that is an instance of the type. Some types accept other objects as well.

\texttt{in\_dll(library, name)}

This method returns a ctypes type instance exported by a shared library. \textit{name} is the name of the symbol that exports the data, \textit{library} is the loaded shared library.

Common instance variables of ctypes data types:

\_b\_base_

Sometimes ctypes data instances do not own the memory block they contain, instead they share part of the memory block of a base object. The \_b\_base\_ read-only member is the root ctypes object that owns the memory block.

\_b\_needsfree_

This read-only variable is true when the ctypes data instance has allocated the memory block itself, false otherwise.

\_objects_

This member is either None or a dictionary containing Python objects that need to be kept alive so that the memory block contents is kept valid. This object is only exposed for debugging; never modify the contents of this dictionary.

16.16.2.7. Fundamental data types

\texttt{class ctypes._SimpleCData}

This non-public class is the base class of all fundamental ctypes data types. It is mentioned here because it contains the common attributes of the fundamental ctypes data types. \_SimpleCData is
a subclass of _CData, so it inherits their methods and attributes. ctypes data types that are not and do not contain pointers can now be pickled.

Instances have a single attribute:

**value**

This attribute contains the actual value of the instance. For integer and pointer types, it is an integer, for character types, it is a single character bytes object or string, for character pointer types it is a Python bytes object or string.

When the value attribute is retrieved from a ctypes instance, usually a new object is returned each time. ctypes does not implement original object return, always a new object is constructed. The same is true for all other ctypes object instances.

Fundamental data types, when returned as foreign function call results, or, for example, by retrieving structure field members or array items, are transparently converted to native Python types. In other words, if a foreign function has a restype of c_char_p, you will always receive a Python bytes object, not a c_char_p instance.

Subclasses of fundamental data types do not inherit this behavior. So, if a foreign functions restype is a subclass of c_void_p, you will receive an instance of this subclass from the function call. Of course, you can get the value of the pointer by accessing the value attribute.

These are the fundamental ctypes data types:

**class ctypes.c_byte**

Represents the C signed char datatype, and interprets the value
as small integer. The constructor accepts an optional integer initializer; no overflow checking is done.

_class ctypes.c_char_

Represents the C char datatype, and interprets the value as a single character. The constructor accepts an optional string initializer, the length of the string must be exactly one character.

_class ctypes.c_char_p_

Represents the C char * datatype when it points to a zero-terminated string. For a general character pointer that may also point to binary data, POINTER(c_char) must be used. The constructor accepts an integer address, or a bytes object.

_class ctypes.c_double_

Represents the C double datatype. The constructor accepts an optional float initializer.

_class ctypes.c_longdouble_

Represents the C long double datatype. The constructor accepts an optional float initializer. On platforms where sizeof(long double) == sizeof(double) it is an alias to c_double.

_class ctypes.c_float_

Represents the C float datatype. The constructor accepts an optional float initializer.

_class ctypes.c_int_

Represents the C signed int datatype. The constructor accepts an optional integer initializer; no overflow checking is done. On platforms where sizeof(int) == sizeof(long) it is an alias
to `c_long`.

```python
class ctypes.c_int8
    Represents the C 8-bit signed `int` datatype. Usually an alias for `c_byte`.

class ctypes.c_int16
    Represents the C 16-bit signed `int` datatype. Usually an alias for `c_short`.

class ctypes.c_int32
    Represents the C 32-bit signed `int` datatype. Usually an alias for `c_int`.

class ctypes.c_int64
    Represents the C 64-bit signed `int` datatype. Usually an alias for `c_longlong`.

class ctypes.c_long
    Represents the C signed `long` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_longlong
    Represents the C signed `long long` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_short
    Represents the C signed `short` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_size_t
    Represents the C `size_t` datatype.
class ctypes.c_ssize_t
    Represents the C ssize_t datatype.

    *New in version 3.2.*

class ctypes.c_ubyte
    Represents the C unsigned char datatype, it interprets the value as small integer. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_uint
    Represents the C unsigned int datatype. The constructor accepts an optional integer initializer; no overflow checking is done. On platforms where sizeof(int) == sizeof(long) it is an alias for c_ulong.

class ctypes.c_uint8
    Represents the C 8-bit unsigned int datatype. Usually an alias for c_ubyte.

class ctypes.c_uint16
    Represents the C 16-bit unsigned int datatype. Usually an alias for c_ushort.

class ctypes.c_uint32
    Represents the C 32-bit unsigned int datatype. Usually an alias for c_uint.

class ctypes.c_uint64
    Represents the C 64-bit unsigned int datatype. Usually an alias for c_ulonglong.

class ctypes.c_ulong
Represents the C unsigned long datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_ulonglong
Represents the C unsigned long long datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_ushort
Represents the C unsigned short datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_void_p
Represents the C void * type. The value is represented as integer. The constructor accepts an optional integer initializer.

class ctypes.c_wchar
Represents the C wchar_t datatype, and interprets the value as a single character unicode string. The constructor accepts an optional string initializer, the length of the string must be exactly one character.

class ctypes.c_wchar_p
Represents the C wchar_t * datatype, which must be a pointer to a zero-terminated wide character string. The constructor accepts an integer address, or a string.

class ctypes.c_bool
Represent the C bool datatype (more accurately, _Bool from C99). Its value can be True or False, and the constructor accepts any object that has a truth value.

class ctypes.HRESULT
Windows only: Represents a HRESULT value, which contains success or error information for a function or method call.

class ctypes.py_object

Represents the C PyObject * datatype. Calling this without an argument creates a NULL PyObject * pointer.

The ctypes.wintypes module provides quite some other Windows specific data types, for example HWND, WPARAM, or DWORD. Some useful structures like MSG or RECT are also defined.

16.16.2.8. Structured data types

class ctypes.Union(*args, **kw)

Abstract base class for unions in native byte order.

class ctypes.BigEndianStructure(*args, **kw)

Abstract base class for structures in big endian byte order.

class ctypes.LittleEndianStructure(*args, **kw)

Abstract base class for structures in little endian byte order.

Structures with non-native byte order cannot contain pointer type fields, or any other data types containing pointer type fields.

class ctypes.Structure(*args, **kw)

Abstract base class for structures in native byte order.

Concrete structure and union types must be created by subclassing one of these types, and at least define a _fields_ class variable. ctypes will create descriptors which allow reading and writing the fields by direct attribute accesses. These are the
_fields_

A sequence defining the structure fields. The items must be 2-tuples or 3-tuples. The first item is the name of the field, the second item specifies the type of the field; it can be any ctypes data type.

For integer type fields like c_int, a third optional item can be given. It must be a small positive integer defining the bit width of the field.

Field names must be unique within one structure or union. This is not checked, only one field can be accessed when names are repeated.

It is possible to define the _fields_ class variable after the class statement that defines the Structure subclass, this allows to create data types that directly or indirectly reference themselves:

```python
class List(Structure):
    pass
List._fields_ = ["pnext", POINTER(List),
    ...
]
```

The _fields_ class variable must, however, be defined before the type is first used (an instance is created, sizeof() is called on it, and so on). Later assignments to the _fields_ class variable will raise an AttributeError.

It is possible to defined sub-subclasses of structure types, they inherit the fields of the base class plus the _fields_ defined in the sub-subclass, if any.
_pack_

An optional small integer that allows to override the alignment of structure fields in the instance. _pack_ must already be defined when _fields_ is assigned, otherwise it will have no effect.

_anonymous_

An optional sequence that lists the names of unnamed (anonymous) fields. _anonymous_ must be already defined when _fields_ is assigned, otherwise it will have no effect.

The fields listed in this variable must be structure or union type fields. ctypes will create descriptors in the structure type that allows to access the nested fields directly, without the need to create the structure or union field.

Here is an example type (Windows):

```python
class _U(Union):
    _fields_ = [(
        "lptdesc", POINTER(TYPEDESC)),
        ("lpadesc", POINTER(ARRAYDESC)),
        ("hreftype", HREFTYPE)]

class TYPEDESC(Structure):
    _anonymous_ = ("u",)
    _fields_ = [(
        "u", _U),
        ("vt", VARTYPE)]
```

The TYPEDESC structure describes a COM data type, the vt field specifies which one of the union fields is valid. Since the u field is defined as anonymous field, it is now possible to access the members directly off the TYPEDESC instance. td.lptdesc and td.u.lptdesc are equivalent, but the
former is faster since it does not need to create a temporary union instance:

```
td = TYPEDESC()
    td.vt = VT_PTR
    td.lptdesc = POINTER(some_type)
    td.u.lptdesc = POINTER(some_type)
```

It is possible to defined sub-subclasses of structures, they inherit the fields of the base class. If the subclass definition has a separate `__fields__` variable, the fields specified in this are appended to the fields of the base class.

Structure and union constructors accept both positional and keyword arguments. Positional arguments are used to initialize member fields in the same order as they are appear in `__fields__`. Keyword arguments in the constructor are interpreted as attribute assignments, so they will initialize `__fields__` with the same name, or create new attributes for names not present in `__fields__`.

### 16.16.2.9. Arrays and pointers

Not yet written - please see the sections `Pointers` and section `Arrays` in the tutorial.
17. Concurrent Execution

The modules described in this chapter provide support for concurrent execution of code. The appropriate choice of tool will depend on the task to be executed (CPU bound vs IO bound) and preferred style of development (event driven cooperative multitasking vs preemptive multitasking). Here’s an overview:

- **17.1. threading — Thread-based parallelism**
  - 17.1.1. Thread-Local Data
  - 17.1.2. Thread Objects
  - 17.1.3. Lock Objects
  - 17.1.4. RLock Objects
  - 17.1.5. Condition Objects
  - 17.1.6. Semaphore Objects
    - 17.1.6.1. Semaphore Example
  - 17.1.7. Event Objects
  - 17.1.8. Timer Objects
  - 17.1.9. Barrier Objects
  - 17.1.10. Using locks, conditions, andsemaphores in the with statement

- **17.2. multiprocessing — Process-based parallelism**
  - 17.2.1. Introduction
    - 17.2.1.1. The Process class
    - 17.2.1.2. Contexts and start methods
    - 17.2.1.3. Exchanging objects between processes
    - 17.2.1.4. Synchronization between processes
    - 17.2.1.5. Sharing state between processes
    - 17.2.1.6. Using a pool of workers
  - 17.2.2. Reference
    - 17.2.2.1. Process and exceptions
    - 17.2.2.2. Pipes and Queues
17.2.2.3. Miscellaneous
17.2.2.4. Connection Objects
17.2.2.5. Synchronization primitives
17.2.2.6. Shared ctypes Objects
   17.2.2.6.1. The multiprocessing.sharedctypes module
17.2.2.7. Managers
   17.2.2.7.1. Namespace objects
   17.2.2.7.2. Customized managers
   17.2.2.7.3. Using a remote manager
17.2.2.8. Proxy Objects
   17.2.2.8.1. Cleanup
17.2.2.9. Process Pools
17.2.2.10. Listeners and Clients
   17.2.2.10.1. Address Formats
17.2.2.11. Authentication keys
17.2.2.12. Logging
17.2.2.13. The multiprocessing.dummy module
   17.2.3. Programming guidelines
      17.2.3.1. All start methods
      17.2.3.2. The spawn and forkserver start methods
   17.2.4. Examples
17.3. The concurrent package
17.4. concurrent.futures — Launching parallel tasks
   17.4.1. Executor Objects
   17.4.2. ThreadPoolExecutor
      17.4.2.1. ThreadPoolExecutor Example
   17.4.3. ProcessPoolExecutor
      17.4.3.1. ProcessPoolExecutor Example
   17.4.4. Future Objects
   17.4.5. Module Functions
   17.4.6. Exception classes
17.5. subprocess — Subprocess management
   17.5.1. Using the subprocess Module
- 17.5.1.1. Frequently Used Arguments
- 17.5.1.2. Popen Constructor
- 17.5.1.3. Exceptions
- 17.5.2. Security Considerations
- 17.5.3. Popen Objects
- 17.5.4. Windows Popen Helpers
  - 17.5.4.1. Constants
- 17.5.5. Older high-level API
- 17.5.6. Replacing Older Functions with the subprocess Module
  - 17.5.6.1. Replacing /bin/sh shell backquote
  - 17.5.6.2. Replacing shell pipeline
  - 17.5.6.3. Replacing os.system()
  - 17.5.6.4. Replacing the os.spawn family
  - 17.5.6.5. Replacing os.popen(), os.popen2(), os.popen3()
  - 17.5.6.6. Replacing functions from the popen2 module
- 17.5.7. Legacy Shell Invocation Functions
- 17.5.8. Notes
  - 17.5.8.1. Converting an argument sequence to a string on Windows
- 17.6. sched — Event scheduler
  - 17.6.1. Scheduler Objects
- 17.7. queue — A synchronized queue class
  - 17.7.1. Queue Objects

The following are support modules for some of the above services:

- 17.8. dummy_threading — Drop-in replacement for the threading module
- 17.9. _thread — Low-level threading API
- 17.10. _dummy_thread — Drop-in replacement for the _thread module
17.1. `threading` — Thread-based parallelism

**Source code:** `Lib/threading.py`

This module constructs higher-level threading interfaces on top of the lower level `_thread` module. See also the `queue` module.

The `dummy_threading` module is provided for situations where `threading` cannot be used because `_thread` is missing.

**Note:** While they are not listed below, the camelCase names used for some methods and functions in this module in the Python 2.x series are still supported by this module.

This module defines the following functions:

- `threading.active_count()`
  Return the number of `Thread` objects currently alive. The returned count is equal to the length of the list returned by `enumerate()`.

- `threading.current_thread()`
  Return the current `Thread` object, corresponding to the caller’s thread of control. If the caller’s thread of control was not created through the `threading` module, a dummy thread object with limited functionality is returned.

- `threading.get_ident()`
  Return the ‘thread identifier’ of the current thread. This is a nonzero
integer. Its value has no direct meaning; it is intended as a magic cookie to be used e.g. to index a dictionary of thread-specific data. Thread identifiers may be recycled when a thread exits and another thread is created.

*New in version 3.3.*

**threading.enumerate()**  
Return a list of all *Thread* objects currently alive. The list includes daemonic threads, dummy thread objects created by `current_thread()`, and the main thread. It excludes terminated threads and threads that have not yet been started.

**threading.main_thread()**  
Return the main *Thread* object. In normal conditions, the main thread is the thread from which the Python interpreter was started.

*New in version 3.4.*

**threading.settrace(func)**  
Set a trace function for all threads started from the *threading* module. The *func* will be passed to `sys.settrace()` for each thread, before its `run()` method is called.

**threading.setprofile(func)**  
Set a profile function for all threads started from the *threading* module. The *func* will be passed to `sys.setprofile()` for each thread, before its `run()` method is called.

**threading.stack_size([size])**  
Return the thread stack size used when creating new threads. The optional *size* argument specifies the stack size to be used for
subsequently created threads, and must be 0 (use platform or configured default) or a positive integer value of at least 32,768 (32 KiB). If size is not specified, 0 is used. If changing the thread stack size is unsupported, a **RuntimeError** is raised. If the specified stack size is invalid, a **ValueError** is raised and the stack size is unmodified. 32 KiB is currently the minimum supported stack size value to guarantee sufficient stack space for the interpreter itself. Note that some platforms may have particular restrictions on values for the stack size, such as requiring a minimum stack size > 32 KiB or requiring allocation in multiples of the system memory page size - platform documentation should be referred to for more information (4 KiB pages are common; using multiples of 4096 for the stack size is the suggested approach in the absence of more specific information). Availability: Windows, systems with POSIX threads.

This module also defines the following constant:

**threading.TIMOUT_MAX**

The maximum value allowed for the *timeout* parameter of blocking functions *(Lock.acquire(), RLock.acquire(), Condition.wait(), etc.)*. Specifying a timeout greater than this value will raise an **OverflowError**.

*New in version 3.2.*

This module defines a number of classes, which are detailed in the sections below.

The design of this module is loosely based on Java’s threading model. However, where Java makes locks and condition variables basic behavior of every object, they are separate objects in Python. Python’s **Thread** class supports a subset of the behavior of Java’s **Thread**
class; currently, there are no priorities, no thread groups, and threads cannot be destroyed, stopped, suspended, resumed, or interrupted. The static methods of Java's Thread class, when implemented, are mapped to module-level functions.

All of the methods described below are executed atomically.
17.1.1. Thread-Local Data

Thread-local data is data whose values are thread specific. To manage thread-local data, just create an instance of `local` (or a subclass) and store attributes on it:

```python
mydata = threading.local()
mydata.x = 1
```

The instance's values will be different for separate threads.

`class threading.local`

A class that represents thread-local data.

For more details and extensive examples, see the documentation string of the `_threading_local` module.
17.1.2. Thread Objects

The **Thread** class represents an activity that is run in a separate thread of control. There are two ways to specify the activity: by passing a callable object to the constructor, or by overriding the `run()` method in a subclass. No other methods (except for the constructor) should be overridden in a subclass. In other words, *only* override the `__init__()` and `run()` methods of this class.

Once a thread object is created, its activity must be started by calling the thread's `start()` method. This invokes the `run()` method in a separate thread of control.

Once the thread's activity is started, the thread is considered ‘alive’. It stops being alive when its `run()` method terminates – either normally, or by raising an unhandled exception. The `is_alive()` method tests whether the thread is alive.

Other threads can call a thread’s `join()` method. This blocks the calling thread until the thread whose `join()` method is called is terminated.

A thread has a name. The name can be passed to the constructor, and read or changed through the `name` attribute.

A thread can be flagged as a “daemon thread”. The significance of this flag is that the entire Python program exits when only daemon threads are left. The initial value is inherited from the creating thread. The flag can be set through the `daemon` property or the `daemon` constructor argument.

**Note:** Daemon threads are abruptly stopped at shutdown. Their
resources (such as open files, database transactions, etc.) may not be released properly. If you want your threads to stop gracefully, make them non-daemonic and use a suitable signalling mechanism such as an Event.

There is a “main thread” object; this corresponds to the initial thread of control in the Python program. It is not a daemon thread.

There is the possibility that “dummy thread objects” are created. These are thread objects corresponding to “alien threads”, which are threads of control started outside the threading module, such as directly from C code. Dummy thread objects have limited functionality; they are always considered alive and daemonic, and cannot be join()ed. They are never deleted, since it is impossible to detect the termination of alien threads.

class threading.Thread(group=None, target=None, name=None, 
args=(), kwargs={}, *, daemon=None)

This constructor should always be called with keyword arguments. Arguments are:

group should be None; reserved for future extension when a ThreadGroup class is implemented.

target is the callable object to be invoked by the run() method. Defaults to None, meaning nothing is called.

name is the thread name. By default, a unique name is constructed of the form “Thread-N” where N is a small decimal number.

args is the argument tuple for the target invocation. Defaults to ()

kwvars is a dictionary of keyword arguments for the target
invocation. Defaults to `{}`.

If not None, `daemon` explicitly sets whether the thread is daemonic. If None (the default), the daemonic property is inherited from the current thread.

If the subclass overrides the constructor, it must make sure to invoke the base class constructor (`Thread.__init__()`)) before doing anything else to the thread.

*Changed in version 3.3:* Added the `daemon` argument.

**start()**
Start the thread's activity.

It must be called at most once per thread object. It arranges for the object's `run()` method to be invoked in a separate thread of control.

This method will raise a `RuntimeError` if called more than once on the same thread object.

**run()**
Method representing the thread's activity.

You may override this method in a subclass. The standard `run()` method invokes the callable object passed to the object's constructor as the `target` argument, if any, with sequential and keyword arguments taken from the `args` and `kwargs` arguments, respectively.

**join(timeout=None)**
Wait until the thread terminates. This blocks the calling thread
until the thread whose `join()` method is called terminates – either normally or through an unhandled exception –, or until the optional timeout occurs.

When the `timeout` argument is present and not None, it should be a floating point number specifying a timeout for the operation in seconds (or fractions thereof). As `join()` always returns None, you must call `is_alive()` after `join()` to decide whether a timeout happened – if the thread is still alive, the `join()` call timed out.

When the `timeout` argument is not present or None, the operation will block until the thread terminates.

A thread can be `join()`ed many times.

`join()` raises a `RuntimeError` if an attempt is made to join the current thread as that would cause a deadlock. It is also an error to `join()` a thread before it has been started and attempts to do so raise the same exception.

**name**

A string used for identification purposes only. It has no semantics. Multiple threads may be given the same name. The initial name is set by the constructor.

**getName()**

**setName()**

Old getter/setter API for `name`; use it directly as a property instead.

**ident**

The ‘thread identifier’ of this thread or None if the thread has
not been started. This is a nonzero integer. See the _thread.get_ident() function. Thread identifiers may be recycled when a thread exits and another thread is created. The identifier is available even after the thread has exited.

**is_alive()**

Return whether the thread is alive.

This method returns True just before the run() method starts until just after the run() method terminates. The module function enumerate() returns a list of all alive threads.

**daemon**

A boolean value indicating whether this thread is a daemon thread (True) or not (False). This must be set before start() is called, otherwise RuntimeError is raised. Its initial value is inherited from the creating thread; the main thread is not a daemon thread and therefore all threads created in the main thread default to daemon = False.

The entire Python program exits when no alive non-daemon threads are left.

**isDaemon()**

**setDaemon()**

Old getter/setter API for daemon; use it directly as a property instead.

**CPython implementation detail:** In CPython, due to the Global Interpreter Lock, only one thread can execute Python code at once (even though certain performance-oriented libraries might overcome this limitation). If you want your application to make better use of the
computational resources of multi-core machines, you are advised to use multiprocessing or concurrent.futures.ProcessPoolExecutor. However, threading is still an appropriate model if you want to run multiple I/O-bound tasks simultaneously.
17.1.3. Lock Objects

A primitive lock is a synchronization primitive that is not owned by a particular thread when locked. In Python, it is currently the lowest level synchronization primitive available, implemented directly by the _thread extension module.

A primitive lock is in one of two states, “locked” or “unlocked”. It is created in the unlocked state. It has two basic methods, acquire() and release(). When the state is unlocked, acquire() changes the state to locked and returns immediately. When the state is locked, acquire() blocks until a call to release() in another thread changes it to unlocked, then the acquire() call resets it to locked and returns. The release() method should only be called in the locked state; it changes the state to unlocked and returns immediately. If an attempt is made to release an unlocked lock, a RuntimeError will be raised.

Locks also support the context management protocol.

When more than one thread is blocked in acquire() waiting for the state to turn to unlocked, only one thread proceeds when a release() call resets the state to unlocked; which one of the waiting threads proceeds is not defined, and may vary across implementations.

All methods are executed atomically.

class threading.Lock

The class implementing primitive lock objects. Once a thread has acquired a lock, subsequent attempts to acquire it block, until it is released; any thread may release it.
*Changed in version 3.3:* Changed from a factory function to a class.

**acquire**(blocking=True, timeout=-1)

Acquire a lock, blocking or non-blocking.

When invoked with the *blocking* argument set to True (the default), block until the lock is unlocked, then set it to locked and return True.

When invoked with the *blocking* argument set to False, do not block. If a call with *blocking* set to True would block, return False immediately; otherwise, set the lock to locked and return True.

When invoked with the floating-point *timeout* argument set to a positive value, block for at most the number of seconds specified by *timeout* and as long as the lock cannot be acquired. A *timeout* argument of -1 specifies an unbounded wait. It is forbidden to specify a *timeout* when *blocking* is false.

The return value is True if the lock is acquired successfully, False if not (for example if the *timeout* expired).

*Changed in version 3.2:* The *timeout* parameter is new.

*Changed in version 3.2:* Lock acquires can now be interrupted by signals on POSIX.

**release**()

Release a lock. This can be called from any thread, not only the thread which has acquired the lock.
When the lock is locked, reset it to unlocked, and return. If any other threads are blocked waiting for the lock to become unlocked, allow exactly one of them to proceed.

When invoked on an unlocked lock, a `RuntimeError` is raised.

There is no return value.
17.1.4. RLock Objects

A reentrant lock is a synchronization primitive that may be acquired multiple times by the same thread. Internally, it uses the concepts of “owning thread” and “recursion level” in addition to the locked/unlocked state used by primitive locks. In the locked state, some thread owns the lock; in the unlocked state, no thread owns it.

To lock the lock, a thread calls its `acquire()` method; this returns once the thread owns the lock. To unlock the lock, a thread calls its `release()` method. `acquire()`/`release()` call pairs may be nested; only the final `release()` (the `release()` of the outermost pair) resets the lock to unlocked and allows another thread blocked in `acquire()` to proceed.

Reentrant locks also support the context management protocol.

`class threading.RLock`

This class implements reentrant lock objects. A reentrant lock must be released by the thread that acquired it. Once a thread has acquired a reentrant lock, the same thread may acquire it again without blocking; the thread must release it once for each time it has acquired it.

Note that RLock is actually a factory function which returns an instance of the most efficient version of the concrete RLock class that is supported by the platform.

`acquire(blocking=True, timeout=-1)`

Acquire a lock, blocking or non-blocking.

When invoked without arguments: if this thread already owns
the lock, increment the recursion level by one, and return immediately. Otherwise, if another thread owns the lock, block until the lock is unlocked. Once the lock is unlocked (not owned by any thread), then grab ownership, set the recursion level to one, and return. If more than one thread is blocked waiting until the lock is unlocked, only one at a time will be able to grab ownership of the lock. There is no return value in this case.

When invoked with the `blocking` argument set to true, do the same thing as when called without arguments, and return true.

When invoked with the `blocking` argument set to false, do not block. If a call without an argument would block, return false immediately; otherwise, do the same thing as when called without arguments, and return true.

When invoked with the floating-point `timeout` argument set to a positive value, block for at most the number of seconds specified by `timeout` and as long as the lock cannot be acquired. Return true if the lock has been acquired, false if the timeout has elapsed.

*Changed in version 3.2:* The `timeout` parameter is new.

`release()`

Release a lock, decrementing the recursion level. If after the decrement it is zero, reset the lock to unlocked (not owned by any thread), and if any other threads are blocked waiting for the lock to become unlocked, allow exactly one of them to proceed. If after the decrement the recursion level is still nonzero, the lock remains locked and owned by the calling thread.

Only call this method when the calling thread owns the lock. A
`RuntimeError` is raised if this method is called when the lock is unlocked.

There is no return value.
17.1.5. Condition Objects

A condition variable is always associated with some kind of lock; this can be passed in or one will be created by default. Passing one in is useful when several condition variables must share the same lock. The lock is part of the condition object: you don’t have to track it separately.

A condition variable obeys the context management protocol: using the with statement acquires the associated lock for the duration of the enclosed block. The acquire() and release() methods also call the corresponding methods of the associated lock.

Other methods must be called with the associated lock held. The wait() method releases the lock, and then blocks until another thread awakens it by calling notify() or notify_all(). Once awakened, wait() re-acquires the lock and returns. It is also possible to specify a timeout.

The notify() method wakes up one of the threads waiting for the condition variable, if any are waiting. The notify_all() method wakes up all threads waiting for the condition variable.

Note: the notify() and notify_all() methods don’t release the lock; this means that the thread or threads awakened will not return from their wait() call immediately, but only when the thread that called notify() or notify_all() finally relinquishes ownership of the lock.

The typical programming style using condition variables uses the lock to synchronize access to some shared state; threads that are
interested in a particular change of state call `wait()` repeatedly until they see the desired state, while threads that modify the state call `notify()` or `notify_all()` when they change the state in such a way that it could possibly be a desired state for one of the waiters. For example, the following code is a generic producer-consumer situation with unlimited buffer capacity:

```python
# Consume one item
with cv:
    while not an_item_is_available():
        cv.wait()
        get_an_available_item()

# Produce one item
with cv:
    make_an_item_available()
    cv.notify()
```

The while loop checking for the application's condition is necessary because `wait()` can return after an arbitrary long time, and the condition which prompted the `notify()` call may no longer hold true. This is inherent to multi-threaded programming. The `wait_for()` method can be used to automate the condition checking, and eases the computation of timeouts:

```python
# Consume an item
with cv:
    cv.wait_for(an_item_is_available)
    get_an_available_item()
```

To choose between `notify()` and `notify_all()`, consider whether one state change can be interesting for only one or several waiting threads. E.g. in a typical producer-consumer situation, adding one item
to the buffer only needs to wake up one consumer thread.

```python
class threading.Condition(lock=None)
```

This class implements condition variable objects. A condition variable allows one or more threads to wait until they are notified by another thread.

If the `lock` argument is given and not `None`, it must be a `Lock` or `RLock` object, and it is used as the underlying lock. Otherwise, a new `RLock` object is created and used as the underlying lock.

*Changed in version 3.3:* changed from a factory function to a class.

### acquire(*args)

Acquire the underlying lock. This method calls the corresponding method on the underlying lock; the return value is whatever that method returns.

### release()

Release the underlying lock. This method calls the corresponding method on the underlying lock; there is no return value.

### wait(timeout=None)

Wait until notified or until a timeout occurs. If the calling thread has not acquired the lock when this method is called, a `RuntimeError` is raised.

This method releases the underlying lock, and then blocks until it is awakened by a `notify()` or `notify_all()` call for the same condition variable in another thread, or until the optional timeout occurs. Once awakened or timed out, it re-acquires the lock and returns.
When the *timeout* argument is present and not None, it should be a floating point number specifying a timeout for the operation in seconds (or fractions thereof).

When the underlying lock is an *RLock*, it is not released using its *release()* method, since this may not actually unlock the lock when it was acquired multiple times recursively. Instead, an internal interface of the *RLock* class is used, which really unlocks it even when it has been recursively acquired several times. Another internal interface is then used to restore the recursion level when the lock is reacquired.

The return value is True unless a given *timeout* expired, in which case it is False.

*Changed in version 3.2:* Previously, the method always returned None.

**wait_for**(predicate, timeout=None)

Wait until a condition evaluates to True. *predicate* should be a callable which result will be interpreted as a boolean value. A *timeout* may be provided giving the maximum time to wait.

This utility method may call *wait()* repeatedly until the predicate is satisfied, or until a timeout occurs. The return value is the last return value of the predicate and will evaluate to False if the method timed out.

Ignoring the timeout feature, calling this method is roughly equivalent to writing:

```python
while not predicate():
    cv.wait()
```
Therefore, the same rules apply as with `wait()`: The lock must be held when called and is re-acquired on return. The predicate is evaluated with the lock held.

*New in version 3.2.*

**notify**(*n=1*)

By default, wake up one thread waiting on this condition, if any. If the calling thread has not acquired the lock when this method is called, a `RuntimeError` is raised.

This method wakes up at most *n* of the threads waiting for the condition variable; it is a no-op if no threads are waiting.

The current implementation wakes up exactly *n* threads, if at least *n* threads are waiting. However, it's not safe to rely on this behavior. A future, optimized implementation may occasionally wake up more than *n* threads.

Note: an awakened thread does not actually return from its `wait()` call until it can reacquire the lock. Since `notify()` does not release the lock, its caller should.

**notify_all()**

Wake up all threads waiting on this condition. This method acts like `notify()`, but wakes up all waiting threads instead of one. If the calling thread has not acquired the lock when this method is called, a `RuntimeError` is raised.
17.1.6. Semaphore Objects

This is one of the oldest synchronization primitives in the history of computer science, invented by the early Dutch computer scientist Edsger W. Dijkstra (he used the names P() and V() instead of acquire() and release()).

A semaphore manages an internal counter which is decremented by each acquire() call and incremented by each release() call. The counter can never go below zero; when acquire() finds that it is zero, it blocks, waiting until some other thread calls release().

Semaphores also support the context management protocol.

```python
class threading.Semaphore(value=1)
    This class implements semaphore objects. A semaphore manages a counter representing the number of release() calls minus the number of acquire() calls, plus an initial value. The acquire() method blocks if necessary until it can return without making the counter negative. If not given, value defaults to 1.
```

The optional argument gives the initial value for the internal counter; it defaults to 1. If the value given is less than 0, ValueError is raised.

*Changed in version 3.3*: changed from a factory function to a class.

```python
acquire(blocking=True, timeout=None)
    Acquire a semaphore.
```

When invoked without arguments: if the internal counter is larger than zero on entry, decrement it by one and return
immediately. If it is zero on entry, block, waiting until some other thread has called `release()` to make it larger than zero. This is done with proper interlocking so that if multiple `acquire()` calls are blocked, `release()` will wake exactly one of them up. The implementation may pick one at random, so the order in which blocked threads are awakened should not be relied on. Returns true (or blocks indefinitely).

When invoked with `blocking` set to false, do not block. If a call without an argument would block, return false immediately; otherwise, do the same thing as when called without arguments, and return true.

When invoked with a `timeout` other than None, it will block for at most `timeout` seconds. If `acquire` does not complete successfully in that interval, return false. Return true otherwise.

*Changed in version 3.2:* The `timeout` parameter is new.

**release()**

Release a semaphore, incrementing the internal counter by one. When it was zero on entry and another thread is waiting for it to become larger than zero again, wake up that thread.

**class threading.BoundedSemaphore(value=1)**

Class implementing bounded semaphore objects. A bounded semaphore checks to make sure its current value doesn’t exceed its initial value. If it does, `ValueError` is raised. In most situations semaphores are used to guard resources with limited capacity. If the semaphore is released too many times it’s a sign of a bug. If not given, `value` defaults to 1.

*Changed in version 3.3:* changed from a factory function to a class.
17.1.6.1. Semaphore Example

Semaphores are often used to guard resources with limited capacity, for example, a database server. In any situation where the size of the resource is fixed, you should use a bounded semaphore. Before spawning any worker threads, your main thread would initialize the semaphore:

```python
maxconnections = 5
# ...
pool_sema = BoundedSemaphore(value=maxconnections)
```

Once spawned, worker threads call the semaphore’s acquire and release methods when they need to connect to the server:

```python
with pool_sema:
    conn = connectdb()
    try:
        # ... use connection ...
    finally:
        conn.close()
```

The use of a bounded semaphore reduces the chance that a programming error which causes the semaphore to be released more than it’s acquired will go undetected.
17.1.7. Event Objects

This is one of the simplest mechanisms for communication between threads: one thread signals an event and other threads wait for it.

An event object manages an internal flag that can be set to true with the set() method and reset to false with the clear() method. The wait() method blocks until the flag is true.

class threading.Event

Class implementing event objects. An event manages a flag that can be set to true with the set() method and reset to false with the clear() method. The wait() method blocks until the flag is true. The flag is initially false.

*Changed in version 3.3:* changed from a factory function to a class.

is_set()

Return true if and only if the internal flag is true.

set()

Set the internal flag to true. All threads waiting for it to become true are awakened. Threads that call wait() once the flag is true will not block at all.

clear()

Reset the internal flag to false. Subsequently, threads calling wait() will block until set() is called to set the internal flag to true again.

wait(timeout=None)

Block until the internal flag is true. If the internal flag is true on
entry, return immediately. Otherwise, block until another thread calls `set()` to set the flag to true, or until the optional timeout occurs.

When the timeout argument is present and not None, it should be a floating point number specifying a timeout for the operation in seconds (or fractions thereof).

This method returns true if and only if the internal flag has been set to true, either before the wait call or after the wait starts, so it will always return `True` except if a timeout is given and the operation times out.

*Changed in version 3.1:* Previously, the method always returned None.
17.1.8. Timer Objects

This class represents an action that should be run only after a certain amount of time has passed — a timer. Timer is a subclass of Thread and as such also functions as an example of creating custom threads.

Timers are started, as with threads, by calling their start() method. The timer can be stopped (before its action has begun) by calling the cancel() method. The interval the timer will wait before executing its action may not be exactly the same as the interval specified by the user.

For example:

```python
def hello():
    print("hello, world")

t = Timer(30.0, hello)
t.start() # after 30 seconds, "hello, world" will be
```

class threading.Timer(interval, function, args=None, kwargs=None)

Create a timer that will run function with arguments args and keyword arguments kwargs, after interval seconds have passed. If args is None (the default) then an empty list will be used. If kwargs is None (the default) then an empty dict will be used.

*Changed in version 3.3:* changed from a factory function to a class.

cancel()

Stop the timer, and cancel the execution of the timer's action. This will only work if the timer is still in its waiting stage.
17.1.9. Barrier Objects

*New in version 3.2.*

This class provides a simple synchronization primitive for use by a fixed number of threads that need to wait for each other. Each of the threads tries to pass the barrier by calling the `wait()` method and will block until all of the threads have made the call. At this points, the threads are released simultaneously.

The barrier can be reused any number of times for the same number of threads.

As an example, here is a simple way to synchronize a client and server thread:

```python
b = Barrier(2, timeout=5)

def server():
    start_server()
    b.wait()
    while True:
        connection = accept_connection()
        process_server_connection(connection)

def client():
    b.wait()
    while True:
        connection = make_connection()
        process_client_connection(connection)
```

```python
class threading.Barrier(parties, action=None, timeout=None)
    Create a barrier object for parties number of threads. An action, when provided, is a callable to be called by one of the threads
```
when they are released. *timeout* is the default timeout value if none is specified for the *wait()* method.

**wait**(timeout=None)

Pass the barrier. When all the threads party to the barrier have called this function, they are all released simultaneously. If a *timeout* is provided, it is used in preference to any that was supplied to the class constructor.

The return value is an integer in the range 0 to parties – 1, different for each thread. This can be used to select a thread to do some special housekeeping, e.g.:

```python
i = barrier.wait()
if i == 0:
    # Only one thread needs to print this
    print("passed the barrier")
```

If an *action* was provided to the constructor, one of the threads will have called it prior to being released. Should this call raise an error, the barrier is put into the broken state.

If the call times out, the barrier is put into the broken state.

This method may raise a *BrokenBarrierError* exception if the barrier is broken or reset while a thread is waiting.

**reset()**

Return the barrier to the default, empty state. Any threads waiting on it will receive the *BrokenBarrierError* exception.

Note that using this function may can require some external synchronization if there are other threads whose state is unknown. If a barrier is broken it may be better to just leave it
and create a new one.

**abort()**

Put the barrier into a broken state. This causes any active or future calls to `wait()` to fail with the `BrokenBarrierError`. Use this for example if one of the needs to abort, to avoid deadlocking the application.

It may be preferable to simply create the barrier with a sensible `timeout` value to automatically guard against one of the threads going awry.

**parties**

The number of threads required to pass the barrier.

**n_waiting**

The number of threads currently waiting in the barrier.

**broken**

A boolean that is True if the barrier is in the broken state.

**exception** `threading.BrokenBarrierError`

This exception, a subclass of `RuntimeError`, is raised when the `Barrier` object is reset or broken.
17.1.10. Using locks, conditions, and semaphores in the `with` statement

All of the objects provided by this module that have `acquire()` and `release()` methods can be used as context managers for a `with` statement. The `acquire()` method will be called when the block is entered, and `release()` will be called when the block is exited. Hence, the following snippet:

```
with some_lock:
    # do something...
```

is equivalent to:

```
some_lock.acquire()
try:
    # do something...
finally:
    some_lock.release()
```

Currently, `Lock`, `RLock`, `Condition`, `Semaphore`, and `BoundedSemaphore` objects may be used as `with` statement context managers.
17.2. *multiprocessing* — Process-based parallelism
17.2.1. Introduction

`multiprocessing` is a package that supports spawning processes using an API similar to the `threading` module. The `multiprocessing` package offers both local and remote concurrency, effectively side-stepping the Global Interpreter Lock by using subprocesses instead of threads. Due to this, the `multiprocessing` module allows the programmer to fully leverage multiple processors on a given machine. It runs on both Unix and Windows.

The `multiprocessing` module also introduces APIs which do not have analogs in the `threading` module. A prime example of this is the `Pool` object which offers a convenient means of parallelizing the execution of a function across multiple input values, distributing the input data across processes (data parallelism). The following example demonstrates the common practice of defining such functions in a module so that child processes can successfully import that module. This basic example of data parallelism using `Pool`,

```python
from multiprocessing import Pool

def f(x):
    return x*x

if __name__ == '__main__':
    with Pool(5) as p:
        print(p.map(f, [1, 2, 3]))
```

will print to standard output

```
[1, 4, 9]
```
17.2.1.1. The **Process** class

In **multiprocessing**, processes are spawned by creating a **Process** object and then calling its **start()** method. **Process** follows the API of **threading.Thread**. A trivial example of a multiprocess program is

```python
from multiprocessing import Process

def f(name):
    print('hello', name)

if __name__ == '__main__':
    p = Process(target=f, args=('bob',))
    p.start()
    p.join()
```

To show the individual process IDs involved, here is an expanded example:

```python
from multiprocessing import Process
import os

def info(title):
    print(title)
    print('module name:', __name__)
    print('parent process:', os.getppid())
    print('process id:', os.getpid())

def f(name):
    info('function f')
    print('hello', name)

if __name__ == '__main__':
    info('main line')
```
p = Process(target=f, args=('bob',))
p.start()
p.join()

For an explanation of why the if __name__ == '__main__' part is necessary, see Programming guidelines.

17.2.1.2. Contexts and start methods

Depending on the platform, multiprocessing supports three ways to start a process. These start methods are

    * **spawn**
      The parent process starts a fresh python interpreter process. The child process will only inherit those resources necessary to run the process objects run() method. In particular, unnecessary file descriptors and handles from the parent process will not be inherited. Starting a process using this method is rather slow compared to using fork or forkserver.

      Available on Unix and Windows. The default on Windows.

    * **fork**
      The parent process uses os.fork() to fork the Python interpreter. The child process, when it begins, is effectively identical to the parent process. All resources of the parent are inherited by the child process. Note that safely forking a multithreaded process is problematic.

      Available on Unix only. The default on Unix.

    * **forkserver**
      When the program starts and selects the forkserver start
method, a server process is started. From then on, whenever a new process is needed, the parent process connects to the server and requests that it fork a new process. The fork server process is single threaded so it is safe for it to use `os.fork()`. No unnecessary resources are inherited.

Available on Unix platforms which support passing file descriptors over Unix pipes.

*Changed in version 3.4:* `spawn` added on all unix platforms, and `forkserver` added for some unix platforms. Child processes no longer inherit all of the parents inheritable handles on Windows.

On Unix using the `spawn` or `forkserver` start methods will also start a `semaphore tracker` process which tracks the unlinked named semaphores created by processes of the program. When all processes have exited the semaphore tracker unlinks any remaining semaphores. Usually there should be none, but if a process was killed by a signal there may some “leaked” semaphores. (Unlinking the named semaphores is a serious matter since the system allows only a limited number, and they will not be automatically unlinked until the next reboot.)

To select a start method you use the `set_start_method()` in the `if __name__ == '__main__':` clause of the main module. For example:

```python
import multiprocessing as mp

def foo(q):
    q.put('hello')

if __name__ == '__main__':
    mp.set_start_method('spawn')
```
Python code:
```python
q = mp.Queue()
p = mp.Process(target=foo, args=(q,))
p.start()
print(q.get())
p.join()
```

`set_start_method()` should not be used more than once in the program.

Alternatively, you can use `get_context()` to obtain a context object. Context objects have the same API as the multiprocessing module, and allow one to use multiple start methods in the same program.

```python
import multiprocessing as mp

def foo(q):
    q.put('hello')

if __name__ == '__main__':
    ctx = mp.get_context('spawn')
    q = ctx.Queue()
    p = ctx.Process(target=foo, args=(q,))
    p.start()
    print(q.get())
p.join()
```

Note that objects related to one context may not be compatible with processes for a different context. In particular, locks created using the `fork` context cannot be passed to a processes started using the `spawn` or `forkserver` start methods.

A library which wants to use a particular start method should probably use `get_context()` to avoid interfering with the choice of the library user.
17.2.1.3. Exchanging objects between processes

`multiprocessing` supports two types of communication channel between processes:

**Queues**

The `Queue` class is a near clone of `queue.Queue`. For example:

```python
from multiprocessing import Process, Queue

def f(q):
    q.put([42, None, 'hello'])

if __name__ == '__main__':
    q = Queue()
    p = Process(target=f, args=(q,))
    p.start()
    print(q.get())  # prints "[42, None, 'hello']"
    p.join()
```

Queues are thread and process safe.

**Pipes**

The `Pipe()` function returns a pair of connection objects connected by a pipe which by default is duplex (two-way). For example:

```python
from multiprocessing import Process, Pipe

def f(conn):
    conn.send([42, None, 'hello'])
    conn.close()
```
if __name__ == '__main__':
    parent_conn, child_conn = Pipe()
    p = Process(target=f, args=(child_conn,))
    p.start()
    print(parent_conn.recv())  # prints "[42, None, 'hello']"
    p.join()

The two connection objects returned by Pipe() represent the two ends of the pipe. Each connection object has send() and recv() methods (among others). Note that data in a pipe may become corrupted if two processes (or threads) try to read from or write to the same end of the pipe at the same time. Of course there is no risk of corruption from processes using different ends of the pipe at the same time.

17.2.1.4. Synchronization between processes

multiprocessing contains equivalents of all the synchronization primitives from threading. For instance one can use a lock to ensure that only one process prints to standard output at a time:

def f(l, i):
    l.acquire()
    try:
        print('hello world', i)
    finally:
        l.release()

if __name__ == '__main__':
    lock = Lock()
for num in range(10):
    Process(target=f, args=(lock, num)).start()

Without using the lock output from the different processes is liable to get all mixed up.

17.2.1.5. Sharing state between processes

As mentioned above, when doing concurrent programming it is usually best to avoid using shared state as far as possible. This is particularly true when using multiple processes.

However, if you really do need to use some shared data then multiprocessing provides a couple of ways of doing so.

Shared memory

Data can be stored in a shared memory map using Value or Array. For example, the following code

from multiprocessing import Process, Value, Array

def f(n, a):
    n.value = 3.1415927
    for i in range(len(a)):
        a[i] = -a[i]

if __name__ == '__main__':
    num = Value('d', 0.0)
    arr = Array('i', range(10))

    p = Process(target=f, args=(num, arr))
p.start()
p.join()
print(num.value)
print(arr[:])

will print

```
3.1415927
[0, -1, -2, -3, -4, -5, -6, -7, -8, -9]
```

The 'd' and 'i' arguments used when creating num and arr are typecodes of the kind used by the array module: 'd' indicates a double precision float and 'i' indicates a signed integer. These shared objects will be process and thread-safe.

For more flexibility in using shared memory one can use the multiprocessing.sharedctypes module which supports the creation of arbitrary ctypes objects allocated from shared memory.

**Server process**

A manager object returned by Manager() controls a server process which holds Python objects and allows other processes to manipulate them using proxies.

A manager returned by Manager() will support types list, dict, Namespace, Lock, RLock, Semaphore, BoundedSemaphore, Condition, Event, Barrier, Queue, Value and Array. For example,

```
from multiprocessing import Process, Manager

def f(d, l):
    d[1] = '1'
```
```python
d['2'] = 2
d[0.25] = None
l.reverse()

if __name__ == '__main__':
    with Manager() as manager:
        d = manager.dict()
        l = manager.list(range(10))

        p = Process(target=f, args=(d, l))
        p.start()
        p.join()

        print(d)
        print(l)
```

will print

```
{0.25: None, 1: '1', '2': 2}
[9, 8, 7, 6, 5, 4, 3, 2, 1, 0]
```

Server process managers are more flexible than using shared memory objects because they can be made to support arbitrary object types. Also, a single manager can be shared by processes on different computers over a network. They are, however, slower than using shared memory.

17.2.1.6. Using a pool of workers

The `Pool` class represents a pool of worker processes. It has methods which allows tasks to be offloaded to the worker processes in a few different ways.

For example:
from multiprocessing import Pool
from time import sleep

def f(x):
    return x*x

if __name__ == '__main__':
    # start 4 worker processes
    with Pool(processes=4) as pool:

        # print "[0, 1, 4,..., 81]"
        print(pool.map(f, range(10)))

        # print same numbers in arbitrary order
        for i in pool.imap_unordered(f, range(10)):
            print(i)

        # evaluate "f(10)" asynchronously
        res = pool.apply_async(f, [10])
        print(res.get(timeout=1))  # print

        # make worker sleep for 10 secs
        res = pool.apply_async(sleep, [10])
        print(res.get(timeout=1))  # raises

        # exiting the 'with'-block has stopped the pool

Note that the methods of a pool should only ever be used by the process which created it.

**Note:** Functionality within this package requires that the __main__ module be importable by the children. This is covered in Programming guidelines however it is worth pointing out here. This means that some examples, such as the multiprocessing.pool.Pool examples will not work in the
interactive interpreter. For example:

```python
>>> from multiprocessing import Pool
>>> p = Pool(5)
>>> def f(x):
...     return x**x
...
>>> p.map(f, [1, 2, 3])
Process PoolWorker-1:
Process PoolWorker-2:
Process PoolWorker-3:
Traceback (most recent call last):
  File "<stdin>", line 7, in <module>
    AttributeError: 'module' object has no attribute 'f'
  File "<stdin>", line 7, in <module>
    AttributeError: 'module' object has no attribute 'f'
  File "<stdin>", line 7, in <module>
    AttributeError: 'module' object has no attribute 'f'
```

(If you try this it will actually output three full tracebacks interleaved in a semi-random fashion, and then you may have to stop the master process somehow.)
17.2.2. Reference

The `multiprocessing` package mostly replicates the API of the `threading` module.

17.2.2.1. Process and exceptions

```
class multiprocessing.Process(group=None, target=None, name=None, args=(), kwargs={}, *, daemon=None)
```

Process objects represent activity that is run in a separate process. The `Process` class has equivalents of all the methods of `threading.Thread`.

The constructor should always be called with keyword arguments. `group` should always be `None`; it exists solely for compatibility with `threading.Thread`. `target` is the callable object to be invoked by the `run()` method. It defaults to `None`, meaning nothing is called. `name` is the process name (see `name` for more details). `args` is the argument tuple for the target invocation. `kwargs` is a dictionary of keyword arguments for the target invocation. If provided, the keyword-only `daemon` argument sets the process `daemon` flag to `True` or `False`. If `None` (the default), this flag will be inherited from the creating process.

By default, no arguments are passed to `target`.

If a subclass overrides the constructor, it must make sure it invokes the base class constructor (`Process.__init__()`) before doing anything else to the process.

*Changed in version 3.3:* Added the `daemon` argument.
**run()**
Method representing the process's activity.

You may override this method in a subclass. The standard `run()` method invokes the callable object passed to the object's constructor as the target argument, if any, with sequential and keyword arguments taken from the `args` and `kwargs` arguments, respectively.

**start()**
Start the process's activity.

This must be called at most once per process object. It arranges for the object's `run()` method to be invoked in a separate process.

**join([timeout])**
If the optional argument `timeout` is None (the default), the method blocks until the process whose `join()` method is called terminates. If `timeout` is a positive number, it blocks at most `timeout` seconds.

A process can be joined many times.

A process cannot join itself because this would cause a deadlock. It is an error to attempt to join a process before it has been started.

**name**
The process's name. The name is a string used for identification purposes only. It has no semantics. Multiple processes may be given the same name.
The initial name is set by the constructor. If no explicit name is provided to the constructor, a name of the form ‘Process-$N_1$:$N_2$:$...$:$N_k$’ is constructed, where each $N_k$ is the $N$-th child of its parent.

is_alive()

Return whether the process is alive.

Roughly, a process object is alive from the moment the start() method returns until the child process terminates.

daemon

The process's daemon flag, a Boolean value. This must be set before start() is called.

The initial value is inherited from the creating process.

When a process exits, it attempts to terminate all of its daemonic child processes.

Note that a daemonic process is not allowed to create child processes. Otherwise a daemonic process would leave its children orphaned if it gets terminated when its parent process exits. Additionally, these are not Unix daemons or services, they are normal processes that will be terminated (and not joined) if non-daemonic processes have exited.

In addition to the threading.Thread API, Process objects also support the following attributes and methods:

pid

Return the process ID. Before the process is spawned, this will be None.
**exitcode**

The child’s exit code. This will be None if the process has not yet terminated. A negative value -N indicates that the child was terminated by signal N.

**authkey**

The process’s authentication key (a byte string).

When `multiprocessing` is initialized the main process is assigned a random string using `os.urandom()`.

When a `Process` object is created, it will inherit the authentication key of its parent process, although this may be changed by setting `authkey` to another byte string.

See Authentication keys.

**sentinel**

A numeric handle of a system object which will become “ready” when the process ends.

You can use this value if you want to wait on several events at once using `multiprocessing.connection.wait()`. Otherwise calling `join()` is simpler.

On Windows, this is an OS handle usable with the `WaitForSingleObject` and `WaitForMultipleObjects` family of API calls. On Unix, this is a file descriptor usable with primitives from the `select` module.

*New in version 3.3.*

**terminate()**
Terminate the process. On Unix this is done using the SIGTERM signal; on Windows TerminateProcess() is used. Note that exit handlers and finally clauses, etc., will not be executed.

Note that descendant processes of the process will not be terminated – they will simply become orphaned.

**Warning:** If this method is used when the associated process is using a pipe or queue then the pipe or queue is liable to become corrupted and may become unusable by other process. Similarly, if the process has acquired a lock or semaphore etc. then terminating it is liable to cause other processes to deadlock.

Note that the `start()`, `join()`, `is_alive()`, `terminate()` and `exitcode` methods should only be called by the process that created the process object.

Example usage of some of the methods of `Process`:

```python
>>> import multiprocessing, time, signal
>>> p = multiprocessing.Process(target=time.sleep)
>>> print(p, p.is_alive())
<Process(Process-1, initial)> False
>>> p.start()
>>> print(p, p.is_alive())
<Process(Process-1, started)> True
>>> p.terminate()
>>> time.sleep(0.1)
>>> print(p, p.is_alive())
<Process(Process-1, stopped[SIGTERM])> False
>>> p.exitcode == -signal.SIGTERM
True
```
exception multiprocessing.ProcessError
   The base class of all multiprocessing exceptions.

exception multiprocessing.BufferTooShort
   Exception raised by Connection.recv_bytes_into() when
   the supplied buffer object is too small for the message read.

   If e is an instance of BufferTooShort then e.args[0] will give
   the message as a byte string.

exception multiprocessing.AuthenticationError
   Raised when there is an authentication error.

exception multiprocessing.TimeoutError
   Raised by methods with a timeout when the timeout expires.

17.2.2.2. Pipes and Queues

When using multiple processes, one generally uses message passing
for communication between processes and avoids having to use any
synchronization primitives like locks.

For passing messages one can use Pipe() (for a connection
between two processes) or a queue (which allows multiple producers
and consumers).

The Queue, SimpleQueue and JoinableQueue types are multi-
producer, multi-consumer FIFO queues modelled on the
queue.Queue class in the standard library. They differ in that Queue
lacks the task_done() and join() methods introduced into Python
2.5's queue.Queue class.

If you use JoinableQueue then you must call
JoinableQueue.task_done() for each task removed from the queue or else the semaphore used to count the number of unfinished tasks may eventually overflow, raising an exception.

Note that one can also create a shared queue by using a manager object – see Managers.

**Note:** multiprocessing uses the usual queue.Empty and queue.Full exceptions to signal a timeout. They are not available in the multiprocessing namespace so you need to import them from queue.

**Note:** When an object is put on a queue, the object is pickled and a background thread later flushes the pickled data to an underlying pipe. This has some consequences which are a little surprising, but should not cause any practical difficulties – if they really bother you then you can instead use a queue created with a manager.

1. After putting an object on an empty queue there may be an infinitesimal delay before the queue's empty() method returns False and get_nowait() can return without raising queue.Empty.
2. If multiple processes are enqueuing objects, it is possible for the objects to be received at the other end out-of-order. However, objects enqueued by the same process will always be in the expected order with respect to each other.

**Warning:** If a process is killed using Process.terminate() or os.kill() while it is trying to use a Queue, then the data in the queue is likely to become corrupted. This may cause any other process to get an exception when it tries to use the queue later on.
**Warning:** As mentioned above, if a child process has put items on a queue (and it has not used `JoinableQueue.cancel_join_thread`), then that process will not terminate until all buffered items have been flushed to the pipe.

This means that if you try joining that process you may get a deadlock unless you are sure that all items which have been put on the queue have been consumed. Similarly, if the child process is non-daemonic then the parent process may hang on exit when it tries to join all its non-daemonic children.

Note that a queue created using a manager does not have this issue. See Programming guidelines.

For an example of the usage of queues for interprocess communication see Examples.

```python
multiprocessing.Pipe([duplex])
```

Returns a pair `(conn1, conn2)` of `Connection` objects representing the ends of a pipe.

If `duplex` is True (the default) then the pipe is bidirectional. If `duplex` is False then the pipe is unidirectional: `conn1` can only be used for receiving messages and `conn2` can only be used for sending messages.

```python
class multiprocessing.Queue([maxsize])
```

Returns a process shared queue implemented using a pipe and a few locks/semaphores. When a process first puts an item on the queue a feeder thread is started which transfers objects from a buffer into the pipe.
The usual `queue.Empty` and `queue.Full` exceptions from the standard library's `queue` module are raised to signal timeouts.

`Queue` implements all the methods of `queue.Queue` except for `task_done()` and `join()`.

`qsize()`  
Return the approximate size of the queue. Because of multithreading/multiprocessing semantics, this number is not reliable.

Note that this may raise `NotImplementedError` on Unix platforms like Mac OS X where `sem_getvalue()` is not implemented.

`empty()`  
Return True if the queue is empty, False otherwise. Because of multithreading/multiprocessing semantics, this is not reliable.

`full()`  
Return True if the queue is full, False otherwise. Because of multithreading/multiprocessing semantics, this is not reliable.

`put(obj[, block[, timeout]])`  
Put obj into the queue. If the optional argument `block` is True (the default) and `timeout` is None (the default), block if necessary until a free slot is available. If `timeout` is a positive number, it blocks at most `timeout` seconds and raises the `queue.Full` exception if no free slot was available within that time. Otherwise (`block` is False), put an item on the queue if a free slot is immediately available, else raise the `queue.Full` exception (`timeout` is ignored in that case).
put_nowait(obj)

Equivalent to put(obj, False).

get([block[, timeout]])

Remove and return an item from the queue. If optional args
block is True (the default) and timeout is None (the default),
block if necessary until an item is available. If timeout is a
positive number, it blocks at most timeout seconds and raises
the queue.Empty exception if no item was available within that
time. Otherwise (block is False), return an item if one is
immediately available, else raise the queue.Empty exception
(timeout is ignored in that case).

get_nowait()

Equivalent to get(False).

multiprocessing.Queue has a few additional methods not
found in queue.Queue. These methods are usually unnecessary
for most code:

close()

Indicate that no more data will be put on this queue by the
current process. The background thread will quit once it has
flushed all buffered data to the pipe. This is called automatically
when the queue is garbage collected.

join_thread()

Join the background thread. This can only be used after
close() has been called. It blocks until the background thread
exits, ensuring that all data in the buffer has been flushed to the
pipe.
By default if a process is not the creator of the queue then on exit it will attempt to join the queue's background thread. The process can call `cancel_join_thread()` to make `join_thread()` do nothing.

**cancel_join_thread()**

Prevent `join_thread()` from blocking. In particular, this prevents the background thread from being joined automatically when the process exits – see `join_thread()`.

A better name for this method might be `allow_exit_without_flush()`. It is likely to cause enqueued data to lost, and you almost certainly will not need to use it. It is really only there if you need the current process to exit immediately without waiting to flush enqueued data to the underlying pipe, and you don't care about lost data.

**Note:** This class’s functionality requires a functioning shared semaphore implementation on the host operating system. Without one, the functionality in this class will be disabled, and attempts to instantiate a `Queue` will result in an `ImportError`. See issue 3770 for additional information. The same holds true for any of the specialized queue types listed below.

**class multiprocessing.SimpleQueue**

It is a simplified `Queue` type, very close to a locked `Pipe`.

**empty()**

Return True if the queue is empty, False otherwise.

**get()**

Remove and return an item from the queue.
**put(item)**

Put *item* into the queue.

*class multiprocessing.JoinableQueue([maxsize])*  

*JoinableQueue*, a *Queue* subclass, is a queue which additionally has *task_done()* and *join()* methods.

**task_done()**

Indicate that a formerly enqueued task is complete. Used by queue consumers. For each *get()* used to fetch a task, a subsequent call to *task_done()* tells the queue that the processing on the task is complete.

If a *join()* is currently blocking, it will resume when all items have been processed (meaning that a *task_done()* call was received for every item that had been *put()* into the queue).

Raises a *ValueError* if called more times than there were items placed in the queue.

**join()**

Block until all items in the queue have been gotten and processed.

The count of unfinished tasks goes up whenever an item is added to the queue. The count goes down whenever a consumer calls *task_done()* to indicate that the item was retrieved and all work on it is complete. When the count of unfinished tasks drops to zero, *join()* unblocks.

17.2.2.3. Miscellaneous
multiprocessing.active_children()
    Return list of all live children of the current process.

    Calling this has the side effect of “joining” any processes which
    have already finished.

multiprocessing.cpu_count()
    Return the number of CPUs in the system. May raise
    NotImplementedError.

        See also: os.cpu_count()

multiprocessing.current_process()
    Return the Process object corresponding to the current process.

    An analogue of threading.current_thread().

multiprocessing.freeze_support()
    Add support for when a program which uses multiprocessing
    has been frozen to produce a Windows executable. (Has been
tested with py2exe, PynInstaller and cx_Freeze.)

    One needs to call this function straight after the if __name__ ==
    '__main__' line of the main module. For example:

        from multiprocessing import Process, freeze_support

def f():
    print('hello world!')

if __name__ == '__main__':
    freeze_support()
    Process(target=f).start()
If the `freeze_support()` line is omitted then trying to run the frozen executable will raise `RuntimeError`.

If the module is being run normally by the Python interpreter then `freeze_support()` has no effect.

`multiprocessing.get_all_start_methods()`

Returns a list of the supported start methods, the first of which is the default. The possible start methods are 'fork', 'spawn' and 'forkserver'. On Windows only 'spawn' is available. On Unix 'fork' and 'spawn' are always supported, with 'fork' being the default.

*New in version 3.4.*

`multiprocessing.get_context(method=None)`

Return a context object which has the same attributes as the `multiprocessing` module.

If `method` is `None` then the default context is returned. Otherwise `method` should be 'fork', 'spawn', 'forkserver'. `ValueError` is raised if the specified start method is not available.

*New in version 3.4.*

`multiprocessing.get_start_method(allow_none=False)`

Return the name of start method used for starting processes.

If the start method has not been fixed and `allow_none` is false, then the start method is fixed to the default and the name is returned. If the start method has not been fixed and `allow_none` is true then `None` is returned.
The return value can be 'fork', 'spawn', 'forkserver' or None. 'fork' is the default on Unix, while 'spawn' is the default on Windows.

*New in version 3.4.*

**multitrocessing.set_executable()**

Sets the path of the Python interpreter to use when starting a child process. (By default *sys.executable* is used). Embedders will probably need to do some thing like

```python
set_executable(os.path.join(sys.exec_prefix, 'pythonw.exe'))
```

before they can create child processes.

*Changed in version 3.4:* Now supported on Unix when the 'spawn' start method is used.

**multitrocessing.set_start_method**(method)

Set the method which should be used to start child processes. *method* can be 'fork', 'spawn' or 'forkserver'.

Note that this should be called at most once, and it should be protected inside the if `__name__` == '__main__' clause of the main module.

*New in version 3.4.*

---

**Note:** *multitrocessing* contains no analogues of

*threading.active_count(), threading.enumerate(),
threading.settrace(), threading.setprofile(),
threading.Timer, or threading.local.*
17.2.2.4. Connection Objects

Connection objects allow the sending and receiving of picklable objects or strings. They can be thought of as message oriented connected sockets.

Connection objects are usually created using `Pipe()` – see also Listeners and Clients.

```python
class multiprocessing.Connection
    send(obj)
        Send an object to the other end of the connection which should be read using `recv()`.
        The object must be picklable. Very large pickles (approximately 32 MB+, though it depends on the OS) may raise a ValueError exception.
    recv()
        Return an object sent from the other end of the connection using `send()`. Blocks until there its something to receive. Raises `EOFError` if there is nothing left to receive and the other end was closed.
    fileno()
        Return the file descriptor or handle used by the connection.
    close()
        Close the connection.
```

This is called automatically when the connection is garbage collected.
poll([timeout])

Return whether there is any data available to be read.

If timeout is not specified then it will return immediately. If timeout is a number then this specifies the maximum time in seconds to block. If timeout is None then an infinite timeout is used.

Note that multiple connection objects may be polled at once by using multiprocessing.connection.wait().

send_bytes(buffer[, offset[, size]])

Send byte data from a bytes-like object as a complete message.

If offset is given then data is read from that position in buffer. If size is given then that many bytes will be read from buffer. Very large buffers (approximately 32 MB+, though it depends on the OS) may raise a ValueError exception.

recv_bytes([maxlength])

Return a complete message of byte data sent from the other end of the connection as a string. Blocks until there is something to receive. Raises EOFError if there is nothing left to receive and the other end has closed.

If maxlength is specified and the message is longer than maxlength then OSError is raised and the connection will no longer be readable.

Changed in version 3.3: This function used to raise IOError, which is now an alias of OSError.
recv_bytes_into(buffer[, offset])

Read into buffer a complete message of byte data sent from the other end of the connection and return the number of bytes in the message. Blocks until there is something to receive. Raises EOFError if there is nothing left to receive and the other end was closed.

buffer must be a writable bytes-like object. If offset is given then the message will be written into the buffer from that position. Offset must be a non-negative integer less than the length of buffer (in bytes).

If the buffer is too short then a BufferTooShort exception is raised and the complete message is available as e.args[0] where e is the exception instance.

Changed in version 3.3: Connection objects themselves can now be transferred between processes using Connection.send() and Connection.recv().

New in version 3.3: Connection objects now support the context management protocol – see Context Manager Types. __enter__() returns the connection object, and __exit__() calls close().

For example:

```python
>>> from multiprocessing import Pipe
>>> a, b = Pipe()
>>> a.send([1, 'hello', None])
>>> b.recv()
[1, 'hello', None]
>>> b.send_bytes(b'thank you')
```
```python
>>> a.recv_bytes()
'b\'thank you\\n'
>>> import array
>>> arr1 = array.array('i', range(5))
>>> arr2 = array.array('i', [0] * 10)
>>> a.send_bytes(arr1)
>>> count = b.recv_bytes_into(arr2)
>>> assert count == len(arr1) * arr1.itemsize
>>> arr2
array('i', [0, 1, 2, 3, 4, 0, 0, 0, 0, 0])
```

**Warning:** The `Connection.recv()` method automatically unpickles the data it receives, which can be a security risk unless you can trust the process which sent the message.

Therefore, unless the connection object was produced using `Pipe()` you should only use the `recv()` and `send()` methods after performing some sort of authentication. See [Authentication keys](https://docs.python.org/3/library/socket.html#socket.socket.recv).

**Warning:** If a process is killed while it is trying to read or write to a pipe then the data in the pipe is likely to become corrupted, because it may become impossible to be sure where the message boundaries lie.

### 17.2.2.5. Synchronization primitives

Generally synchronization primitives are not as necessary in a multiprocess program as they are in a multithreaded program. See the documentation for the `threading` module.

Note that one can also create synchronization primitives by using a manager object – see [Managers](https://docs.python.org/3/library/queue.html#module-queue).
class multiprocessing.Barrier(parties[, action[, timeout]])

A barrier object: a clone of threading.Barrier.

*New in version 3.3.*

class multiprocessing.BoundedSemaphore([value])

A bounded semaphore object: a close analog of threading.BoundedSemaphore.

A solitary difference from its close analog exists: its acquire method's first argument is named block, as is consistent with Lock.acquire().

**Note:** On Mac OS X, this is indistinguishable from Semaphore because sem_getvalue() is not implemented on that platform.

class multiprocessing.Condition([lock])


If lock is specified then it should be a Lock or RLock object from multiprocessing.

*Changed in version 3.3:* The wait_for() method was added.

class multiprocessing.Event

A clone of threading.Event.

class multiprocessing.Lock

A non-recursive lock object: a close analog of threading.Lock. Once a process or thread has acquired a lock, subsequent attempts to acquire it from any process or thread will block until it is released; any process or thread may release it. The concepts and
behaviors of `threading.Lock` as it applies to threads are replicated here in `multiprocessing.Lock` as it applies to either processes or threads, except as noted.

Note that `Lock` is actually a factory function which returns an instance of `multiprocessing.synchronize.Lock` initialized with a default context.

`Lock` supports the context manager protocol and thus may be used in `with` statements.

**acquire**(block=True, timeout=None)

Acquire a lock, blocking or non-blocking.

With the `block` argument set to `True` (the default), the method call will block until the lock is in an unlocked state, then set it to locked and return `True`. Note that the name of this first argument differs from that in `threading.Lock.acquire()`.

With the `block` argument set to `False`, the method call does not block. If the lock is currently in a locked state, return `False`; otherwise set the lock to a locked state and return `True`.

When invoked with a positive, floating-point value for `timeout`, block for at most the number of seconds specified by `timeout` as long as the lock can not be acquired. Invocations with a negative value for `timeout` are equivalent to a `timeout` of zero. Invocations with a `timeout` value of `None` (the default) set the timeout period to infinite. Note that the treatment of negative or `None` values for `timeout` differs from the implemented behavior in `threading.Lock.acquire()`. The `timeout` argument has no practical implications if the `block` argument is set to `False`. 
and is thus ignored. Returns True if the lock has been acquired or False if the timeout period has elapsed.

**release()**

Release a lock. This can be called from any process or thread, not only the process or thread which originally acquired the lock.

Behavior is the same as in `threading.Lock.release()` except that when invoked on an unlocked lock, a `ValueError` is raised.

```python
class multiprocessing.RLock
```

A recursive lock object: a close analog of `threading.RLock`. A recursive lock must be released by the process or thread that acquired it. Once a process or thread has acquired a recursive lock, the same process or thread may acquire it again without blocking; that process or thread must release it once for each time it has been acquired.

Note that `RLock` is actually a factory function which returns an instance of `multiprocessing.synchronize.RLock` initialized with a default context.

`RLock` supports the context manager protocol and thus may be used in `with` statements.

**acquire(block=True, timeout=None)**

Acquire a lock, blocking or non-blocking.

When invoked with the `block` argument set to True, block until the lock is in an unlocked state (not owned by any process or thread) unless the lock is already owned by the current process
or thread. The current process or thread then takes ownership of the lock (if it does not already have ownership) and the recursion level inside the lock increments by one, resulting in a return value of True. Note that there are several differences in this first argument’s behavior compared to the implementation of `threading.RLock.acquire()`, starting with the name of the argument itself.

When invoked with the `block` argument set to `False`, do not block. If the lock has already been acquired (and thus is owned) by another process or thread, the current process or thread does not take ownership and the recursion level within the lock is not changed, resulting in a return value of `False`. If the lock is in an unlocked state, the current process or thread takes ownership and the recursion level is incremented, resulting in a return value of `True`.

Use and behaviors of the `timeout` argument are the same as in `Lock.acquire()`. Note that some of these behaviors of `timeout` differ from the implemented behaviors in `threading.RLock.acquire()`.

**release()**

Release a lock, decrementing the recursion level. If after the decrement the recursion level is zero, reset the lock to unlocked (not owned by any process or thread) and if any other processes or threads are blocked waiting for the lock to become unlocked, allow exactly one of them to proceed. If after the decrement the recursion level is still nonzero, the lock remains locked and owned by the calling process or thread.

Only call this method when the calling process or thread owns
the lock. An `AssertionError` is raised if this method is called by a process or thread other than the owner or if the lock is in an unlocked (unowned) state. Note that the type of exception raised in this situation differs from the implemented behavior in `threading.RLock.release()`.

```python
class multiprocessing.Semaphore([value])
```

A semaphore object: a close analog of `threading.Semaphore`.

A solitary difference from its close analog exists: its acquire method's first argument is named `block`, as is consistent with `Lock.acquire()`.

**Note:** On Mac OS X, `sem_timedwait` is unsupported, so calling `acquire()` with a timeout will emulate that function's behavior using a sleeping loop.

**Note:** If the SIGINT signal generated by Ctrl-C arrives while the main thread is blocked by a call to `BoundedSemaphore.acquire()`, `Lock.acquire()`, `RLock.acquire()`, `Semaphore.acquire()`, `Condition.acquire()` or `Condition.wait()` then the call will be immediately interrupted and `KeyboardInterrupt` will be raised.

This differs from the behaviour of `threading` where SIGINT will be ignored while the equivalent blocking calls are in progress.

**Note:** Some of this package's functionality requires a functioning shared semaphore implementation on the host operating system. Without one, the `multiprocessing.synchronize` module will be
17.2.2.6. Shared ctypes Objects

It is possible to create shared objects using shared memory which can be inherited by child processes.

```
multiprocessing.Value(typecode_or_type, *args, lock=True)
```

Return a ctypes object allocated from shared memory. By default the return value is actually a synchronized wrapper for the object. The object itself can be accessed via the value attribute of a Value.

`typecode_or_type` determines the type of the returned object: it is either a ctypes type or a one character typecode of the kind used by the array module. `*args` is passed on to the constructor for the type.

If `lock` is True (the default) then a new recursive lock object is created to synchronize access to the value. If `lock` is a Lock or RLock object then that will be used to synchronize access to the value. If `lock` is False then access to the returned object will not be automatically protected by a lock, so it will not necessarily be “process-safe”.

Operations like `+=` which involve a read and write are not atomic. So if, for instance, you want to atomically increment a shared value it is insufficient to just do

```
counter.value += 1
```
Assuming the associated lock is recursive (which it is by default) you can instead do

```python
with counter.get_lock():
    counter.value += 1
```

Note that `lock` is a keyword-only argument.

``multiprocessing.Array``(``typecode_or_type``, ``size_or_initializer``, *, `lock=True`)``

Return a ctypes array allocated from shared memory. By default the return value is actually a synchronized wrapper for the array.

typecode_or_type determines the type of the elements of the returned array: it is either a ctypes type or a one character typecode of the kind used by the array module. If size_or_initializer is an integer, then it determines the length of the array, and the array will be initially zeroed. Otherwise, size_or_initializer is a sequence which is used to initialize the array and whose length determines the length of the array.

If lock is True (the default) then a new lock object is created to synchronize access to the value. If lock is a Lock or RLock object then that will be used to synchronize access to the value. If lock is False then access to the returned object will not be automatically protected by a lock, so it will not necessarily be “process-safe”.

Note that lock is a keyword only argument.

Note that an array of ctypes.c_char has value and raw attributes which allow one to use it to store and retrieve strings.

17.2.2.6.1. The multiprocessing.sharedctypes
module

The `multiprocessing.sharedctypes` module provides functions for allocating `ctypes` objects from shared memory which can be inherited by child processes.

**Note:** Although it is possible to store a pointer in shared memory remember that this will refer to a location in the address space of a specific process. However, the pointer is quite likely to be invalid in the context of a second process and trying to dereference the pointer from the second process may cause a crash.

`multiprocessing.sharedctypes.RawArray(typecode_or_type, size_or_initializer)`

Return a `ctypes` array allocated from shared memory.

`typecode_or_type` determines the type of the elements of the returned array: it is either a `ctypes` type or a one character `typecode` of the kind used by the `array` module. If `size_or_initializer` is an integer then it determines the length of the array, and the array will be initially zeroed. Otherwise `size_or_initializer` is a sequence which is used to initialize the array and whose length determines the length of the array.

Note that setting and getting an element is potentially non-atomic – use `Array()` instead to make sure that access is automatically synchronized using a lock.

`multiprocessing.sharedctypes.RawValue(typecode_or_type, *args)`

Return a `ctypes` object allocated from shared memory.
typecode_or_type determines the type of the returned object: it is either a ctypes type or a one character typecode of the kind used by the array module. *args is passed on to the constructor for the type.

Note that setting and getting the value is potentially non-atomic – use Value() instead to make sure that access is automatically synchronized using a lock.

Note that an array of ctypes.c_char has value and raw attributes which allow one to use it to store and retrieve strings – see documentation for ctypes.

```
multiprocessing.sharedctypes.Array(typecode_or_type, size_or_initializer, *, lock=True)
```

The same as RawArray() except that depending on the value of lock a process-safe synchronization wrapper may be returned instead of a raw ctypes array.

If lock is True (the default) then a new lock object is created to synchronize access to the value. If lock is a Lock or RLock object then that will be used to synchronize access to the value. If lock is False then access to the returned object will not be automatically protected by a lock, so it will not necessarily be “process-safe”.

Note that lock is a keyword-only argument.

```
multiprocessing.sharedctypes.Value(typecode_or_type, *args, lock=True)
```

The same as RawValue() except that depending on the value of lock a process-safe synchronization wrapper may be returned instead of a raw ctypes object.
If `lock` is True (the default) then a new lock object is created to synchronize access to the value. If `lock` is a `Lock` or `RLock` object then that will be used to synchronize access to the value. If `lock` is False then access to the returned object will not be automatically protected by a lock, so it will not necessarily be “process-safe”.

Note that `lock` is a keyword-only argument.

```python
multiprocessing.sharedctypes.copy(obj)
```

Return a ctypes object allocated from shared memory which is a copy of the ctypes object `obj`.

```python
multiprocessing.sharedctypes.synchronized(obj, lock)
```

Return a process-safe wrapper object for a ctypes object which uses `lock` to synchronize access. If `lock` is None (the default) then a `multiprocessing.RLock` object is created automatically.

A synchronized wrapper will have two methods in addition to those of the object it wraps: `get_obj()` returns the wrapped object and `get_lock()` returns the lock object used for synchronization.

Note that accessing the ctypes object through the wrapper can be a lot slower than accessing the raw ctypes object.

*Changed in version 3.5:* Synchronized objects support the context manager protocol.

The table below compares the syntax for creating shared ctypes objects from shared memory with the normal ctypes syntax. (In the table MyStruct is some subclass of `ctypes.Structure`.)

<table>
<thead>
<tr>
<th>ctypes</th>
<th>sharedctypes using type</th>
<th>sharedctypes using typecode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RawValue(c_double, 2.4)</td>
<td>RawValue('d', 2.4)</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>c_double(2.4)</td>
<td>RawValue(c_double, 2.4)</td>
<td></td>
</tr>
<tr>
<td>MyStruct(4, 6)</td>
<td>RawValue(MyStruct, 4, 6)</td>
<td></td>
</tr>
<tr>
<td>(c_short * 7)()</td>
<td>RawArray(c_short, 7)</td>
<td>RawArray('h', 7)</td>
</tr>
<tr>
<td>(c_int * 3)(9, 2, 8)</td>
<td>RawArray(c_int, (9, 2, 8))</td>
<td>RawArray('i', (9, 2, 8))</td>
</tr>
</tbody>
</table>

Below is an example where a number of ctypes objects are modified by a child process:

```python
from multiprocessing import Process, Lock
from multiprocessing.sharedctypes import Value, Array
from ctypes import Structure, c_double

class Point(Structure):
    _fields_ = [('x', c_double), ('y', c_double)]

def modify(n, x, s, A):
    n.value *= 2
    x.value *= 2
    s.value = s.value.upper()
    for a in A:
        a.x *= 2
        a.y *= 2

if __name__ == '__main__':
    lock = Lock()
    n = Value('i', 7)
    x = Value(c_double, 1.0/3.0, lock=False)
    s = Array('c', b'hello world', lock=lock)
    A = Array(Point, [(1.875,-6.25), (-5.75,2.0), (2
    p = Process(target=modify, args=(n, x, s, A))
```
```python
def main():
    p = Process(target=do_something)
    p.start()
    p.join()

    print(n[0].value)
    print(x[0].value)
    print(s[0].value)
    print(((a.x, a.y) for a in A))
```

The results printed are

```
49
0.1111111111111111
HELLO WORLD
[(3.515625, 39.0625), (33.0625, 4.0), (5.640625, 90.0)]
```

## 17.2.2.7. Managers

Managers provide a way to create data which can be shared between different processes, including sharing over a network between processes running on different machines. A manager object controls a server process which manages *shared objects*. Other processes can access the shared objects by using proxies.

```python
import multiprocessing

class Manager:
    def __init__(self):
        # Initialize manager
        pass

m = Manager()
m.set()  # Set the manager
```

Returns a started `SyncManager` object which can be used for sharing objects between processes. The returned manager object corresponds to a spawned child process and has methods which will create shared objects and return corresponding proxies.

Manager processes will be shutdown as soon as they are garbage collected or their parent process exits. The manager classes are defined in the `multiprocessing.managers` module:
class multiprocessing.managers.BaseManager([address, authkey])

Create a BaseManager object.

Once created one should call start() or get_server().serve_forever() to ensure that the manager object refers to a started manager process.

address is the address on which the manager process listens for new connections. If address is None then an arbitrary one is chosen.

authkey is the authentication key which will be used to check the validity of incoming connections to the server process. If authkey is None then current_process().authkey is used. Otherwise authkey is used and it must be a byte string.

start([initializer, initargs])

Start a subprocess to start the manager. If initializer is not None then the subprocess will call initializer(*initargs) when it starts.

get_server()

Returns a Server object which represents the actual server under the control of the Manager. The Server object supports the serve_forever() method:

```python
>>> from multiprocessing.managers import BaseManager
>>> manager = BaseManager(address=('localhost', 50000),
>>> server = manager.get_server()
>>> server.serve_forever()
```
Server additionally has an **address** attribute.

**connect()**
Connect a local manager object to a remote manager process:

```python
>>> from multiprocessing.managers import BaseManager
>>> m = BaseManager(address=('127.0.0.1', 5000))
>>> m.connect()
```

**shutdown()**
Stop the process used by the manager. This is only available if `start()` has been used to start the server process.

This can be called multiple times.

**register(typeid[, callable[, proxytype[, exposed[, method_to_typeid[, create_method]]]]])**
A classmethod which can be used for registering a type or callable with the manager class.

- **typeid** is a “type identifier” which is used to identify a particular type of shared object. This must be a string.

- **callable** is a callable used for creating objects for this type identifier. If a manager instance will be connected to the server using the `connect()` method, or if the `create_method` argument is `False` then this can be left as None.

- **proxytype** is a subclass of `BaseProxy` which is used to create proxies for shared objects with this `typeid`. If None then a proxy class is created automatically.
exposed is used to specify a sequence of method names which proxies for this typeid should be allowed to access using BaseProxy._callmethod(). (If exposed is None then proxytype._exposed_ is used instead if it exists.) In the case where no exposed list is specified, all “public methods” of the shared object will be accessible. (Here a “public method” means any attribute which has a __call__() method and whose name does not begin with '_' .)

method_to_typeid is a mapping used to specify the return type of those exposed methods which should return a proxy. It maps method names to typeid strings. (If method_to_typeid is None then proxytype._method_to_typeid_ is used instead if it exists.) If a method’s name is not a key of this mapping or if the mapping is None then the object returned by the method will be copied by value.

create_method determines whether a method should be created with name typeid which can be used to tell the server process to create a new shared object and return a proxy for it. By default it is True.

BaseManager instances also have one read-only property:

**address**

The address used by the manager.

*Changed in version 3.3:* Manager objects support the context management protocol – see Context Manager Types. __enter__() starts the server process (if it has not already started) and then returns the manager object. __exit__() calls shutdown().
In previous versions `__enter__()` did not start the manager's server process if it was not already started.

```python
class multiprocessing.managers.SyncManager
A subclass of `BaseManager` which can be used for the synchronization of processes. Objects of this type are returned by `multiprocessing.Manager()`.

It also supports creation of shared lists and dictionaries.
```

**Barrier**(*parties[, action[, timeout]]*)
Create a shared `threading.Barrier` object and return a proxy for it.

*New in version 3.3.*

**BoundedSemaphore**(*value*)
Create a shared `threading.BoundedSemaphore` object and return a proxy for it.

**Condition**(*lock*)
Create a shared `threading.Condition` object and return a proxy for it.

If `lock` is supplied then it should be a proxy for a `threading.Lock` or `threading.RLock` object.

*Changed in version 3.3:* The `wait_for()` method was added.

**Event**()
Create a shared `threading.Event` object and return a proxy for it.
**Lock()**
Create a shared `threading.Lock` object and return a proxy for it.

**Namespace()**
Create a shared `Namespace` object and return a proxy for it.

**Queue([maxsize])**
Create a shared `queue.Queue` object and return a proxy for it.

**RLock()**
Create a shared `threading.RLock` object and return a proxy for it.

**Semaphore([value])**
Create a shared `threading.Semaphore` object and return a proxy for it.

**Array(typecode, sequence)**
Create an array and return a proxy for it.

**Value(typecode, value)**
Create an object with a writable value attribute and return a proxy for it.

**dict()**
**dict(mapping)**
**dict(sequence)**
Create a shared `dict` object and return a proxy for it.

**list()**
**list(sequence)**
Create a shared list object and return a proxy for it.

**Note:** Modifications to mutable values or items in dict and list proxies will not be propagated through the manager, because the proxy has no way of knowing when its values or items are modified. To modify such an item, you can re-assign the modified object to the container proxy:

```
# create a list proxy and append a mutable object
lproxy = manager.list()
lproxy.append({})
# now mutate the dictionary
d = lproxy[0]
d['a'] = 1
d['b'] = 2
# at this point, the changes to d are not yet sync'd
# reassigning the dictionary, the proxy is notified
lproxy[0] = d
```

17.2.2.7.1. Namespace objects

A namespace object has no public methods, but does have writable attributes. Its representation shows the values of its attributes.

However, when using a proxy for a namespace object, an attribute beginning with '_' will be an attribute of the proxy and not an attribute of the referent:

```
>>> manager = multiprocessing.Manager()
>>> Global = manager.Namespace()
>>> Global.x = 10
>>> Global.y = 'hello'
>>> Global._z = 12.3  # this is an attribute of the proxy
```
17.2.2.7.2. Customized managers

To create one's own manager, one creates a subclass of BaseManager and uses the register() classmethod to register new types or callables with the manager class. For example:

```python
from multiprocessing.managers import BaseManager
class MathsClass:
    def add(self, x, y):
        return x + y
    def mul(self, x, y):
        return x * y
class MyManager(BaseManager):
    pass
MyManager.register('Maths', MathsClass)
if __name__ == '__main__':
    with MyManager() as manager:
        maths = manager.Maths()
        print(maths.add(4, 3))  # prints 7
        print(maths.mul(7, 8))  # prints 56
```

17.2.2.7.3. Using a remote manager

It is possible to run a manager server on one machine and have clients use it from other machines (assuming that the firewalls involved allow it).
Running the following commands creates a server for a single shared queue which remote clients can access:

```python
>>> from multiprocessing.managers import BaseManager
>>> import queue
>>> queue = queue.Queue()
>>> class QueueManager(BaseManager): pass
>>> QueueManager.register('get_queue', callable=lambda: queue)
>>> m = QueueManager(address=('', 50000), authkey=b'abracadabra')
>>> s = m.get_server()
>>> s.serve_forever()
```

One client can access the server as follows:

```python
>>> from multiprocessing.managers import BaseManager
>>> class QueueManager(BaseManager): pass
>>> QueueManager.register('get_queue')
>>> m = QueueManager(address=('foo.bar.org', 50000))
>>> m.connect()
>>> queue = m.get_queue()
>>> queue.put('hello')
```

Another client can also use it:

```python
>>> from multiprocessing.managers import BaseManager
>>> class QueueManager(BaseManager): pass
>>> QueueManager.register('get_queue')
>>> m = QueueManager(address=('foo.bar.org', 50000))
>>> m.connect()
>>> queue = m.get_queue()
>>> queue.get()
'hello'
```

Local processes can also access that queue, using the code from
above on the client to access it remotely:

```python
>>> from multiprocessing import Process, Queue
>>> from multiprocessing.managers import BaseManager
>>> class Worker(Process):
...     def __init__(self, q):
...         self.q = q
...     super(Worker, self).__init__()
...     def run(self):
...         self.q.put('local hello')

>>> queue = Queue()
>>> w = Worker(queue)
>>> w.start()
>>> class QueueManager(BaseManager): pass
...
>>> QueueManager.register('get_queue', callable=lambda: queue)
>>> m = QueueManager(address=('172.2.8.', 50000), authkey=b'abracadabra')
>>> s = m.get_server()
>>> s.serve_forever()
```

17.2.2.8. Proxy Objects

A proxy is an object which refers to a shared object which lives (presumably) in a different process. The shared object is said to be the referent of the proxy. Multiple proxy objects may have the same referent.

A proxy object has methods which invoke corresponding methods of its referent (although not every method of the referent will necessarily be available through the proxy). A proxy can usually be used in most of the same ways that its referent can:

```python
>>> from multiprocessing import Manager
```
Notice that applying `str()` to a proxy will return the representation of the referent, whereas applying `repr()` will return the representation of the proxy.

An important feature of proxy objects is that they are picklable so they can be passed between processes. Note, however, that if a proxy is sent to the corresponding manager’s process then unpickling it will produce the referent itself. This means, for example, that one shared object can contain a second:

```python
>>> a = manager.list()
>>> b = manager.list()
>>> a.append(b)           # referent of a now contains
>>> print(a, b)
[['']] []
>>> b.append('hello')
>>> print(a, b)
[['hello']] ['hello']
```

**Note:** The proxy types in `multiprocessing` do nothing to support comparisons by value. So, for instance, we have:

```python
>>> manager.list([1,2,3]) == [1,2,3]
```
One should just use a copy of the referent instead when making comparisons.

```python
class multiprocessing.managers.BaseProxy
    Proxy objects are instances of subclasses of BaseProxy.

    def _callmethod(self, methodname, args=[], kwds={}):
        ... Call and return the result of a method of the proxy's referent.
        
        If `proxy` is a proxy whose referent is `obj` then the expression
        ```python
        proxy._callmethod(methodname, args, kwds)
        ```
        will evaluate the expression
        ```python
        getattr(obj, methodname)(*args, **kwds)
        ```
        in the manager's process.

        The returned value will be a copy of the result of the call or a
        proxy to a new shared object – see documentation for the
        `method_to_typeid` argument of `BaseManager.register()`.

        If an exception is raised by the call, then is re-raised by
        `_callmethod()`. If some other exception is raised in the
        manager's process then this is converted into a RemoteError
        exception and is raised by `_callmethod()`.

        Note in particular that an exception will be raised if
        `methodname` has not been exposed.
```
An example of the usage of \_callmethod():

```python
>>> l = manager.list(range(10))
>>> l._callmethod('\_\_len\_\_')
10
>>> l._callmethod('\_\_getitem\_\_', (slice(2, 7),))
[2, 3, 4, 5, 6]
>>> l._callmethod('\_\_getitem\_\_', (20,))
Traceback (most recent call last):
  ... 
IndexError: list index out of range
```

\_\_getvalue\_(

Return a copy of the referent.

If the referent is unpicklable then this will raise an exception.

\_\_repr\_(

Return a representation of the proxy object.

\_\_str\_(

Return the representation of the referent.

17.2.2.8.1. Cleanup

A proxy object uses a weakref callback so that when it gets garbage collected it deregisters itself from the manager which owns its referent.

A shared object gets deleted from the manager process when there are no longer any proxies referring to it.

17.2.2.9. Process Pools
One can create a pool of processes which will carry out tasks submitted to it with the `Pool` class.

```python
class multiprocessing.pool.Pool([processes[, initializer[, initargs[, maxtasksperchild[, context]]]]])
```

A process pool object which controls a pool of worker processes to which jobs can be submitted. It supports asynchronous results with timeouts and callbacks and has a parallel map implementation.

`processes` is the number of worker processes to use. If `processes` is None then the number returned by `os.cpu_count()` is used.

If `initializer` is not None then each worker process will call `initializer(*initargs)` when it starts.

`maxtasksperchild` is the number of tasks a worker process can complete before it will exit and be replaced with a fresh worker process, to enable unused resources to be freed. The default `maxtasksperchild` is None, which means worker processes will live as long as the pool.

`context` can be used to specify the context used for starting the worker processes. Usually a pool is created using the function `multiprocessing.Pool()` or the `Pool()` method of a context object. In both cases `context` is set appropriately.

Note that the methods of the pool object should only be called by the process which created the pool.

*New in version 3.2:* `maxtasksperchild`

*New in version 3.4:* `context`
Note: Worker processes within a Pool typically live for the complete duration of the Pool’s work queue. A frequent pattern found in other systems (such as Apache, mod_wsgi, etc) to free resources held by workers is to allow a worker within a pool to complete only a set amount of work before being exiting, being cleaned up and a new process spawned to replace the old one. The maxtasksperchild argument to the Pool exposes this ability to the end user.

**apply**(*func*, *args*, *kwds*)

Call `func` with arguments `args` and keyword arguments `kwds`. It blocks until the result is ready. Given this blocks, `apply_async()` is better suited for performing work in parallel. Additionally, `func` is only executed in one of the workers of the pool.

**apply_async**(*func*, *args*, *kwds*, *callback*, *error_callback*)

A variant of the `apply()` method which returns a result object.

If `callback` is specified then it should be a callable which accepts a single argument. When the result becomes ready `callback` is applied to it, that is unless the call failed, in which case the `error_callback` is applied instead.

If `error_callback` is specified then it should be a callable which accepts a single argument. If the target function fails, then the `error_callback` is called with the exception instance.

Callbacks should complete immediately since otherwise the thread which handles the results will get blocked.

**map**(*func*, *iterable*, *chunksize*)
A parallel equivalent of the \texttt{map()} built-in function (it supports only one \textit{iterable} argument though). It blocks until the result is ready.

This method chops the iterable into a number of chunks which it submits to the process pool as separate tasks. The (approximate) size of these chunks can be specified by setting \textit{chunksize} to a positive integer.

\begin{verbatim}
map_async(func, iterable[, chunksize[, callback[, error_callback]]]])
\end{verbatim}

A variant of the \texttt{map()} method which returns a result object.

If \textit{callback} is specified then it should be a callable which accepts a single argument. When the result becomes ready \textit{callback} is applied to it, that is unless the call failed, in which case the \textit{error_callback} is applied instead.

If \textit{error_callback} is specified then it should be a callable which accepts a single argument. If the target function fails, then the \textit{error_callback} is called with the exception instance.

Callbacks should complete immediately since otherwise the thread which handles the results will get blocked.

\begin{verbatim}
imap(func, iterable[, chunksize])
\end{verbatim}

A lazier version of \texttt{map()}.

The \textit{chunksize} argument is the same as the one used by the \texttt{map()} method. For very long iterables using a large value for \textit{chunksize} can make the job complete \textbf{much} faster than using the default value of 1.
Also if `chunksize` is 1 then the `next()` method of the iterator returned by the `imap()` method has an optional `timeout` parameter: `next(timeout)` will raise `multiprocessing.TimeoutError` if the result cannot be returned within `timeout` seconds.

```python
imap_unordered(func, iterable[, chunksize])
```

The same as `imap()` except that the ordering of the results from the returned iterator should be considered arbitrary. (Only when there is only one worker process is the order guaranteed to be “correct”.)

```python
starmap(func, iterable[, chunksize])
```

Like `map()` except that the elements of the `iterable` are expected to be iterables that are unpacked as arguments.

Hence an `iterable` of `[(1,2), (3, 4)]` results in `[func(1,2), func(3,4)]`.

*New in version 3.3.*

```python
starmap_async(func, iterable[, chunksize[, callback[, error_back]]]])
```

A combination of `starmap()` and `map_async()` that iterates over `iterable` of iterables and calls `func` with the iterables unpacked. Returns a result object.

*New in version 3.3.*

```python
close()
```

Prevents any more tasks from being submitted to the pool. Once all the tasks have been completed the worker processes
will exit.

**terminate()**

Stops the worker processes immediately without completing outstanding work. When the pool object is garbage collected `terminate()` will be called immediately.

**join()**

Wait for the worker processes to exit. One must call `close()` or `terminate()` before using `join()`.

*New in version 3.3:* Pool objects now support the context management protocol – see Context Manager Types. `__enter__()` returns the pool object, and `__exit__()` calls `terminate()`.

**class multiprocessing.pool.AsyncResult**

The class of the result returned by `Pool.apply_async()` and `Pool.map_async()`.

**get([timeout])**

Return the result when it arrives. If `timeout` is not None and the result does not arrive within `timeout` seconds then `multiprocessing.TimeoutError` is raised. If the remote call raised an exception then that exception will be reraised by `get()`.

**wait([timeout])**

Wait until the result is available or until `timeout` seconds pass.

**ready()**

Return whether the call has completed.
**successful()**

Return whether the call completed without raising an exception. Will raise `AssertionError` if the result is not ready.

The following example demonstrates the use of a pool:

```python
from multiprocessing import Pool

def f(x):
    return x*x

if __name__ == '__main__':
    with Pool(processes=4) as pool:
        result = pool.apply_async(f, (10,))  # evaluate "f(10)" asynchronously
        print(result.get(timeout=1))  # prints 100 unless your computer is *very* slow

        print(pool.map(f, range(10)))  # prints [0, 1, 4, ..., 81]

        it = pool.imap(f, range(10))
        print(next(it))  # prints 0
        print(next(it))  # prints 1
        print(it.next(timeout=1))  # prints 4 unless your computer is *very* slow

import time
result = pool.apply_async(time.sleep, (10,))  # raises TimeoutError
print(result.get(timeout=1))
```

**17.2.2.10. Listeners and Clients**

Usually message passing between processes is done using queues or by using `Connection` objects returned by `Pipe()`.

However, the `multiprocessing.connection` module allows some extra flexibility. It basically gives a high level message oriented API for
dealing with sockets or Windows named pipes. It also has support for digest authentication using the hmac module, and for polling multiple connections at the same time.

multiprocessing.connection.deliver_challenge(connec authkey)
Send a randomly generated message to the other end of the connection and wait for a reply.

If the reply matches the digest of the message using authkey as the key then a welcome message is sent to the other end of the connection. Otherwise AuthenticationError is raised.

multiprocessing.connection.answer_challenge(connecti authkey)
Receive a message, calculate the digest of the message using authkey as the key, and then send the digest back.

If a welcome message is not received, then AuthenticationError is raised.

multiprocessing.connection.Client(address[, family[, authenticate[, authkey]]])
Attempt to set up a connection to the listener which is using address address, returning a Connection.

The type of the connection is determined by family argument, but this can generally be omitted since it can usually be inferred from the format of address. (See Address Formats)

If authenticate is True or authkey is a byte string then digest authentication is used. The key used for authentication will be either authkey or current_process().authkey if authkey is
None. If authentication fails then `AuthenticationError` is raised. See `Authentication keys`.

```python
class multiprocessing.connection.Listener([address[, family[, backlog[, authenticate[, authkey]]]]])
```
A wrapper for a bound socket or Windows named pipe which is 'listening' for connections.

`address` is the address to be used by the bound socket or named pipe of the listener object.

**Note:** If an address of '0.0.0.0' is used, the address will not be a connectable end point on Windows. If you require a connectable end-point, you should use '127.0.0.1'.

`family` is the type of socket (or named pipe) to use. This can be one of the strings 'AF_INET' (for a TCP socket), 'AF_UNIX' (for a Unix domain socket) or 'AF_PIPE' (for a Windows named pipe). Of these only the first is guaranteed to be available. If `family` is None then the family is inferred from the format of `address`. If `address` is also None then a default is chosen. This default is the family which is assumed to be the fastest available. See `Address Formats`. Note that if `family` is 'AF_UNIX' and `address` is None then the socket will be created in a private temporary directory created using `tempfile.mkstemp()`.

If the listener object uses a socket then `backlog` (1 by default) is passed to the `listen()` method of the socket once it has been bound.

If `authenticate` is True (False by default) or `authkey` is not None then digest authentication is used.
If `authkey` is a byte string then it will be used as the authentication key; otherwise it must be `None`.

If `authkey` is `None` and `authenticate` is `True` then `current_process().authkey` is used as the authentication key. If `authkey` is `None` and `authenticate` is `False` then no authentication is done. If authentication fails then `AuthenticationError` is raised. See Authentication keys.

**accept()**

Accept a connection on the bound socket or named pipe of the listener object and return a `Connection` object. If authentication is attempted and fails, then `AuthenticationError` is raised.

**close()**

Close the bound socket or named pipe of the listener object. This is called automatically when the listener is garbage collected. However it is advisable to call it explicitly.

Listener objects have the following read-only properties:

**address**

The address which is being used by the Listener object.

**last_accepted**

The address from which the last accepted connection came. If this is unavailable then it is `None`.

*New in version 3.3:* Listener objects now support the context management protocol – see Context Manager Types. `__enter__( )` returns the listener object, and `__exit__( )` calls `close()`. 
multiprocessing.connection\.wait\(object\_list, timeout=None\)

Wait till an object in \textit{object\_list} is ready. Returns the list of those objects in \textit{object\_list} which are ready. If \textit{timeout} is a float then the call blocks for at most that many seconds. If \textit{timeout} is None then it will block for an unlimited period. A negative timeout is equivalent to a zero timeout.

For both Unix and Windows, an object can appear in \textit{object\_list} if it is

- a readable \texttt{Connection} object;
- a connected and readable \texttt{socket.socket} object; or
- the \texttt{sentinel} attribute of a \texttt{Process} object.

A connection or socket object is ready when there is data available to be read from it, or the other end has been closed.

**Unix**: \texttt{wait(object\_list, timeout)} almost equivalent to \texttt{select.select(object\_list, [], [], timeout)}. The difference is that, if \texttt{select.select()} is interrupted by a signal, it can raise \texttt{OSError} with an error number of EINTR, whereas \texttt{wait()} will not.

**Windows**: An item in \textit{object\_list} must either be an integer handle which is waitable (according to the definition used by the documentation of the Win32 function \texttt{WaitForMultipleObjects()}) or it can be an object with a \texttt{fileno()} method which returns a socket handle or pipe handle. (Note that pipe handles and socket handles are \textbf{not} waitable handles.)

\textit{New in version 3.3}. 

Examples

The following server code creates a listener which uses 'secret password' as an authentication key. It then waits for a connection and sends some data to the client:

```python
from multiprocessing.connection import Listener
from array import array

address = ('localhost', 6000)  # family is deduced

with Listener(address, authkey=b'secret password') as listener:
    with listener.accept() as conn:
        print('connection accepted from', listener.last_accepted)

        conn.send([2.25, None, 'junk', float])
        conn.send_bytes(b'hello')
        conn.send_bytes(array('i', [42, 1729]))
```

The following code connects to the server and receives some data from the server:

```python
from multiprocessing.connection import Client
from array import array

address = ('localhost', 6000)

with Client(address, authkey=b'secret password') as conn:
    print(conn.recv())  # => [2.25,
    print(conn.recv_bytes())  # => 'hello'

arr = array('i', [0, 0, 0, 0, 0])
```
print(conn.recv_bytes_into(arr))  # => 8
print(arr)                     # => array('i',
                                 # [42,
                                 # 1729,
                                 # 0,
                                 # 0,
                                 # 0])

The following code uses `wait()` to wait for messages from multiple processes at once:

```python
import time, random
from multiprocessing import Process, Pipe, current_process
from multiprocessing.connection import wait

def foo(w):
    for i in range(10):
        w.send((i, current_process().name))
    w.close()

if __name__ == '__main__':
    readers = []
    for i in range(4):
        r, w = Pipe(duplex=False)
        readers.append(r)
        p = Process(target=foo, args=(w,))
        p.start()
        # We close the writable end of the pipe now
        # p is the only process which owns a handle
        # ensures that when p closes its handle for
        # wait() will promptly report the readable end
        w.close()

while readers:
    for r in wait(readers):
        try:
            msg = r.recv()
        except EOFError:
            readers.remove(r)
        else:
```
17.2.2.10.1. Address Formats

- An 'AF_INET' address is a tuple of the form (hostname, port) where hostname is a string and port is an integer.

- An 'AF_UNIX' address is a string representing a filename on the filesystem.

- An 'AF_PIPE' address is a string of the form r'\\.pipe\PipeName'. To use Client() to connect to a named pipe on a remote computer called ServerName one should use an address of the form r'\\ServerName\pipe\PipeName' instead.

Note that any string beginning with two backslashes is assumed by default to be an 'AF_PIPE' address rather than an 'AF_UNIX' address.

17.2.2.11. Authentication keys

When one uses Connection.recv, the data received is automatically unpickled. Unfortunately unpickling data from an untrusted source is a security risk. Therefore Listener and Client() use the hmac module to provide digest authentication.

An authentication key is a byte string which can be thought of as a password: once a connection is established both ends will demand proof that the other knows the authentication key. (Demonstrating that both ends are using the same key does not involve sending the key
over the connection.)

If authentication is requested but no authentication key is specified then the return value of current_process().authkey is used (see Process). This value will automatically inherited by any Process object that the current process creates. This means that (by default) all processes of a multi-process program will share a single authentication key which can be used when setting up connections between themselves.

Suitable authentication keys can also be generated by using os.urandom().

17.2.2.12. Logging

Some support for logging is available. Note, however, that the logging package does not use process shared locks so it is possible (depending on the handler type) for messages from different processes to get mixed up.

multiprocessing.get_logger()

Returns the logger used by multiprocessing. If necessary, a new one will be created.

When first created the logger has level logging.NOTSET and no default handler. Messages sent to this logger will not by default propagate to the root logger.

Note that on Windows child processes will only inherit the level of the parent process’s logger – any other customization of the logger will not be inherited.

multiprocessing.log_to_stderr()
This function performs a call to `get_logger()` but in addition to returning the logger created by `get_logger`, it adds a handler which sends output to `sys.stderr` using format '

```
[%(levelname)s/%(processName)s] %(message)s'
```

Below is an example session with logging turned on:

```python
>>> import multiprocessing, logging
>>> logger = multiprocessing.log_to_stderr()
>>> logger.setLevel(logging.INFO)
>>> logger.warning('doomed')
[WARNING/MainProcess] doomed
>>> m = multiprocessing.Manager()
[INFO/SyncManager-....] child process calling self.run()
[INFO/SyncManager-....] created temp directory /.../pymp-
[INFO/SyncManager-....] manager serving at '/.../listener-
>>> del m
[INFO/MainProcess] sending shutdown message to manager
[INFO/SyncManager-....] manager exiting with exitcode
```

For a full table of logging levels, see the `logging` module.

17.2.2.13. The `multiprocessing.dummy` module

`multiprocessing.dummy` replicates the API of `multiprocessing` but is no more than a wrapper around the `threading` module.
17.2.3. Programming guidelines

There are certain guidelines and idioms which should be adhered to when using multiprocessing.

17.2.3.1. All start methods

The following applies to all start methods.

Avoid shared state

As far as possible one should try to avoid shifting large amounts of data between processes.

It is probably best to stick to using queues or pipes for communication between processes rather than using the lower level synchronization primitives.

Picklability

Ensure that the arguments to the methods of proxies are picklable.

Thread safety of proxies

Do not use a proxy object from more than one thread unless you protect it with a lock.

(There is never a problem with different processes using the same proxy.)

Joining zombie processes

On Unix when a process finishes but has not been joined it
becomes a zombie. There should never be very many because each time a new process starts (or active_children() is called) all completed processes which have not yet been joined will be joined. Also calling a finished process's Process.is_alive will join the process. Even so it is probably good practice to explicitly join all the processes that you start.

Better to inherit than pickle/unpickle

When using the spawn or forkserver start methods many types from multiprocessing need to be picklable so that child processes can use them. However, one should generally avoid sending shared objects to other processes using pipes or queues. Instead you should arrange the program so that a process which needs access to a shared resource created elsewhere can inherit it from an ancestor process.

Avoid terminating processes

Using the Process.terminate method to stop a process is liable to cause any shared resources (such as locks, semaphores, pipes and queues) currently being used by the process to become broken or unavailable to other processes. Therefore it is probably best to only consider using Process.terminate on processes which never use any shared resources.

Joining processes that use queues

Bear in mind that a process that has put items in a queue will wait before terminating until all the buffered items are fed by the “feeder” thread to the underlying pipe. (The child process can call the Queue.cancel_join_thread method of the queue to avoid this behaviour.)
This means that whenever you use a queue you need to make sure that all items which have been put on the queue will eventually be removed before the process is joined. Otherwise you cannot be sure that processes which have put items on the queue will terminate. Remember also that non-daemonic processes will be joined automatically.

An example which will deadlock is the following:

```python
from multiprocessing import Process, Queue

def f(q):
    q.put('X' * 1000000)

if __name__ == '__main__':
    queue = Queue()
    p = Process(target=f, args=(queue,))
    p.start()
    p.join() # this deadlocks
    obj = queue.get()
```

A fix here would be to swap the last two lines (or simply remove the `p.join()` line).

Explicitly pass resources to child processes

On Unix using the `fork` start method, a child process can make use of a shared resource created in a parent process using a global resource. However, it is better to pass the object as an argument to the constructor for the child process.

Apart from making the code (potentially) compatible with Windows and the other start methods this also ensures that as long as the child process is still alive the object will not be garbage collected
in the parent process. This might be important if some resource is freed when the object is garbage collected in the parent process.

So for instance

```python
from multiprocessing import Process, Lock

def f():
    ... do something using "lock" ...

if __name__ == '__main__':
    lock = Lock()
    for i in range(10):
        Process(target=f).start()
```

should be rewritten as

```python
from multiprocessing import Process, Lock

def f(l):
    ... do something using "l" ...

if __name__ == '__main__':
    lock = Lock()
    for i in range(10):
        Process(target=f, args=(lock,)).start()
```

Beware of replacing `sys.stdin` with a “file like object”

`multiprocessing` originally unconditionally called:

```python
os.close(sys.stdin.fileno())
```

in the `multiprocessing.Process._bootstrap()` method — this resulted in issues with processes-in-processes. This has been
changed to:

```python
sys.stdin.close()
sys.stdin = open(os.devnull)
```

Which solves the fundamental issue of processes colliding with each other resulting in a bad file descriptor error, but introduces a potential danger to applications which replace `sys.stdin()` with a “file-like object” with output buffering. This danger is that if multiple processes call `close()` on this file-like object, it could result in the same data being flushed to the object multiple times, resulting in corruption.

If you write a file-like object and implement your own caching, you can make it fork-safe by storing the pid whenever you append to the cache, and discarding the cache when the pid changes. For example:

```python
@property
def cache(self):
    pid = os.getpid()
    if pid != self._pid:
        self._pid = pid
        self._cache = []
    return self._cache
```

For more information, see issue 5155, issue 5313 and issue 5331

17.2.3.2. The spawn and forkserver start methods

There are a few extra restriction which don’t apply to the fork start method.
More picklability

Ensure that all arguments to Process.__init__() are picklable. This means, in particular, that bound or unbound methods cannot be used directly as the target (unless you use the fork start method) — just define a function and use that instead.

Also, if you subclass Process then make sure that instances will be picklable when the Process.start method is called.

Global variables

Bear in mind that if code run in a child process tries to access a global variable, then the value it sees (if any) may not be the same as the value in the parent process at the time that Process.start was called.

However, global variables which are just module level constants cause no problems.

Safe importing of main module

Make sure that the main module can be safely imported by a new Python interpreter without causing unintended side effects (such a starting a new process).

For example, using the spawn or forkserver start method running the following module would fail with a RuntimeError:

```python
from multiprocessing import Process

def foo():
    print('hello')
```
Instead one should protect the “entry point” of the program by using `if __name__ == '__main__':` as follows:

```python
from multiprocessing import Process, freeze_support

def foo():
    print('hello')

if __name__ == '__main__':
    freeze_support()
    set_start_method('spawn')
    p = Process(target=foo)
    p.start()
```

(The `freeze_support()` line can be omitted if the program will be run normally instead of frozen.)

This allows the newly spawned Python interpreter to safely import the module and then run the module’s `foo()` function.

Similar restrictions apply if a pool or manager is created in the main module.
17.2.4. Examples

Demonstration of how to create and use customized managers and proxies:

```python
from multiprocessing import freeze_support
from multiprocessing.managers import BaseManager, BaseProxy
import operator

##

class Foo:
    def f(self):
        print('you called Foo.f()')
    def g(self):
        print('you called Foo.g()')
    def _h(self):
        print('you called Foo._h()')

# A simple generator function
def baz():
    for i in range(10):
        yield i*i

# Proxy type for generator objects
class GeneratorProxy(BaseProxy):
    _exposed_ = ['__next__']
    def __iter__(self):
        return self
    def __next__(self):
        return self._callmethod('__next__')

# Function to return the operator module
def get_operator_module():
    return operator
```
##

```python
class MyManager(BaseManager):
    pass

# register the Foo class; make `f()` and `g()` accessible via proxy
MyManager.register('Foo1', Foo)

# register the Foo class; make `g()` and `_h()` accessible via proxy
MyManager.register('Foo2', Foo, exposed=('g', '_h'))

# register the generator function baz; use `GeneratorProxy` to make proxies
MyManager.register('baz', baz, proxytype=GeneratorProxy)

# register get_operator_module(); make public functions accessible via proxy
MyManager.register('operator', get_operator_module)
```

##

```python
def test():
    manager = MyManager()
    manager.start()

    print('-' * 20)

    f1 = manager.Foo1()
    f1.f()
    f1.g()
    assert not hasattr(f1, '_h')
    assert sorted(f1._exposed_) == sorted(['f', 'g'])

    print('-' * 20)

    f2 = manager.Foo2()
    f2.g()
    f2._h()
```
assert not hasattr(f2, 'f')
assert sorted(f2._exposed_) == sorted(['g', '_h'])

print('-' * 20)

it = manager.baz()
for i in it:
    print('<%d>' % i, end=' ')
print()

print('-' * 20)

op = manager.operator()
print('op.add(23, 45) =', op.add(23, 45))
print('op.pow(2, 94) =', op.pow(2, 94))
print('op._exposed_ =', op._exposed_)

#
if __name__ == '__main__':
    freeze_support()
    test()

Using Pool:

import multiprocessing
import time
import random
import sys

# # Functions used by test code#
#
def calculate(func, args):
    result = func(*args)
return '%%s says that %%s%%s = %%s' % (multiprocessing.current_process().name, func.__name__, args, result)

def calculatestar(args):
    return calculate(*args)

def mul(a, b):
    time.sleep(0.5 * random.random())
    return a * b

def plus(a, b):
    time.sleep(0.5 * random.random())
    return a + b

def f(x):
    return 1.0 / (x - 5.0)

def pow3(x):
    return x ** 3

def noop(x):
    pass

#
# Test code
#

def test():
    PROCESSES = 4
    print('Creating pool with %d processes\n' % PROCESSES)

    with multiprocessing.Pool(PROCESSES) as pool:
        #
        # Tests
        #
TASKS = [(mul, (i, 7)) for i in range(10)] +
[(plus, (i, 8)) for i in range(10)]

results = [pool.apply_async(calculate, t) for t in TASKS]
imap_it = pool.imap(calculatestar, TASKS)
imap_unordered_it = pool.imap_unordered(calculatestar)

print('Ordered results using pool.apply_async():
for r in results:
    print('	', r.get())
print()

print('Ordered results using pool.imap():
for x in imap_it:
    print('	', x)
print()

print('Unordered results using pool.imap_unordered():
for x in imap_unordered_it:
    print('	', x)
print()

print('Ordered results using pool.map() ---
for x in pool.map(calculatestar, TASKS):
    print('	', x)
print()

#
# Test error handling
#
print('Testing error handling:"

try:  
    print(pool.apply(f, (5,)))
except ZeroDivisionError:
try:
    print(pool.map(f, list(range(10))))
except ZeroDivisionError:
    print('Got ZeroDivisionError as expected from pool.map()')
else:
    raise AssertionError('expected ZeroDivisionError')

try:
    print(list(pool.imap(f, list(range(10)))))
except ZeroDivisionError:
    print('Got ZeroDivisionError as expected from list(pool.imap())')
else:
    raise AssertionError('expected ZeroDivisionError')

it = pool.imap(f, list(range(10)))
for i in range(10):
    try:
        x = next(it)
    except ZeroDivisionError:
        if i == 5:
            pass
        except StopIteration:
            break
    else:
        if i == 5:
            raise AssertionError('expected ZeroDivisionError')

assert i == 9
print('Got ZeroDivisionError as expected for')
print()

#  # Testing timeouts
An example showing how to use queues to feed tasks to a collection of worker processes and collect the results:

```python
import time
```
import random

from multiprocessing import Process, Queue, current_process

# Function run by worker processes
#
def worker(input, output):
    for func, args in iter(input.get, 'STOP'):
        result = calculate(func, args)
        output.put(result)

# Function used to calculate result
#
def calculate(func, args):
    result = func(*args)
    return '%s says that %s%ss = %s' % 
            (current_process().name, func.__name__, args

# Functions referenced by tasks
#
def mul(a, b):
    time.sleep(0.5*random.random())
    return a * b

def plus(a, b):
    time.sleep(0.5*random.random())
    return a + b
def test():
    NUMBER_OF_PROCESSES = 4
    TASKS1 = [(mul, (i, 7)) for i in range(20)]
    TASKS2 = [(plus, (i, 8)) for i in range(10)]

    # Create queues
    task_queue = Queue()
    done_queue = Queue()

    # Submit tasks
    for task in TASKS1:
        task_queue.put(task)

    # Start worker processes
    for i in range(NUMBER_OF_PROCESSES):
        Process(target=worker, args=(task_queue, done_queue,)).start()

    # Get and print results
    print('Unordered results:"
    for i in range(len(TASKS1)):
        print('\t', done_queue.get())

    # Add more tasks using `put`
    for task in TASKS2:
        task_queue.put(task)

    # Get and print some more results
    for i in range(len(TASKS2)):
        print('\t', done_queue.get())

    # Tell child processes to stop
    for i in range(NUMBER_OF_PROCESSES):
        task_queue.put('STOP')

if __name__ == '__main__':
17.3. The concurrent package

Currently, there is only one module in this package:

- **concurrent.futures** – Launching parallel tasks
17.4. `concurrent.futures` — Launching parallel tasks

*New in version 3.2.*

**Source code:** `Lib/concurrent/futures/thread.py` and `Lib/concurrent/futures/process.py`

The `concurrent.futures` module provides a high-level interface for asynchronously executing callables.

The asynchronous execution can be performed with threads, using `ThreadPoolExecutor`, or separate processes, using `ProcessPoolExecutor`. Both implement the same interface, which is defined by the abstract `Executor` class.
### 17.4.1. Executor Objects

**class concurrent.futures.Executor**

An abstract class that provides methods to execute calls asynchronously. It should not be used directly, but through its concrete subclasses.

**submit(fn, *args, **kwargs)**

Schedules the callable, `fn`, to be executed as `fn(*args, **kwargs)` and returns a `Future` object representing the execution of the callable.

```python
with ThreadPoolExecutor(max_workers=1) as executor:
    future = executor.submit(pow, 323, 1235)
    print(future.result())
```

**map(func, *iterables, timeout=None, chunksize=1)**

Equivalent to `map(func, *iterables)` except `func` is executed asynchronously and several calls to `func` may be made concurrently. The returned iterator raises a `TimeoutError` if `__next__()` is called and the result isn’t available after `timeout` seconds from the original call to `Executor.map()`. `timeout` can be an int or a float. If `timeout` is not specified or `None`, there is no limit to the wait time. If a call raises an exception, then that exception will be raised when its value is retrieved from the iterator. When using `ProcessPoolExecutor`, this method chops `iterables` into a number of chunks which it submits to the pool as separate tasks. The (approximate) size of these chunks can be specified by setting `chunksize` to a positive
integer. For very long iterables, using a large value for chunksize can significantly improve performance compared to the default size of 1. With ThreadPoolExecutor, chunksize has no effect.

*Changed in version 3.5:* Added the chunksize argument.

**shutdown**(wait=True)

Signal the executor that it should free any resources that it is using when the currently pending futures are done executing. Calls to Executor.submit() and Executor.map() made after shutdown will raise RuntimeError.

If wait is True then this method will not return until all the pending futures are done executing and the resources associated with the executor have been freed. If wait is False then this method will return immediately and the resources associated with the executor will be freed when all pending futures are done executing. Regardless of the value of wait, the entire Python program will not exit until all pending futures are done executing.

You can avoid having to call this method explicitly if you use the with statement, which will shutdown the Executor (waiting as if Executor.shutdown() were called with wait set to True):

```python
import shutil
with ThreadPoolExecutor(max_workers=4) as e:
    e.submit(shutil.copy, 'src1.txt', 'dest1.txt')
    e.submit(shutil.copy, 'src2.txt', 'dest2.txt')
    e.submit(shutil.copy, 'src3.txt', 'dest3.txt')
```
e.submit(shutil.copy, 'src4.txt', 'dest4.txt')
17.4.2. ThreadPoolExecutor

ThreadPoolExecutor is an Executor subclass that uses a pool of threads to execute calls asynchronously.

Deadlocks can occur when the callable associated with a Future waits on the results of another Future. For example:

```python
import time

def wait_on_b():
    time.sleep(5)
    print(b.result())  # b will never complete because it is waiting on a.
    return 5

def wait_on_a():
    time.sleep(5)
    print(a.result())  # a will never complete because it is waiting on b.
    return 6

executor = ThreadPoolExecutor(max_workers=2)
a = executor.submit(wait_on_b)
b = executor.submit(wait_on_a)
```

And:

```python
def wait_on_future():
    f = executor.submit(pow, 5, 2)
    # This will never complete because there is only one worker thread and it is executing this function.
    print(f.result())

executor = ThreadPoolExecutor(max_workers=1)
executor.submit(wait_on_future)
```
class concurrent.futures.ThreadPoolExecutor(max_workers=None):
    
    An Executor subclass that uses a pool of at most max_workers threads to execute calls asynchronously.

    Changed in version 3.5: If max_workers is None or not given, it will default to the number of processors on the machine, multiplied by 5, assuming that ThreadPoolExecutor is often used to overlap I/O instead of CPU work and the number of workers should be higher than the number of workers for ProcessPoolExecutor.

17.4.2.1. ThreadPoolExecutor Example

```python
import concurrent.futures
import urllib.request

URLS = ['http://www.foxnews.com/',
        'http://www.cnn.com/',
        'http://europe.wsj.com/',
        'http://www.bbc.co.uk/',
        'http://some-made-up-domain.com/']

# Retrieve a single page and report the url and content
def load_url(url, timeout):
    with urllib.request.urlopen(url, timeout=timeout) as conn:
        return conn.read()

# We can use a with statement to ensure threads are cleaned up promptly
with concurrent.futures.ThreadPoolExecutor(max_workers=)
    # Start the load operations and mark each future
    future_to_url = {executor.submit(load_url, url, url):
        for future in concurrent.futures.as_completed(future_to_url)
            url = future_to_url[future]
```
try:
    data = future.result()
except Exception as exc:
    print('%r generated an exception: %s' %
else:
    print('%r page is %d bytes' % (url, len(data)))
17.4.3. ProcessPoolExecutor

The `ProcessPoolExecutor` class is an `Executor` subclass that uses a pool of processes to execute calls asynchronously. `ProcessPoolExecutor` uses the `multiprocessing` module, which allows it to side-step the Global Interpreter Lock but also means that only picklable objects can be executed and returned.

The `__main__` module must be importable by worker subprocesses. This means that `ProcessPoolExecutor` will not work in the interactive interpreter.

Calling `Executor` or `Future` methods from a callable submitted to a `ProcessPoolExecutor` will result in deadlock.

class concurrent.futures.ProcessPoolExecutor(max_workers=None)

An `Executor` subclass that executes calls asynchronously using a pool of at most `max_workers` processes. If `max_workers` is None or not given, it will default to the number of processors on the machine. If `max_workers` is lower or equal to 0, then a `ValueError` will be raised.

*Changed in version 3.3:* When one of the worker processes terminates abruptly, a `BrokenProcessPool` error is now raised. Previously, behaviour was undefined but operations on the executor or its futures would often freeze or deadlock.

17.4.3.1. ProcessPoolExecutor Example

```python
import concurrent.futures
```
import math

PRIMES = [
    11272535095293,
    112582705942171,
    112272535095293,
    115280095190773,
    115797848077099,
    1099726899285419
]

def is_prime(n):
    if n % 2 == 0:
        return False

    sqrt_n = int(math.floor(math.sqrt(n)))
    for i in range(3, sqrt_n + 1, 2):
        if n % i == 0:
            return False

    return True

def main():
    with concurrent.futures.ProcessPoolExecutor() as executor:
        for number, prime in zip(PRIMES, executor.map(is_prime, PRIMES)):
            print('%d is prime: %s' % (number, prime))

if __name__ == '__main__':
    main()
17.4.4. Future Objects

The `Future` class encapsulates the asynchronous execution of a callable. `Future` instances are created by `Executor.submit()`.

```python
class concurrent.futures.Future
    Encapsulates the asynchronous execution of a callable. `Future` instances are created by `Executor.submit()` and should not be created directly except for testing.

    cancel()
    Attempt to cancel the call. If the call is currently being executed and cannot be cancelled then the method will return False, otherwise the call will be cancelled and the method will return True.

    cancelled()
    Return True if the call was successfully cancelled.

    running()
    Return True if the call is currently being executed and cannot be cancelled.

    done()
    Return True if the call was successfully cancelled or finished running.

    result(timeout=None)
    Return the value returned by the call. If the call hasn’t yet completed then this method will wait up to `timeout` seconds. If the call hasn’t completed in `timeout` seconds,
then a `TimeoutError` will be raised. `timeout` can be an int or float. If `timeout` is not specified or None, there is no limit to the wait time.

If the future is cancelled before completing then `CancelledError` will be raised.

If the call raised, this method will raise the same exception.

```python
def exception(timeout=None):
    # Return the exception raised by the call. If the call hasn’t yet completed then this method will wait up to `timeout` seconds. If the call hasn’t completed in `timeout` seconds, then a `TimeoutError` will be raised. `timeout` can be an int or float. If `timeout` is not specified or None, there is no limit to the wait time.

    If the future is cancelled before completing then `CancelledError` will be raised.

    If the call completed without raising, None is returned.
```

```python
def add_done_callback(fn):
    # Attaches the callable `fn` to the future. `fn` will be called, with the future as its only argument, when the future is cancelled or finishes running.

    Added callables are called in the order that they were added and are always called in a thread belonging to the process that added them. If the callable raises an `Exception` subclass, it will be logged and ignored. If the callable raises a `BaseException` subclass, the behavior is undefined.
```
If the future has already completed or been cancelled, \( fn \) will be called immediately.

The following \texttt{Future} methods are meant for use in unit tests and \texttt{Executor} implementations.

\textbf{set\_running\_or\_notify\_cancel()}
This method should only be called by \texttt{Executor} implementations before executing the work associated with the \texttt{Future} and by unit tests.

If the method returns \texttt{False} then the \texttt{Future} was cancelled, i.e. \texttt{Future.cancel()} was called and returned \texttt{True}. Any threads waiting on the \texttt{Future} completing (i.e. through \texttt{as\_completed()} or \texttt{wait()}) will be woken up.

If the method returns \texttt{True} then the \texttt{Future} was not cancelled and has been put in the running state, i.e. calls to \texttt{Future.running()} will return \texttt{True}.

This method can only be called once and cannot be called after \texttt{Future.set\_result()} or \texttt{Future.set\_exception()} have been called.

\textbf{set\_result}(\texttt{result})
Sets the result of the work associated with the \texttt{Future} to \texttt{result}.

This method should only be used by \texttt{Executor} implementations and unit tests.

\textbf{set\_exception}(\texttt{exception})
Sets the result of the work associated with the `Future` to the `Exception` exception.

This method should only be used by `Executor` implementations and unit tests.
17.4.5. Module Functions

```python
concurrent.futures.wait(fs, timeout=None, return_when=ALL_COMPLETED)
```

Wait for the `Future` instances (possibly created by different `Executor` instances) given by `fs` to complete. Returns a named 2-tuple of sets. The first set, named `done`, contains the futures that completed (finished or were cancelled) before the wait completed. The second set, named `not_done`, contains uncompleted futures.

`timeout` can be used to control the maximum number of seconds to wait before returning. `timeout` can be an int or float. If `timeout` is not specified or `None`, there is no limit to the wait time.

`return_when` indicates when this function should return. It must be one of the following constants:

<table>
<thead>
<tr>
<th>Constant</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRST_COMPLETED</td>
<td>The function will return when any future finishes or is cancelled.</td>
</tr>
<tr>
<td>FIRST_EXCEPTION</td>
<td>The function will return when any future finishes by raising an exception. If no future raises an exception then it is equivalent to ALL_COMPLETED.</td>
</tr>
<tr>
<td>ALL_COMPLETED</td>
<td>The function will return when all futures finish or are cancelled.</td>
</tr>
</tbody>
</table>

```python
concurrent.futures.as_completed(fs, timeout=None)
```

Returns an iterator over the `Future` instances (possibly created by different `Executor` instances) given by `fs` that yields futures as
they complete (finished or were cancelled). Any futures given by `fs` that are duplicated will be returned once. Any futures that completed before `as_completed()` is called will be yielded first. The returned iterator raises a `TimeoutError` if `__next__()` is called and the result isn't available after `timeout` seconds from the original call to `as_completed()`. `timeout` can be an int or float. If `timeout` is not specified or None, there is no limit to the wait time.

See also:

**PEP 3148 – futures - execute computations asynchronously**

The proposal which described this feature for inclusion in the Python standard library.
17.4.6. Exception classes

```
exception concurrent.futures.process.BrokenProcessPool
```

Derived from `RuntimeError`, this exception class is raised when one of the workers of a `ProcessPoolExecutor` has terminated in a non-clean fashion (for example, if it was killed from the outside).

*New in version 3.3.*
17.5. subprocess — Subprocess management

The subprocess module allows you to spawn new processes, connect to their input/output/error pipes, and obtain their return codes. This module intends to replace several older modules and functions:

```python
os.system
os.spawn*
```

Information about how the subprocess module can be used to replace these modules and functions can be found in the following sections.

See also: PEP 324 – PEP proposing the subprocess module
17.5.1. Using the subprocess Module

The recommended approach to invoking subprocesses is to use the run() function for all use cases it can handle. For more advanced use cases, the underlying Popen interface can be used directly.

The run() function was added in Python 3.5; if you need to retain compatibility with older versions, see the Older high-level API section.

subprocess.run(args, *, stdin=None, input=None, stdout=None, stderr=None, shell=False, timeout=None, check=False)

Run the command described by args. Wait for command to complete, then return a CompletedProcess instance.

The arguments shown above are merely the most common ones, described below in Frequently Used Arguments (hence the use of keyword-only notation in the abbreviated signature). The full function signature is largely the same as that of the Popen constructor - apart from timeout, input and check, all the arguments to this function are passed through to that interface.

This does not capture stdout or stderr by default. To do so, pass PIPE for the stdout and/or stderr arguments.

The timeout argument is passed to Popen.communicate(). If the timeout expires, the child process will be killed and waited for. The TimeoutExpired exception will be re-raised after the child process has terminated.

The input argument is passed to Popen.communicate() and thus to the subprocess's stdin. If used it must be a byte sequence, or a string if universal_newlines=True. When used, the
internal `Popen` object is automatically created with stdin=PIPE, and the `stdin` argument may not be used as well.

If `check` is True, and the process exits with a non-zero exit code, a `CalledProcessError` exception will be raised. Attributes of that exception hold the arguments, the exit code, and stdout and stderr if they were captured.

Examples:

```python
>>> subprocess.run(['ls', '-l'])  # doesn't capture output
CompletedProcess(args=['ls', '-l'], returncode=0)

>>> subprocess.run('exit 1', shell=True, check=True)
Traceback (most recent call last):
  ...  
subprocess.CalledProcessError: Command 'exit 1' returned non-zero exit status 1

>>> subprocess.run(['ls', '-l', '/dev/null'], stdout=subprocess.PIPE)
CompletedProcess(args=['ls', '-l', '/dev/null'], returncode=0, stdout=b'crw-rw-rw- 1 root root 1, 3 Jan 23 16:23 /dev/null')
```

New in version 3.5.

class subprocess.CompletedProcess

The return value from `run()`, representing a process that has finished.

args

The arguments used to launch the process. This may be a list or a string.

returncode

Exit status of the child process. Typically, an exit status of 0
indicates that it ran successfully.

A negative value -N indicates that the child was terminated by signal N (POSIX only).

**stdout**
Captured stdout from the child process. A bytes sequence, or a string if `run()` was called with `universal_newlines=True`. None if stdout was not captured.

If you ran the process with `stderr=subprocess.STDOUT`, stdout and stderr will be combined in this attribute, and `stderr` will be None.

**stderr**
Captured stderr from the child process. A bytes sequence, or a string if `run()` was called with `universal_newlines=True`. None if stderr was not captured.

**check_returncode()**
If `returncode` is non-zero, raise a `CalledProcessError`.

*New in version 3.5.*

**subprocess.DEVNULL**
Special value that can be used as the `stdin`, `stdout` or `stderr` argument to `Popen` and indicates that the special file `os.devnull` will be used.

*New in version 3.3.*

**subprocess.PIPE**
Special value that can be used as the `stdin`, `stdout` or `stderr`
argument to `Popen` and indicates that a pipe to the standard stream should be opened. Most useful with `Popen.communicate()`.

`subprocess.STDOUT`
Special value that can be used as the `stderr` argument to `Popen` and indicates that standard error should go into the same handle as standard output.

`exception subprocess.SubprocessError`
Base class for all other exceptions from this module.

*New in version 3.3.*

`exception subprocess.TimeoutExpired`
Subclass of `SubprocessError`, raised when a timeout expires while waiting for a child process.

`cmd`
Command that was used to spawn the child process.

`timeout`
Timeout in seconds.

`output`
Output of the child process if it was captured by `run()` or `check_output()`. Otherwise, None.

`stdout`
Alias for output, for symmetry with `stderr`.

`stderr`
Stderr output of the child process if it was captured by `run()`.
Otherwise, None.

New in version 3.3.

Changed in version 3.5: stdout and stderr attributes added

exception subprocess. **CalledProcessError**

Subclass of SubprocessError, raised when a process run by check_call() or check_output() returns a non-zero exit status.

**returncode**

Exit status of the child process.

**cmd**

Command that was used to spawn the child process.

**output**

Output of the child process if it was captured by run() or check_output(). Otherwise, None.

**stdout**

Alias for output, for symmetry with stderr.

**stderr**

Stderr output of the child process if it was captured by run(). Otherwise, None.

Changed in version 3.5: stdout and stderr attributes added

17.5.1.1. Frequently Used Arguments

To support a wide variety of use cases, the Popen constructor (and
the convenience functions) accept a large number of optional arguments. For most typical use cases, many of these arguments can be safely left at their default values. The arguments that are most commonly needed are:

- **args** is required for all calls and should be a string, or a sequence of program arguments. Providing a sequence of arguments is generally preferred, as it allows the module to take care of any required escaping and quoting of arguments (e.g. to permit spaces in file names). If passing a single string, either shell must be **True** (see below) or else the string must simply name the program to be executed without specifying any arguments.

- **stdin**, **stdout** and **stderr** specify the executed program's standard input, standard output and standard error file handles, respectively. Valid values are **PIPE**, **DEVNULL**, an existing file descriptor (a positive integer), an existing file object, and None. **PIPE** indicates that a new pipe to the child should be created. **DEVNULL** indicates that the special file **os.devnull** will be used. With the default settings of None, no redirection will occur; the child’s file handles will be inherited from the parent. Additionally, **stderr** can be **STDOUT**, which indicates that the stderr data from the child process should be captured into the same file handle as for **stdout**.

If **universal_newlines** is False the file objects **stdin**, **stdout** and **stderr** will be opened as binary streams, and no line ending conversion is done.

If **universal_newlines** is True, these file objects will be opened as text streams in **universal newlines** mode using the encoding returned by **locale.getpreferredencoding(False)**. For
\texttt{stdin}, line ending characters '\n' in the input will be converted to the default line separator \texttt{os.linesep}. For \texttt{stdout} and \texttt{stderr}, all line endings in the output will be converted to '\n'. For more information see the documentation of the \texttt{io.TextIOWrapper} class when the \texttt{newline} argument to its constructor is \texttt{None}.

**Note:** The \texttt{newlines} attribute of the file objects \texttt{Popen.stdin}, \texttt{Popen.stdout} and \texttt{Popen.stderr} are not updated by the \texttt{Popen.communicate()} method.

If \texttt{shell} is \texttt{True}, the specified command will be executed through the shell. This can be useful if you are using Python primarily for the enhanced control flow it offers over most system shells and still want convenient access to other shell features such as shell pipes, filename wildcards, environment variable expansion, and expansion of \texttt{~} to a user's home directory. However, note that Python itself offers implementations of many shell-like features (in particular, \texttt{glob}, \texttt{fnmatch}, \texttt{os.walk()}, \texttt{os.path.expandvars()}, \texttt{os.path.expanduser()}, and \texttt{shutil}).

*Changed in version 3.3:* When \texttt{universal_newlines} is \texttt{True}, the class uses the encoding \texttt{locale.getpreferredencoding(False)} instead of \texttt{locale.getpreferredencoding()}. See the \texttt{io.TextIOWrapper} class for more information on this change.

**Note:** Read the \texttt{Security Considerations} section before using \texttt{shell=True}.

These options, along with all of the other options, are described in
more detail in the `Popen` constructor documentation.

17.5.1.2. Popen Constructor

The underlying process creation and management in this module is handled by the `Popen` class. It offers a lot of flexibility so that developers are able to handle the less common cases not covered by the convenience functions.

```python
class subprocess.Popen(args, bufsize=-1, executable=None,
stdin=None, stdout=None, stderr=None, preexec_fn=None,
close_fds=True, shell=False, cwd=None, env=None,
universal_newlines=False, startupinfo=None, creationflags=0,
restore_signals=True, start_new_session=False, pass_fds=())
```

Execute a child program in a new process. On POSIX, the class uses `os.execvp()`-like behavior to execute the child program. On Windows, the class uses the Windows `CreateProcess()` function. The arguments to `Popen` are as follows.

`args` should be a sequence of program arguments or else a single string. By default, the program to execute is the first item in `args` if `args` is a sequence. If `args` is a string, the interpretation is platform-dependent and described below. See the `shell` and `executable` arguments for additional differences from the default behavior. Unless otherwise stated, it is recommended to pass `args` as a sequence.

On POSIX, if `args` is a string, the string is interpreted as the name or path of the program to execute. However, this can only be done if not passing arguments to the program.

**Note:** `shlex.split()` can be useful when determining the
correct tokenization for `args`, especially in complex cases:

```python
>>> import shlex, subprocess
>>> command_line = input()
/bin/vikings -input eggs.txt -output "spam spam.
>>> args = shlex.split(command_line)
>>> print(args)
['/bin/vikings', '-input', 'eggs.txt', '-output'
>>> p = subprocess.Popen(args) # Success!
```

Note in particular that options (such as `-input`) and arguments (such as `eggs.txt`) that are separated by whitespace in the shell go in separate list elements, while arguments that need quoting or backslash escaping when used in the shell (such as filenames containing spaces or the `echo` command shown above) are single list elements.

On Windows, if `args` is a sequence, it will be converted to a string in a manner described in [Converting an argument sequence to a string on Windows](https://docs.python.org/3/library/subprocess.html#converting-an-argument-sequence-to-a-string-on-windows). This is because the underlying `CreateProcess()` operates on strings.

The `shell` argument (which defaults to `False`) specifies whether to use the shell as the program to execute. If `shell` is `True`, it is recommended to pass `args` as a string rather than as a sequence.

On POSIX with `shell=True`, the shell defaults to `/bin/sh`. If `args` is a string, the string specifies the command to execute through the shell. This means that the string must be formatted exactly as it would be when typed at the shell prompt. This includes, for example, quoting or backslash escaping filenames with spaces in them. If `args` is a sequence, the first item specifies the command string, and any additional items will be treated as
additional arguments to the shell itself. That is to say, `Popen` does the equivalent of:

```
Popen(['/bin/sh', '-c', args[0], args[1], ...])
```

On Windows with `shell=True`, the `COMSPEC` environment variable specifies the default shell. The only time you need to specify `shell=True` on Windows is when the command you wish to execute is built into the shell (e.g. `dir` or `copy`). You do not need `shell=True` to run a batch file or console-based executable.

**Note:** Read the Security Considerations section before using `shell=True`.

`bufsize` will be supplied as the corresponding argument to the `open()` function when creating the stdin/stdout/stderr pipe file objects:

- 0 means unbuffered (read and write are one system call and can return short)
- 1 means line buffered (only usable if `universal_newlines=True` i.e., in a text mode)
- any other positive value means use a buffer of approximately that size
- negative `bufsize` (the default) means the system default of `io.DEFAULT_BUFFER_SIZE` will be used.

*Changed in version 3.3.1:* `bufsize` now defaults to `-1` to enable buffering by default to match the behavior that most code expects. In versions prior to Python 3.2.4 and 3.3.1 it incorrectly defaulted to 0 which was unbuffered and allowed short reads. This was unintentional and did not match the behavior of Python 2 as most code expected.
The `executable` argument specifies a replacement program to execute. It is very seldom needed. When `shell=False`, `executable` replaces the program to execute specified by `args`. However, the original `args` is still passed to the program. Most programs treat the program specified by `args` as the command name, which can then be different from the program actually executed. On POSIX, the `args` name becomes the display name for the executable in utilities such as `ps`. If `shell=True`, on POSIX the `executable` argument specifies a replacement shell for the default `/bin/sh`.

`stdin`, `stdout` and `stderr` specify the executed program’s standard input, standard output and standard error file handles, respectively. Valid values are `PIPE`, `DEVNULL`, an existing file descriptor (a positive integer), an existing file object, and None. `PIPE` indicates that a new pipe to the child should be created. `DEVNULL` indicates that the special file `os.devnull` will be used. With the default settings of None, no redirection will occur; the child’s file handles will be inherited from the parent. Additionally, `stderr` can be `STDOUT`, which indicates that the stderr data from the applications should be captured into the same file handle as for stdout.

If `preexec_fn` is set to a callable object, this object will be called in the child process just before the child is executed. (POSIX only)

**Warning:** The `preexec_fn` parameter is not safe to use in the presence of threads in your application. The child process could deadlock before `exec` is called. If you must use it, keep it trivial! Minimize the number of libraries you call into.

**Note:** If you need to modify the environment for the child use the `env` parameter rather than doing it in a `preexec_fn`. The
**start_new_session** parameter can take the place of a previously common use of **preexec_fn** to call os.setsid() in the child.

If **close_fds** is true, all file descriptors except 0, 1 and 2 will be closed before the child process is executed. (POSIX only). The default varies by platform: Always true on POSIX. On Windows it is true when stdin/stdout/stderr are **None**, false otherwise. On Windows, if **close_fds** is true then no handles will be inherited by the child process. Note that on Windows, you cannot set **close_fds** to true and also redirect the standard handles by setting **stdin**, **stdout** or **stderr**.

*Changed in version 3.2:* The default for **close_fds** was changed from **False** to what is described above.

**pass_fds** is an optional sequence of file descriptors to keep open between the parent and child. Providing any **pass_fds** forces **close_fds** to be **True**. (POSIX only)

*New in version 3.2:* The **pass_fds** parameter was added.

If **cwd** is not None, the function changes the working directory to **cwd** before executing the child. In particular, the function looks for **executable** (or for the first item in **args**) relative to **cwd** if the executable path is a relative path.

If **restore_signals** is true (the default) all signals that Python has set to SIG_IGN are restored to SIG_DFL in the child process before the exec. Currently this includes the SIGPIPE, SIGXFZ and SIGXFSZ signals. (POSIX only)

*Changed in version 3.2:* **restore_signals** was added.

If **start_new_session** is true the setsid() system call will be made in
the child process prior to the execution of the subprocess. (POSIX only)

*Changed in version 3.2: start_new_session was added.*

If `env` is not None, it must be a mapping that defines the environment variables for the new process; these are used instead of the default behavior of inheriting the current process’ environment.

**Note:** If specified, `env` must provide any variables required for the program to execute. On Windows, in order to run a side-by-side assembly the specified `env` must include a valid `SystemRoot`.

If `universal_newlines` is `True`, the file objects `stdin`, `stdout` and `stderr` are opened as text streams in universal newlines mode, as described above in Frequently Used Arguments, otherwise they are opened as binary streams.

If given, `startupinfo` will be a `STARTUPINFO` object, which is passed to the underlying CreateProcess function. `creationflags`, if given, can be `CREATE_NEW_CONSOLE` or `CREATE_NEW_PROCESS_GROUP`. (Windows only)

Popen objects are supported as context managers via the `with` statement: on exit, standard file descriptors are closed, and the process is waited for.

```
with Popen(["ifconfig"], stdout=PIPE) as proc:
    log.write(proc.stdout.read())
```

*Changed in version 3.2: Added context manager support.*
17.5.1.3. Exceptions

Exceptions raised in the child process, before the new program has started to execute, will be re-raised in the parent. Additionally, the exception object will have one extra attribute called child_traceback, which is a string containing traceback information from the child’s point of view.

The most common exception raised is OSError. This occurs, for example, when trying to execute a non-existant file. Applications should prepare for OSError exceptions.

A ValueError will be raised if Popen is called with invalid arguments.

check_call() and check_output() will raise CalledProcessError if the called process returns a non-zero return code.

All of the functions and methods that accept a timeout parameter, such as call() and Popen.communicate() will raise TimeoutExpired if the timeout expires before the process exits.

Exceptions defined in this module all inherit from SubprocessError.

New in version 3.3: The SubprocessError base class was added.
17.5.2. Security Considerations

Unlike some other popen functions, this implementation will never implicitly call a system shell. This means that all characters, including shell metacharacters, can safely be passed to child processes. If the shell is invoked explicitly, via `shell=True`, it is the application’s responsibility to ensure that all whitespace and metacharacters are quoted appropriately to avoid shell injection vulnerabilities.

When using `shell=True`, the `shlex.quote()` function can be used to properly escape whitespace and shell metacharacters in strings that are going to be used to construct shell commands.
17.5.3. Popen Objects

Instances of the `Popen` class have the following methods:

Popen.

**poll()**

Check if child process has terminated. Set and return `returncode` attribute.

Popen.**wait**(timeout=None)

Wait for child process to terminate. Set and return `returncode` attribute.

If the process does not terminate after `timeout` seconds, raise a `TimeoutExpired` exception. It is safe to catch this exception and retry the wait.

**Note:** This will deadlock when using `stdout=PIPE` or `stderr=PIPE` and the child process generates enough output to a pipe such that it blocks waiting for the OS pipe buffer to accept more data. Use `Popen.communicate()` when using pipes to avoid that.

**Note:** The function is implemented using a busy loop (non-blocking call and short sleeps). Use the `asyncio` module for an asynchronous wait: see `asyncio.create_subprocess_exec`.

*Changed in version 3.3:* `timeout` was added.

*Deprecated since version 3.4:* Do not use the `endtime` parameter. It is was unintentionally exposed in 3.3 but was left undocumented as it was intended to be private for internal use. Use `timeout` instead.
Popen.communicate(input=None, timeout=None)

Interact with process: Send data to stdin. Read data from stdout and stderr, until end-of-file is reached. Wait for process to terminate. The optional input argument should be data to be sent to the child process, or None, if no data should be sent to the child. The type of input must be bytes or, if universal_newlines was True, a string.

communicate() returns a tuple (stdout_data, stderr_data). The data will be bytes or, if universal_newlines was True, strings.

Note that if you want to send data to the process's stdin, you need to create the Popen object with stdin=PIPE. Similarly, to get anything other than None in the result tuple, you need to give stdout=PIPE and/or stderr=PIPE too.

If the process does not terminate after timeout seconds, a TimeoutExpired exception will be raised. Catching this exception and retrying communication will not lose any output.

The child process is not killed if the timeout expires, so in order to cleanup properly a well-behaved application should kill the child process and finish communication:

```python
proc = subprocess.Popen(...)  
try:  
    outs, errs = proc.communicate(timeout=15)  
except TimeoutExpired:  
    proc.kill()  
    outs, errs = proc.communicate()
```

Note: The data read is buffered in memory, so do not use this
method if the data size is large or unlimited.

*Changed in version 3.3: timeout was added.*

Popen\texttt{.send\_signal}(\textit{signal})

Sends the signal \textit{signal} to the child.

\begin{quote}
\textbf{Note: } On Windows, SIGTERM is an alias for \texttt{terminate()}. CTRL\_C\_EVENT and CTRL\_BREAK\_EVENT can be sent to processes started with a \textit{creationflags} parameter which includes \texttt{CREATE\_NEW\_PROCESS\_GROUP}.
\end{quote}

Popen\texttt{.terminate()}

Stop the child. On Posix OSs the method sends SIGTERM to the child. On Windows the Win32 API function \texttt{TerminateProcess()} is called to stop the child.

Popen\texttt{.kill()}

Kills the child. On Posix OSs the function sends SIGKILL to the child. On Windows \texttt{kill()} is an alias for \texttt{terminate()}.

The following attributes are also available:

Popen\texttt{.args}

The \textit{args} argument as it was passed to Popen – a sequence of program arguments or else a single string.

\textit{New in version 3.3.}

Popen\texttt{.stdin}

If the \textit{stdin} argument was PIPE, this attribute is a writeable stream object as returned by \texttt{open()}. If the \textit{universal\_newlines} argument was True, the stream is a text stream, otherwise it is a byte
stream. If the stdin argument was not PIPE, this attribute is None.

Popen.stdout
If the stdout argument was PIPE, this attribute is a readable stream object as returned by open(). Reading from the stream provides output from the child process. If the universal_newlines argument was True, the stream is a text stream, otherwise it is a byte stream. If the stdout argument was not PIPE, this attribute is None.

Popen.stderr
If the stderr argument was PIPE, this attribute is a readable stream object as returned by open(). Reading from the stream provides error output from the child process. If the universal_newlines argument was True, the stream is a text stream, otherwise it is a byte stream. If the stderr argument was not PIPE, this attribute is None.

Warning: Use communicate() rather than .stdin.write, .stdout.read or .stderr.read to avoid deadlocks due to any of the other OS pipe buffers filling up and blocking the child process.

Popen.pid
The process ID of the child process.

Note that if you set the shell argument to True, this is the process ID of the spawned shell.

Popen.returncode
The child return code, set by poll() and wait() (and indirectly by communicate()). A None value indicates that the process hasn't terminated yet.
A negative value -N indicates that the child was terminated by signal N (POSIX only).
17.5.4. Windows Popen Helpers

The **STARTUPINFO** class and following constants are only available on Windows.

```python
si = subprocess.STARTUPINFO()
si.dwFlags = subprocess.STARTF_USESTDHANDLES |
```

**class subprocess.STARTUPINFO**

Partial support of the Windows **STARTUPINFO** structure is used for **Popen** creation.

**dwFlags**

A bit field that determines whether certain **STARTUPINFO** attributes are used when the process creates a window.

**hStdInput**

If **dwFlags** specifies **STARTF_USESTDHANDLES**, this attribute is the standard input handle for the process. If **STARTF_USESTDHANDLES** is not specified, the default for standard input is the keyboard buffer.

**hStdOutput**

If **dwFlags** specifies **STARTF_USESTDHANDLES**, this attribute is the standard output handle for the process. Otherwise, this attribute is ignored and the default for standard output is the console window’s buffer.

**hStdError**

If **dwFlags** specifies **STARTF_USESTDHANDLES**, this attribute is the standard error handle for the process. Otherwise, this...
attribute is ignored and the default for standard error is the console window's buffer.

**wShowWindow**

If `dwFlags` specifies `STARTF_USESHOWWINDOW`, this attribute can be any of the values that can be specified in the `nCmdShow` parameter for the `ShowWindow` function, except for `SW_SHOWDEFAULT`. Otherwise, this attribute is ignored.

`SW_HIDE` is provided for this attribute. It is used when `Popen` is called with `shell=True`.

### 17.5.4.1. Constants

The `subprocess` module exposes the following constants.

**subprocess.**`STD_INPUT_HANDLE`

The standard input device. Initially, this is the console input buffer, `CONIN$`.

**subprocess.**`STD_OUTPUT_HANDLE`

The standard output device. Initially, this is the active console screen buffer, `CONOUT$`.

**subprocess.**`STD_ERROR_HANDLE`

The standard error device. Initially, this is the active console screen buffer, `CONOUT$`.

**subprocess.**`SW_HIDE`

Hides the window. Another window will be activated.

**subprocess.**`STARTF_USESTDHANDLES`
Specifies that the `STARTUPINFO.hStdInput`, `STARTUPINFO.hStdOutput`, and `STARTUPINFO.hStdError` attributes contain additional information.

**subprocess.**`STARTF_USESHOWWINDOW`

Specifies that the `STARTUPINFO.wShowWindow` attribute contains additional information.

**subprocess.**`CREATE_NEW_CONSOLE`

The new process has a new console, instead of inheriting its parent's console (the default).

**subprocess.**`CREATE_NEW_PROCESS_GROUP`

A `Popen` creationflags parameter to specify that a new process group will be created. This flag is necessary for using `os.kill()` on the subprocess.

This flag is ignored if `CREATE_NEW_CONSOLE` is specified.
17.5.5. Older high-level API

Prior to Python 3.5, these three functions comprised the high level API to subprocess. You can now use run() in many cases, but lots of existing code calls these functions.

```
subprocess.call(args, *, stdin=None, stdout=None, stderr=None, shell=False, timeout=None)
```

Run the command described by `args`. Wait for command to complete, then return the returncode attribute.

This is equivalent to:

```
run(...).returncode
```

(except that the input and check parameters are not supported)

The arguments shown above are merely the most common ones. The full function signature is largely the same as that of the Popen constructor - this function passes all supplied arguments other than `timeout` directly through to that interface.

**Note:** Do not use `stdout=PIPE` or `stderr=PIPE` with this function. The child process will block if it generates enough output to a pipe to fill up the OS pipe buffer as the pipes are not being read from.

*Changed in version 3.3:* `timeout` was added.

```
subprocess.check_call(args, *, stdin=None, stdout=None, stderr=None, shell=False, timeout=None)
```

Run command with arguments. Wait for command to complete. If
the return code was zero then return, otherwise raise \texttt{CalledProcessError}. The \texttt{CalledProcessError} object will have the return code in the \texttt{returncode} attribute.

This is equivalent to:

\begin{verbatim}
run(..., check=True)
\end{verbatim}

(except that the \texttt{input} parameter is not supported)

The arguments shown above are merely the most common ones. The full function signature is largely the same as that of the \texttt{Popen} constructor - this function passes all supplied arguments other than \texttt{timeout} directly through to that interface.

\textbf{Note:} Do not use \texttt{stdout=PIPE} or \texttt{stderr=PIPE} with this function. The child process will block if it generates enough output to a pipe to fill up the OS pipe buffer as the pipes are not being read from.

\textit{Changed in version 3.3: timeout was added.}

\begin{verbatim}
subprocess.check_output(args, *, stdin=None, stderr=None, shell=False, universal_newlines=False, timeout=None)
\end{verbatim}

Run command with arguments and return its output.

If the return code was non-zero it raises a \texttt{CalledProcessError}. The \texttt{CalledProcessError} object will have the return code in the \texttt{returncode} attribute and any output in the \texttt{output} attribute.

This is equivalent to:

\begin{verbatim}
run(..., check=True, stdout=PIPE).stdout
\end{verbatim}
The arguments shown above are merely the most common ones. The full function signature is largely the same as that of `run()` - most arguments are passed directly through to that interface. However, explicitly passing `input=None` to inherit the parent's standard input file handle is not supported.

By default, this function will return the data as encoded bytes. The actual encoding of the output data may depend on the command being invoked, so the decoding to text will often need to be handled at the application level.

This behaviour may be overridden by setting `universal_newlines` to `True` as described above in Frequentely Used Arguments.

To also capture standard error in the result, use `stderr=subprocess.STDOUT`:

```python
>>> import subprocess

>>> subprocess.check_output(...
    "ls non_existent_file; exit 0",
    ..., stderr=subprocess.STDOUT,
    ..., shell=True)
'ls: non_existent_file: No such file or directory
```

*New in version 3.1.*

*Changed in version 3.3*: `timeout` was added.

*Changed in version 3.4*: Support for the `input` keyword argument was added.
17.5.6. Replacing Older Functions with the subprocess Module

In this section, “a becomes b” means that b can be used as a replacement for a.

**Note:** All “a” functions in this section fail (more or less) silently if the executed program cannot be found; the “b” replacements raise OSError instead.

In addition, the replacements using `check_output()` will fail with a CalledProcessError if the requested operation produces a non-zero return code. The output is still available as the output attribute of the raised exception.

In the following examples, we assume that the relevant functions have already been imported from the subprocess module.

17.5.6.1. Replacing /bin/sh shell backquote

```python
output=`mycmd myarg`
# becomes
output = check_output(['mycmd', 'myarg'])
```

17.5.6.2. Replacing shell pipeline

```python
output=`dmesg | grep hda`
# becomes
p1 = Popen(['dmesg'], stdout=PIPE)
p2 = Popen(['grep', 'hda'], stdin=p1.stdout, stdout=PIPE)
```
The `p1.stdout.close()` call after starting the p2 is important in order for p1 to receive a SIGPIPE if p2 exits before p1.

Alternatively, for trusted input, the shell's own pipeline support may still be used directly:

```bash
output=`dmesg | grep hda`
# becomes
output=check_output("dmesg | grep hda", shell=True)
```

### 17.5.6.3. Replacing `os.system()`

```python
sts = os.system("mycmd" + " myarg")
# becomes
sts = call("mycmd" + " myarg", shell=True)
```

**Notes:**

- Calling the program through the shell is usually not required.

A more realistic example would look like this:

```python
try:
    retcode = call("mycmd" + " myarg", shell=True)
    if retcode < 0:
        print("Child was terminated by signal", -ret)
    else:
        print("Child returned", retcode, file=sys.stderr)
except OSError as e:
    print("Execution failed:", e, file=sys.stderr)
```
17.5.6.4. Replacing the `os.spawn` family

P_NOWAIT example:

```python
pid = os.spawnlp(os.P_NOWAIT, "/bin/mymcd", "mymcd",
==>
pid = Popen(["/bin/mymcd", "myarg"])
```

P_WAIT example:

```python
retcode = os.spawnlp(os.P_WAIT, "/bin/mymcd", "mymcd",
==>
retcode = call(["/bin/mymcd", "myarg"])
```

Vector example:

```python
os.spawnvp(os.P_NOWAIT, path, args)
==>
Popen([path] + args[1:])
```

Environment example:

```python
os.spawnlpe(os.P_NOWAIT, "/bin/mymcd", "mymcd", "myarg",
==>
Popen(["/bin/mymcd", "myarg"], env={"PATH": "/usr/bin")
```

17.5.6.5. Replacing `os.popen()`, `os.popen2()`, `os.popen3()`

```python
(child_stdin, child_stdout) = os.popen2(cmd, mode, b)
==>
```
p = Popen(cmd, shell=True, bufsize=bufsize,
           stdin=PIPE, stdout=PIPE, close_fds=True)
    (child_stdin, child_stdout) = (p.stdin, p.stdout)

(child_stdin,
     child_stdout,
     child_stderr) = os.popen3(cmd, mode, bufsize)

p = Popen(cmd, shell=True, bufsize=bufsize,
           stdin=PIPE, stdout=PIPE, stderr=PIPE, close_fds=True)
    (child_stdin, child_stdout, child_stderr) = (p.stdin, p.stdout, p.stderr)

(child_stdin, child_stdout_and_stderr) = os.popen4(cmd)

p = Popen(cmd, shell=True, bufsize=bufsize,
           stdin=PIPE, stdout=PIPE, stderr=STDOUT, close_fds=True)
    (child_stdin, child_stdout_and_stderr) = (p.stdin, p.stdout)

Return code handling translates as follows:

pipe = os.popen(cmd, 'w')
...
rc = pipe.close()
if rc is not None and rc >> 8:
    print("There were some errors")

process = Popen(cmd, stdin=PIPE)
...
process.stdin.close()
if process.wait() != 0:
    print("There were some errors")
17.5.6.6. Replacing functions from the popen2 module

**Note:** If the cmd argument to popen2 functions is a string, the command is executed through /bin/sh. If it is a list, the command is directly executed.

```python
(child_stdout, child_stdin) = popen2.popen2("somestring")
p = Popen("somestring", shell=True, bufsize=bufsize,
        stdin=PIPE, stdout=PIPE, close_fds=True)
(child_stdout, child_stdin) = (p.stdout, p.stdin)
```

```python
(child_stdout, child_stdin) = popen2.popen2(["mycmd"]

p = Popen(["mycmd", "myarg"], bufsize=bufsize,
        stdin=PIPE, stdout=PIPE, close_fds=True)
(child_stdout, child_stdin) = (p.stdout, p.stdin)
```

popen2.Popen3 and popen2.Popen4 basically work as `subprocess.Popen`, except that:

- **Popen** raises an exception if the execution fails.
- the `capturestderr` argument is replaced with the `stderr` argument.
- `stdin=PIPE` and `stdout=PIPE` must be specified.
- `popen2` closes all file descriptors by default, but you have to specify `close_fds=True` with `Popen` to guarantee this behavior on all platforms or past Python versions.
17.5.7. Legacy Shell Invocation Functions

This module also provides the following legacy functions from the 2.x commands module. These operations implicitly invoke the system shell and none of the guarantees described above regarding security and exception handling consistency are valid for these functions.

```
subprocess.getstatusoutput(cmd)
```

Return `(status, output)` of executing `cmd` in a shell.

Execute the string `cmd` in a shell with `Popen.check_output()` and return a 2-tuple `(status, output)`. Universal newlines mode is used; see the notes on Frequently Used Arguments for more details.

A trailing newline is stripped from the output. The exit status for the command can be interpreted according to the rules for the C function `wait()`. Example:

```
>>> subprocess.getstatusoutput('ls /bin/ls')
(0, '/bin/ls')
>>> subprocess.getstatusoutput('cat /bin/junk')
(256, 'cat: /bin/junk: No such file or directory')
>>> subprocess.getstatusoutput('/bin/junk')
(256, 'sh: /bin/junk: not found')
```

Availability: POSIX & Windows

*Changed in version 3.3.4: Windows support added*

```
subprocess.getoutput(cmd)
```

Return output (stdout and stderr) of executing `cmd` in a shell.
Like `getstatusoutput()`, except the exit status is ignored and the return value is a string containing the command's output. Example:

```python
>>> subprocess.getoutput('ls /bin/ls')
'/bin/ls'
```

Availability: POSIX & Windows

*Changed in version 3.3.4: Windows support added*
17.5.8. Notes

17.5.8.1. Converting an argument sequence to a string on Windows

On Windows, an args sequence is converted to a string that can be parsed using the following rules (which correspond to the rules used by the MS C runtime):

1. Arguments are delimited by white space, which is either a space or a tab.
2. A string surrounded by double quotation marks is interpreted as a single argument, regardless of white space contained within. A quoted string can be embedded in an argument.
3. A double quotation mark preceded by a backslash is interpreted as a literal double quotation mark.
4. Backslashes are interpreted literally, unless they immediately precede a double quotation mark.
5. If backslashes immediately precede a double quotation mark, every pair of backslashes is interpreted as a literal backslash. If the number of backslashes is odd, the last backslash escapes the next double quotation mark as described in rule 3.

See also:

shlex
Module which provides function to parse and escape command lines.
17.6. sched — Event scheduler

Source code: Lib/sched.py

The sched module defines a class which implements a general purpose event scheduler:

class sched.schedulertimefunc=time.monotonic,
delayfunc=time.sleep)

The scheduler class defines a generic interface to scheduling events. It needs two functions to actually deal with the “outside world” — timefunc should be callable without arguments, and return a number (the “time”, in any units whatsoever). If time.monotonic is not available, the timefunc default is time.time instead. The delayfunc function should be callable with one argument, compatible with the output of timefunc, and should delay that many time units. delayfunc will also be called with the argument 0 after each event is run to allow other threads an opportunity to run in multi-threaded applications.

Changed in version 3.3: timefunc and delayfunc parameters are optional.

Changed in version 3.3: scheduler class can be safely used in multi-threaded environments.

Example:

```python
>>> import sched, time
>>> s = sched.schedulertime.time, time.sleep)
>>> def print_time(a='default'):
```
...    print("From print_time", time.time(), a)
...

>>> def print_some_times():
...    print(time.time())
...    s.enter(10, 1, print_time)
...    s.enter(5, 2, print_time, argument=("positional");
...    s.enter(5, 1, print_time, kwargs={"a": "keyword")
...    s.run()
...    print(time.time())
...

>>> print_some_times()
930343690.257
From print_time 930343695.274 positional
From print_time 930343695.275 keyword
From print_time 930343700.273 default
930343700.276
17.6.1. Scheduler Objects

`scheduler` instances have the following methods and attributes:

`scheduler.enterabs(time, priority, action, argument=(), kwargs={})`

Schedule a new event. The `time` argument should be a numeric type compatible with the return value of the `timefunc` function passed to the constructor. Events scheduled for the same `time` will be executed in the order of their `priority`.

Executing the event means executing `action(*argument, **kwargs)`. `argument` is a sequence holding the positional arguments for `action`. `kwargs` is a dictionary holding the keyword arguments for `action`.

Return value is an event which may be used for later cancellation of the event (see `cancel()`).

*Changed in version 3.3:* `argument` parameter is optional.

*New in version 3.3:* `kwargs` parameter was added.

`scheduler.enter(delay, priority, action, argument=(), kwargs={})`

Schedule an event for `delay` more time units. Other than the relative time, the other arguments, the effect and the return value are the same as those for `enterabs()`.

*Changed in version 3.3:* `argument` parameter is optional.

*New in version 3.3:* `kwargs` parameter was added.

`scheduler.cancel(event)`
Remove the event from the queue. If `event` is not an event currently in the queue, this method will raise a `ValueError`.

`scheduler.empty()`
Return true if the event queue is empty.

`scheduler.run(blocking=True)`
Run all scheduled events. This method will wait (using the `delayfunc()` function passed to the constructor) for the next event, then execute it and so on until there are no more scheduled events.

If `blocking` is false executes the scheduled events due to expire soonest (if any) and then return the deadline of the next scheduled call in the scheduler (if any).

Either `action` or `delayfunc` can raise an exception. In either case, the scheduler will maintain a consistent state and propagate the exception. If an exception is raised by `action`, the event will not be attempted in future calls to `run()`.

If a sequence of events takes longer to run than the time available before the next event, the scheduler will simply fall behind. No events will be dropped; the calling code is responsible for canceling events which are no longer pertinent.

*New in version 3.3:* `blocking` parameter was added.

`scheduler.queue`
Read-only attribute returning a list of upcoming events in the order they will be run. Each event is shown as a named tuple with the following fields: time, priority, action, argument, kwargs.
17.7. queue — A synchronized queue class

Source code: Lib/queue.py

The queue module implements multi-producer, multi-consumer queues. It is especially useful in threaded programming when information must be exchanged safely between multiple threads. The Queue class in this module implements all the required locking semantics. It depends on the availability of thread support in Python; see the threading module.

The module implements three types of queue, which differ only in the order in which the entries are retrieved. In a FIFO queue, the first tasks added are the first retrieved. In a LIFO queue, the most recently added entry is the first retrieved (operating like a stack). With a priority queue, the entries are kept sorted (using the heapq module) and the lowest valued entry is retrieved first.

The queue module defines the following classes and exceptions:

class queue.Queue(maxsize=0)

Constructor for a FIFO queue. maxsize is an integer that sets the upperbound limit on the number of items that can be placed in the queue. Insertion will block once this size has been reached, until queue items are consumed. If maxsize is less than or equal to zero, the queue size is infinite.

class queue.LifoQueue(maxsize=0)

Constructor for a LIFO queue. maxsize is an integer that sets the
upperbound limit on the number of items that can be placed in the queue. Insertion will block once this size has been reached, until queue items are consumed. If maxsize is less than or equal to zero, the queue size is infinite.

```python
class queue.PriorityQueue(maxsize=0)
```
Constructor for a priority queue. maxsize is an integer that sets the upperbound limit on the number of items that can be placed in the queue. Insertion will block once this size has been reached, until queue items are consumed. If maxsize is less than or equal to zero, the queue size is infinite.

The lowest valued entries are retrieved first (the lowest valued entry is the one returned by `sorted(list(entries))[0]`). A typical pattern for entries is a tuple in the form: (priority_number, data).

```python
exception queue.Empty
```
Exception raised when non-blocking `get()` (or `get_nowait()`) is called on a `Queue` object which is empty.

```python
exception queue.Full
```
Exception raised when non-blocking `put()` (or `put_nowait()`) is called on a `Queue` object which is full.
17.7.1. Queue Objects

Queue objects (Queue, LifoQueue, or PriorityQueue) provide the public methods described below.

Queue.qsize()

Return the approximate size of the queue. Note, qsize() > 0 doesn’t guarantee that a subsequent get() will not block, nor will qsize() < maxsize guarantee that put() will not block.

Queue.empty()

Return True if the queue is empty, False otherwise. If empty() returns True it doesn’t guarantee that a subsequent call to put() will not block. Similarly, if empty() returns False it doesn’t guarantee that a subsequent call to get() will not block.

Queue.full()

Return True if the queue is full, False otherwise. If full() returns True it doesn’t guarantee that a subsequent call to get() will not block. Similarly, if full() returns False it doesn’t guarantee that a subsequent call to put() will not block.

Queue.put(item, block=True, timeout=None)

Put item into the queue. If optional args block is true and timeout is None (the default), block if necessary until a free slot is available. If timeout is a positive number, it blocks at most timeout seconds and raises the Full exception if no free slot was available within that time. Otherwise (block is false), put an item on the queue if a free slot is immediately available, else raise the Full exception (timeout is ignored in that case).
Queue.\texttt{put\_nowait}(item)

Equivalent to put(item, False).

Queue.\texttt{get}(block=True, timeout=None)

Remove and return an item from the queue. If optional args block is true and timeout is None (the default), block if necessary until an item is available. If timeout is a positive number, it blocks at most timeout seconds and raises the \texttt{Empty} exception if no item was available within that time. Otherwise (block is false), return an item if one is immediately available, else raise the \texttt{Empty} exception (timeout is ignored in that case).

Queue.\texttt{get\_nowait}()

Equivalent to get(False).

Two methods are offered to support tracking whether enqueued tasks have been fully processed by daemon consumer threads.

Queue.\texttt{task\_done}()

Indicate that a formerly enqueued task is complete. Used by queue consumer threads. For each \texttt{get()} used to fetch a task, a subsequent call to \texttt{task\_done()} tells the queue that the processing on the task is complete.

If a \texttt{join()} is currently blocking, it will resume when all items have been processed (meaning that a \texttt{task\_done()} call was received for every item that had been \texttt{put()} into the queue).

Raises a \texttt{ValueError} if called more times than there were items placed in the queue.

Queue.\texttt{join}()}
Blocks until all items in the queue have been gotten and processed.

The count of unfinished tasks goes up whenever an item is added to the queue. The count goes down whenever a consumer thread calls `task_done()` to indicate that the item was retrieved and all work on it is complete. When the count of unfinished tasks drops to zero, `join()` unblocks.

Example of how to wait for enqueued tasks to be completed:

```python
def worker():
    while True:
        item = q.get()
        if item is None:
            break
        do_work(item)
        q.task_done()

q = queue.Queue()
threads = []
for i in range(num_worker_threads):
    t = threading.Thread(target=worker)
    t.start()
    threads.append(t)

for item in source():
    q.put(item)

# block until all tasks are done
q.join()

# stop workers
for i in range(num_worker_threads):
    q.put(None)
for t in threads:
```
t.join()

See also:

**Class** `multiprocessing.Queue`

A queue class for use in a multi-processing (rather than multi-threading) context.

`collections.deque` is an alternative implementation of unbounded queues with fast atomic `append()` and `popleft()` operations that do not require locking.
17.8. **dummy_threading** — Drop-in replacement for the **threading** module

**Source code:** Lib/dummy_threading.py

This module provides a duplicate interface to the `threading` module. It is meant to be imported when the `_thread` module is not provided on a platform.

Suggested usage is:

```python
try:
    import threading
except ImportError:
    import dummy_threading as threading
```

Be careful to not use this module where deadlock might occur from a thread being created that blocks waiting for another thread to be created. This often occurs with blocking I/O.
17.9. \_thread — Low-level threading API

This module provides low-level primitives for working with multiple threads (also called light-weight processes or tasks) — multiple threads of control sharing their global data space. For synchronization, simple locks (also called mutexes or binary semaphores) are provided. The \texttt{threading} module provides an easier to use and higher-level threading API built on top of this module.

The module is optional. It is supported on Windows, Linux, SGI IRIX, Solaris 2.x, as well as on systems that have a POSIX thread (a.k.a. “pthread”) implementation. For systems lacking the \_thread module, the \_dummy\_thread module is available. It duplicates this module’s interface and can be used as a drop-in replacement.

It defines the following constants and functions:

\texttt{exception \_thread.error}

Raised on thread-specific errors.

\textit{Changed in version 3.3:} This is now a synonym of the built-in \texttt{RuntimeError}.

\texttt{\_thread.LockType}

This is the type of lock objects.

\texttt{\_thread.start\_new\_thread(function, args[, kwargs])}

Start a new thread and return its identifier. The thread executes the function \texttt{function} with the argument list \texttt{args} (which must be a
tuple). The optional `kwargs` argument specifies a dictionary of keyword arguments. When the function returns, the thread silently exits. When the function terminates with an unhandled exception, a stack trace is printed and then the thread exits (but other threads continue to run).

```python
_thread.interrupt_main()
```
Raise a `KeyboardInterrupt` exception in the main thread. A subthread can use this function to interrupt the main thread.

```python
_thread.exit()
```
Raise the `SystemExit` exception. When not caught, this will cause the thread to exit silently.

```python
_thread.allocate_lock()
```
Return a new lock object. Methods of locks are described below. The lock is initially unlocked.

```python
_thread.get_ident()
```
Return the ‘thread identifier’ of the current thread. This is a nonzero integer. Its value has no direct meaning; it is intended as a magic cookie to be used e.g. to index a dictionary of thread-specific data. Thread identifiers may be recycled when a thread exits and another thread is created.

```python
_thread.stack_size([size])
```
Return the thread stack size used when creating new threads. The optional `size` argument specifies the stack size to be used for subsequently created threads, and must be 0 (use platform or configured default) or a positive integer value of at least 32,768 (32 KiB). If `size` is not specified, 0 is used. If changing the thread stack size is unsupported, a `RuntimeError` is raised. If the specified
stack size is invalid, a `ValueError` is raised and the stack size is unmodified. 32 KiB is currently the minimum supported stack size value to guarantee sufficient stack space for the interpreter itself. Note that some platforms may have particular restrictions on values for the stack size, such as requiring a minimum stack size > 32 KiB or requiring allocation in multiples of the system memory page size - platform documentation should be referred to for more information (4 KiB pages are common; using multiples of 4096 for the stack size is the suggested approach in the absence of more specific information). Availability: Windows, systems with POSIX threads.

`_thread.TIMEOUT_MAX`

The maximum value allowed for the `timeout` parameter of `Lock.acquire()`. Specifying a timeout greater than this value will raise an `OverflowError`.

`New in version 3.2.`

Lock objects have the following methods:

`lock.acquire(waitflag=1, timeout=-1)`

Without any optional argument, this method acquires the lock unconditionally, if necessary waiting until it is released by another thread (only one thread at a time can acquire a lock — that's their reason for existence).

If the integer `waitflag` argument is present, the action depends on its value: if it is zero, the lock is only acquired if it can be acquired immediately without waiting, while if it is nonzero, the lock is acquired unconditionally as above.

If the floating-point `timeout` argument is present and positive, it
specifies the maximum wait time in seconds before returning. A negative timeout argument specifies an unbounded wait. You cannot specify a timeout if waitflag is zero.

The return value is True if the lock is acquired successfully, False if not.

Changed in version 3.2: The timeout parameter is new.

Changed in version 3.2: Lock acquires can now be interrupted by signals on POSIX.

lock.release()
Releases the lock. The lock must have been acquired earlier, but not necessarily by the same thread.

lock.locked()
Return the status of the lock: True if it has been acquired by some thread, False if not.

In addition to these methods, lock objects can also be used via the with statement, e.g.:

```python
import _thread

a_lock = _thread.allocate_lock()

with a_lock:
    print("a_lock is locked while this executes")
```

Caveats:

- Threads interact strangely with interrupts: the KeyboardInterrupt exception will be received by an arbitrary
thread. (When the `signal` module is available, interrupts always go to the main thread.)

- Calling `sys.exit()` or raising the `SystemExit` exception is equivalent to calling `_thread.exit()`.
- It is not possible to interrupt the `acquire()` method on a lock — the `KeyboardInterrupt` exception will happen after the lock has been acquired.
- When the main thread exits, it is system defined whether the other threads survive. On most systems, they are killed without executing `try ... finally` clauses or executing object destructors.
- When the main thread exits, it does not do any of its usual cleanup (except that `try ... finally` clauses are honored), and the standard I/O files are not flushed.
17.10. __dummy_thread — Drop-in replacement for the _thread module

**Source code:** Lib/_dummy_thread.py

This module provides a duplicate interface to the _thread module. It is meant to be imported when the _thread module is not provided on a platform.

Suggested usage is:

```python
try:
    import _thread
except ImportError:
    import __dummy_thread as _thread
```

Be careful to not use this module where deadlock might occur from a thread being created that blocks waiting for another thread to be created. This often occurs with blocking I/O.
18. Interprocess Communication and Networking

The modules described in this chapter provide mechanisms for different processes to communicate.

Some modules only work for two processes that are on the same machine, e.g. `signal` and `mmap`. Other modules support networking protocols that two or more processes can use to communicate across machines.

The list of modules described in this chapter is:

- **18.1. socket** — Low-level networking interface
  - 18.1.1. Socket families
  - 18.1.2. Module contents
    - 18.1.2.1. Exceptions
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18.1. socket — Low-level networking interface

This module provides access to the BSD socket interface. It is available on all modern Unix systems, Windows, MacOS, and probably additional platforms.

**Note:** Some behavior may be platform dependent, since calls are made to the operating system socket APIs.

The Python interface is a straightforward transliteration of the Unix system call and library interface for sockets to Python's object-oriented style: the `socket()` function returns a *socket object* whose methods implement the various socket system calls. Parameter types are somewhat higher-level than in the C interface: as with `read()` and `write()` operations on Python files, buffer allocation on receive operations is automatic, and buffer length is implicit on send operations.

**See also:**

- **Module** `socketserver`  
  Classes that simplify writing network servers.
- **Module** `ssl`  
  A TLS/SSL wrapper for socket objects.
18.1.1. Socket families

Depending on the system and the build options, various socket families are supported by this module.

The address format required by a particular socket object is automatically selected based on the address family specified when the socket object was created. Socket addresses are represented as follows:

- The address of an AF_UNIX socket bound to a file system node is represented as a string, using the file system encoding and the 'surrogateescape' error handler (see PEP 383). An address in Linux's abstract namespace is returned as a bytes-like object with an initial null byte; note that sockets in this namespace can communicate with normal file system sockets, so programs intended to run on Linux may need to deal with both types of address. A string or bytes-like object can be used for either type of address when passing it as an argument.

  Changed in version 3.3: Previously, AF_UNIX socket paths were assumed to use UTF-8 encoding.

- A pair (host, port) is used for the AF_INET address family, where host is a string representing either a hostname in Internet domain notation like 'daring.cwi.nl' or an IPv4 address like '100.50.200.5', and port is an integer.

- For AF_INET6 address family, a four-tuple (host, port, flowinfo, scopeid) is used, where flowinfo and scopeid represent the sin6_flowinfo and sin6_scope_id members in struct sockaddr_in6 in C. For socket module methods,
flowinfo and scopeid can be omitted just for backward compatibility. Note, however, omission of scopeid can cause problems in manipulating scoped IPv6 addresses.

- AF_NETLINK sockets are represented as pairs (pid, groups).

- Linux-only support for TIPC is available using the AF_TIPC address family. TIPC is an open, non-IP based networked protocol designed for use in clustered computer environments. Addresses are represented by a tuple, and the fields depend on the address type. The general tuple form is (addr_type, v1, v2, v3 [, scope]), where:
  - *addr_type* is one of TIPC_ADDR_NAMESEQ, TIPC_ADDR_NAME, or TIPC_ADDR_ID.
  - *scope* is one of TIPC_ZONE_SCOPE, TIPC_CLUSTER_SCOPE, and TIPC_NODE_SCOPE.
  - If *addr_type* is TIPC_ADDR_NAME, then v1 is the server type, v2 is the port identifier, and v3 should be 0.

    If *addr_type* is TIPC_ADDR_NAMESEQ, then v1 is the server type, v2 is the lower port number, and v3 is the upper port number.

    If *addr_type* is TIPC_ADDR_ID, then v1 is the node, v2 is the reference, and v3 should be set to 0.

- A tuple (interface, ) is used for the AF_CAN address family, where interface is a string representing a network interface name like 'can0'. The network interface name '' can be used to receive packets from all network interfaces of this family.
A string or a tuple (id, unit) is used for the SYSPROTO_CONTROL protocol of the PF_SYSTEM family. The string is the name of a kernel control using a dynamically-assigned ID. The tuple can be used if ID and unit number of the kernel control are known or if a registered ID is used.

*New in version 3.3.*

- AF_BLUETOOTH supports the following protocols and address formats:
  - BTPROTO_L2CAP accepts (bdaddr, psm) where bdaddr is the Bluetooth address as a string and psm is an integer.
  - BTPROTO_RFCOMM accepts (bdaddr, channel) where bdaddr is the Bluetooth address as a string and channel is an integer.
  - BTPROTO_HCI accepts (device_id,) where device_id is either an integer or a string with the Bluetooth address of the interface. (This depends on your OS; NetBSD and DragonFlyBSD expect a Bluetooth address while everything else expects an integer.)

  *Changed in version 3.2:* NetBSD and DragonFlyBSD support added.
  - BTPROTO_SCO accepts bdaddr where bdaddr is a bytes object containing the Bluetooth address in a string format. (ex. `b'12:23:34:45:56:67'`) This protocol is not supported under FreeBSD.

- Certain other address families (AF_PACKET, AF_CAN) support
specific representations.

For IPv4 addresses, two special forms are accepted instead of a host address: the empty string represents INADDR_ANY, and the string '<broadcast>' represents INADDR_BROADCAST. This behavior is not compatible with IPv6, therefore, you may want to avoid these if you intend to support IPv6 with your Python programs.

If you use a hostname in the host portion of IPv4/v6 socket address, the program may show a nondeterministic behavior, as Python uses the first address returned from the DNS resolution. The socket address will be resolved differently into an actual IPv4/v6 address, depending on the results from DNS resolution and/or the host configuration. For deterministic behavior use a numeric address in host portion.

All errors raise exceptions. The normal exceptions for invalid argument types and out-of-memory conditions can be raised; starting from Python 3.3, errors related to socket or address semantics raise OSError or one of its subclasses (they used to raise socket.error).

Non-blocking mode is supported through setblocking(). A generalization of this based on timeouts is supported through settimeout().
18.1.2. Module contents

The module `socket` exports the following elements.

18.1.2.1. Exceptions

`exception socket.error`

A deprecated alias of `OSError`.

*Changed in version 3.3:* Following [PEP 3151](https://www.python.org/dev/peps/pep-03151), this class was made an alias of `OSError`.

`exception socket.herror`

A subclass of `OSError`, this exception is raised for address-related errors, i.e. for functions that use `h_errno` in the POSIX C API, including `gethostbyname_ex()` and `gethostbyaddr()`. The accompanying value is a pair `(h_errno, string)` representing an error returned by a library call. `h_errno` is a numeric value, while `string` represents the description of `h_errno`, as returned by the `hstrerror()` C function.

*Changed in version 3.3:* This class was made a subclass of `OSError`.

`exception socket.gaierror`

A subclass of `OSError`, this exception is raised for address-related errors by `getaddrinfo()` and `getlineinfo()`. The accompanying value is a pair `(error, string)` representing an error returned by a library call. `string` represents the description of `error`, as returned by the `gai_strerror()` C function. The numeric `error` value will match one of the `EAI_*` constants defined
in this module.

*Changed in version 3.3:* This class was made a subclass of OSError.

`exception socket.timeout`
A subclass of OSError, this exception is raised when a timeout occurs on a socket which has had timeouts enabled via a prior call to `settimeout()` (or implicitly through `setdefaulttimeout()`). The accompanying value is a string whose value is currently always “timed out”.

*Changed in version 3.3:* This class was made a subclass of OSError.

### 18.1.2.2. Constants

The AF_* and SOCK_* constants are now AddressFamily and SocketKind `IntEnum` collections.

*New in version 3.4.*

`socket.AF_UNIX`
`socket.AF_INET`
`socket.AF_INET6`

These constants represent the address (and protocol) families, used for the first argument to `socket()`. If the `AF_UNIX` constant is not defined then this protocol is unsupported. More constants may be available depending on the system.

`socket.SOCK_STREAM`
`socket.SOCK_DGRAM`
`socket.SOCK_RAW`
socket.**SOCK_RDM**

socket.**SOCK_SEQPACKET**

These constants represent the socket types, used for the second argument to `socket()`. More constants may be available depending on the system. (Only `SOCK_STREAM` and `SOCK_DGRAM` appear to be generally useful.)

socket.**SOCK_CLOEXEC**

socket.**SOCK_NONBLOCK**

These two constants, if defined, can be combined with the socket types and allow you to set some flags atomically (thus avoiding possible race conditions and the need for separate calls).

**See also:** Secure File Descriptor Handling for a more thorough explanation.

Availability: Linux >= 2.6.27.

*New in version 3.2.*

**SO_*

socket.**SOMAXCONN**

**MSG_*

**SOL_*

**SCM_*

**IPPROTO_*

**IPPORT_*

**INADDR_*

**IP_*

**IPV6_*

**EAI_*

**AI_*

**NI_*
TCP_*

Many constants of these forms, documented in the Unix documentation on sockets and/or the IP protocol, are also defined in the socket module. They are generally used in arguments to the setsockopt() and getsockopt() methods of socket objects. In most cases, only those symbols that are defined in the Unix header files are defined; for a few symbols, default values are provided.

socket.AF_CAN
socket.PF_CAN
SOL_CAN_*
CAN_*

Many constants of these forms, documented in the Linux documentation, are also defined in the socket module.

Availability: Linux >= 2.6.25.

New in version 3.3.

socket.CAN_BCM
CAN_BCM_*

CAN_BCM, in the CAN protocol family, is the broadcast manager (BCM) protocol. Broadcast manager constants, documented in the Linux documentation, are also defined in the socket module.

Availability: Linux >= 2.6.25.

New in version 3.4.

socket.CAN_RAW_FD_FRAMES

Enables CAN FD support in a CAN_RAW socket. This is disabled by default. This allows your application to send both CAN and CAN
FD frames; however, you one must accept both CAN and CAN FD frames when reading from the socket.

This constant is documented in the Linux documentation.

Availability: Linux >= 3.6.

New in version 3.5.

socket.AF_RDS
socket.PF_RDS
socket.SOL_RDS
RDS_*

Many constants of these forms, documented in the Linux documentation, are also defined in the socket module.

Availability: Linux >= 2.6.30.

New in version 3.3.

SIO_*
RCVALL_*

Constants for Windows’ WSAIoctl(). The constants are used as arguments to the ioctl() method of socket objects.

TIPC_*

TIPC related constants, matching the ones exported by the C socket API. See the TIPC documentation for more information.

socket.AF_LINK

Availability: BSD, OSX.

New in version 3.4.

socket.has_ipv6
This constant contains a boolean value which indicates if IPv6 is supported on this platform.

socket.**BDADDR_ANY**
socket.**BDADDR_LOCAL**

These are string constants containing Bluetooth addresses with special meanings. For example, **BDADDR_ANY** can be used to indicate any address when specifying the binding socket with BTPROTO_RFCOMM.

socket.**HCI_FILTER**
socket.**HCI_TIME_STAMP**
socket.**HCI_DATA_DIR**

For use with BTPROTO_HCI. **HCI_FILTER** is not available for NetBSD or DragonFlyBSD. **HCI_TIME_STAMP** and **HCI_DATA_DIR** are not available for FreeBSD, NetBSD, or DragonFlyBSD.

### 18.1.2.3. Functions

#### 18.1.2.3.1. Creating sockets

The following functions all create socket objects.

socket.**socket**(family=AF_INET, type=SOCK_STREAM, proto=0, fileno=None)

Create a new socket using the given address family, socket type and protocol number. The address family should be **AF_INET** (the default), **AF_INET6**, **AF_UNIX**, **AF_CAN** or **AF_RDS**. The socket type should be **SOCK_STREAM** (the default), **SOCK_DGRAM**, **SOCK_RAW** or perhaps one of the other SOCK_ constants. The protocol number is usually zero and may be omitted or in the case
where the address family is \texttt{AF\_CAN} the protocol should be one of \texttt{CAN\_RAW} or \texttt{CAN\_BCM}. If \texttt{fileno} is specified, the other arguments are ignored, causing the socket with the specified file descriptor to return. Unlike \texttt{socket.fromfd()}, \texttt{fileno} will return the same socket and not a duplicate. This may help close a detached socket using \texttt{socket.close()}. 

The newly created socket is non-inheritable.

\textit{Changed in version 3.3:} The \texttt{AF\_CAN} family was added. The \texttt{AF\_RDS} family was added.

\textit{Changed in version 3.4:} The \texttt{CAN\_BCM} protocol was added.

\textit{Changed in version 3.4:} The returned socket is now non-inheritable.

\texttt{socket.socketpair([family[, type[, proto]]])}

Build a pair of connected socket objects using the given address family, socket type, and protocol number. Address family, socket type, and protocol number are as for the \texttt{socket()} function above. The default family is \texttt{AF\_UNIX} if defined on the platform; otherwise, the default is \texttt{AF\_INET}.

The newly created sockets are non-inheritable.

\textit{Changed in version 3.2:} The returned socket objects now support the whole socket API, rather than a subset.

\textit{Changed in version 3.4:} The returned sockets are now non-inheritable.

\textit{Changed in version 3.5:} Windows support added.
Connect to a TCP service listening on the Internet address (a 2-tuple (host, port)), and return the socket object. This is a higher-level function than `socket.connect()`: if host is a non-numeric hostname, it will try to resolve it for both `AF_INET` and `AF_INET6`, and then try to connect to all possible addresses in turn until a connection succeeds. This makes it easy to write clients that are compatible to both IPv4 and IPv6.

Passing the optional `timeout` parameter will set the timeout on the socket instance before attempting to connect. If no `timeout` is supplied, the global default timeout setting returned by `getdefaulttimeout()` is used.

If supplied, `source_address` must be a 2-tuple (host, port) for the socket to bind to as its source address before connecting. If host or port are '' or 0 respectively the OS default behavior will be used.

*Changed in version 3.2*: `source_address` was added.

*Changed in version 3.2*: support for the `with` statement was added.

Duplicate the file descriptor `fd` (an integer as returned by a file object’s `fileno()` method) and build a socket object from the result. Address family, socket type and protocol number are as for the `socket()` function above. The file descriptor should refer to a socket, but this is not checked — subsequent operations on the object may fail if the file descriptor is invalid. This function is rarely
needed, but can be used to get or set socket options on a socket passed to a program as standard input or output (such as a server started by the Unix inet daemon). The socket is assumed to be in blocking mode.

The newly created socket is non-inheritable.

*Changed in version 3.4:* The returned socket is now non-inheritable.

socket.`fromshare(data)`

Instantiate a socket from data obtained from the `socket.share()` method. The socket is assumed to be in blocking mode.

*Availability:* Windows.

*New in version 3.3.*

socket.`SocketType`

This is a Python type object that represents the socket object type. It is the same as `type(socket(...))`.

18.1.2.3.2. Other functions

The `socket` module also offers various network-related services:

socket.`getaddrinfo(host, port, family=0, type=0, proto=0, flags=0)`

Translate the `host/port` argument into a sequence of 5-tuples that contain all the necessary arguments for creating a socket connected to that service. `host` is a domain name, a string representation of an IPv4/v6 address or None. `port` is a string
service name such as 'http', a numeric port number or None. By passing None as the value of host and port, you can pass NULL to the underlying C API.

The family, type and proto arguments can be optionally specified in order to narrow the list of addresses returned. Passing zero as a value for each of these arguments selects the full range of results. The flags argument can be one or several of the AI_* constants, and will influence how results are computed and returned. For example, AI_NUMERICHOST will disable domain name resolution and will raise an error if host is a domain name.

The function returns a list of 5-tuples with the following structure:

(family, type, proto, canonname, sockaddr)

In these tuples, family, type, proto are all integers and are meant to be passed to the socket() function. canonname will be a string representing the canonical name of the host if AI_CANONNAME is part of the flags argument; else canonname will be empty. sockaddr is a tuple describing a socket address, whose format depends on the returned family (a (address, port) 2-tuple for AF_INET, a (address, port, flow info, scope id) 4-tuple for AF_INET6), and is meant to be passed to the socket.connect() method.

The following example fetches address information for a hypothetical TCP connection to example.org on port 80 (results may differ on your system if IPv6 isn’t enabled):

```python
>>> socket.getaddrinfo("example.org", 80, proto=socket.IPPROTO_TCP)[0]
((<AddressFamily.AF_INET6: 10>, <SocketType.SOCK_STREAM: 1>, 6, '', ('2606:2800:220:1:248:1893:25c8:1946', 80,...
```
Changed in version 3.2: parameters can now be passed using keyword arguments.

socket.getfqdn([name])
Return a fully qualified domain name for name. If name is omitted or empty, it is interpreted as the local host. To find the fully qualified name, the hostname returned by gethostbyaddr() is checked, followed by aliases for the host, if available. The first name which includes a period is selected. In case no fully qualified domain name is available, the hostname as returned by gethostname() is returned.

socket.gethostbyname(hostname)
Translate a host name to IPv4 address format. The IPv4 address is returned as a string, such as '100.50.200.5'. If the host name is an IPv4 address itself it is returned unchanged. See gethostbyname_ex() for a more complete interface. gethostbyname() does not support IPv6 name resolution, and getaddrinfo() should be used instead for IPv4/v6 dual stack support.

socket.gethostbyname_ex(hostname)
Translate a host name to IPv4 address format, extended interface. Return a triple (hostname, aliaslist, ipaddrlist) where hostname is the primary host name responding to the given ip_address, aliaslist is a (possibly empty) list of alternative host names for the same address, and ipaddrlist is a list of IPv4 addresses for the same interface on the same host (often but not
always a single address). gethostbyname_ex() does not support IPv6 name resolution, and getaddrinfo() should be used instead for IPv4/v6 dual stack support.

socket.gethostname()

Return a string containing the hostname of the machine where the Python interpreter is currently executing.

If you want to know the current machine's IP address, you may want to use gethostbyname(gethostname()). This operation assumes that there is a valid address-to-host mapping for the host, and the assumption does not always hold.

Note: gethostname() doesn’t always return the fully qualified domain name; use getfqdn() for that.

socket.gethostbyaddr(ip_address)

Return a triple (hostname, aliaslist, ipaddrlist) where hostname is the primary host name responding to the given ip_address, aliaslist is a (possibly empty) list of alternative host names for the same address, and ipaddrlist is a list of IPv4/v6 addresses for the same interface on the same host (most likely containing only a single address). To find the fully qualified domain name, use the function getfqdn(). gethostbyaddr() supports both IPv4 and IPv6.

socket.getnameinfo(sockaddr, flags)

Translate a socket address sockaddr into a 2-tuple (host, port). Depending on the settings of flags, the result can contain a fully-qualified domain name or numeric address representation in host. Similarly, port can contain a string port name or a numeric port number.
socket.getprotobynamel(protocolname)

Translate an Internet protocol name (for example, 'icmp') to a constant suitable for passing as the (optional) third argument to the socket() function. This is usually only needed for sockets opened in “raw” mode (SOCK_RAW); for the normal socket modes, the correct protocol is chosen automatically if the protocol is omitted or zero.

socket.getservbyname(servicename[, protocolname])

Translate an Internet service name and protocol name to a port number for that service. The optional protocol name, if given, should be 'tcp' or 'udp', otherwise any protocol will match.

socket.getservbyport(port[, protocolname])

Translate an Internet port number and protocol name to a service name for that service. The optional protocol name, if given, should be 'tcp' or 'udp', otherwise any protocol will match.

socket.ntohl(x)

Convert 32-bit positive integers from network to host byte order. On machines where the host byte order is the same as network byte order, this is a no-op; otherwise, it performs a 4-byte swap operation.

socket.ntohs(x)

Convert 16-bit positive integers from network to host byte order. On machines where the host byte order is the same as network byte order, this is a no-op; otherwise, it performs a 2-byte swap operation.

socket.htonl(x)

Convert 32-bit positive integers from host to network byte order. On
machines where the host byte order is the same as network byte order, this is a no-op; otherwise, it performs a 4-byte swap operation.

socket.\texttt{htons}(x)
Conversion 16-bit positive integers from host to network byte order. On machines where the host byte order is the same as network byte order, this is a no-op; otherwise, it performs a 2-byte swap operation.

socket.\texttt{inet\_atons}(ip\_string)
Conversion an IPv4 address from dotted-quad string format (for example, ‘123.45.67.89’) to 32-bit packed binary format, as a bytes object four characters in length. This is useful when conversing with a program that uses the standard C library and needs objects of type \texttt{struct in\_addr}, which is the C type for the 32-bit packed binary this function returns.

\texttt{inet\_atons()} also accepts strings with less than three dots; see the Unix manual page \texttt{inet(3)} for details.

If the IPv4 address string passed to this function is invalid, \texttt{OSError} will be raised. Note that exactly what is valid depends on the underlying C implementation of \texttt{inet\_atons()}.

\texttt{inet\_atons()} does not support IPv6, and \texttt{inet\_pton()} should be used instead for IPv4/v6 dual stack support.

socket.\texttt{inet\_ntoa}(packed\_ip)
Conversion a 32-bit packed IPv4 address (a bytes-like object four bytes in length) to its standard dotted-quad string representation (for example, ‘123.45.67.89’). This is useful when conversing with a program that uses the standard C library and needs objects of type
struct in_addr, which is the C type for the 32-bit packed binary data this function takes as an argument.

If the byte sequence passed to this function is not exactly 4 bytes in length, OSError will be raised. inet_ntoa() does not support IPv6, and inet_ntop() should be used instead for IPv4/v6 dual stack support.

socket.inet_pton(address_family, ip_string)
Convert an IP address from its family-specific string format to a packed, binary format. inet_pton() is useful when a library or network protocol calls for an object of type struct in_addr (similar to inet_aton()) or struct in6_addr.

Supported values for address_family are currently AF_INET and AF_INET6. If the IP address string ip_string is invalid, OSError will be raised. Note that exactly what is valid depends on both the value of address_family and the underlying implementation of inet_pton().

Availability: Unix (maybe not all platforms), Windows.

Changed in version 3.4: Windows support added

socket.inet_ntop(address_family, packed_ip)
Convert a packed IP address (a bytes-like object of some number of bytes) to its standard, family-specific string representation (for example, '7.10.0.5' or '5aef:2b::8'). inet_ntop() is useful when a library or network protocol returns an object of type struct in_addr (similar to inet_ntoa()) or struct in6_addr.
Supported values for `address_family` are currently `AF_INET` and `AF_INET6`. If the bytes object `packed_ip` is not the correct length for the specified address family, `ValueError` will be raised. `OSError` is raised for errors from the call to `inet_ntop()`.

Availability: Unix (maybe not all platforms), Windows.

*Changed in version 3.4:* Windows support added

**socket.CMSG_LEN**(length)

Return the total length, without trailing padding, of an ancillary data item with associated data of the given `length`. This value can often be used as the buffer size for `recvmsg()` to receive a single item of ancillary data, but **RFC 3542** requires portable applications to use `CMSG_SPACE()` and thus include space for padding, even when the item will be the last in the buffer. Raises `OverflowError` if `length` is outside the permissible range of values.

Availability: most Unix platforms, possibly others.

*New in version 3.3.*

**socket.CMSG_SPACE**(length)

Return the buffer size needed for `recvmsg()` to receive an ancillary data item with associated data of the given `length`, along with any trailing padding. The buffer space needed to receive multiple items is the sum of the `CMSG_SPACE()` values for their associated data lengths. Raises `OverflowError` if `length` is outside the permissible range of values.

Note that some systems might support ancillary data without providing this function. Also note that setting the buffer size using
the results of this function may not precisely limit the amount of ancillary data that can be received, since additional data may be able to fit into the padding area.

Availability: most Unix platforms, possibly others.

*New in version 3.3.*

**socket.getdefaulttimeout()**

Return the default timeout in seconds (float) for new socket objects. A value of None indicates that new socket objects have no timeout. When the socket module is first imported, the default is None.

**socket.setdefaulttimeout(timeout)**

Set the default timeout in seconds (float) for new socket objects. When the socket module is first imported, the default is None. See `settimeout()` for possible values and their respective meanings.

**socket.sethostname(name)**

Set the machine's hostname to name. This will raise an OSError if you don’t have enough rights.

Availability: Unix.

*New in version 3.3.*

**socket.if_nameindex()**

Return a list of network interface information (index int, name string) tuples. OSError if the system call fails.

Availability: Unix.

*New in version 3.3.*
socket.if_nametoindex(if_name)

Return a network interface index number corresponding to an interface name. OSError if no interface with the given name exists.

Availability: Unix.

New in version 3.3.

socket.if_indextoname(if_index)

Return a network interface name corresponding to an interface index number. OSError if no interface with the given index exists.

Availability: Unix.

New in version 3.3.
18.1.3. Socket Objects

Socket objects have the following methods. Except for `makefile()`, these correspond to Unix system calls applicable to sockets.

socket.accept()

Accept a connection. The socket must be bound to an address and listening for connections. The return value is a pair (conn, address) where `conn` is a new socket object usable to send and receive data on the connection, and `address` is the address bound to the socket on the other end of the connection.

The newly created socket is non-inheritable.

*Changed in version 3.4:* The socket is now non-inheritable.

*Changed in version 3.5:* If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an `InterruptedError` exception (see PEP 475 for the rationale).

socket.bind(address)

Bind the socket to `address`. The socket must not already be bound. (The format of `address` depends on the address family — see above.)

socket.close()

Mark the socket closed. The underlying system resource (e.g. a file descriptor) is also closed when all file objects from `makefile()` are closed. Once that happens, all future operations on the socket object will fail. The remote end will receive no more data (after queued data is flushed).
Sockets are automatically closed when they are garbage-collected, but it is recommended to \texttt{close()} them explicitly, or to use a \texttt{with} statement around them.

\begin{quote}
\textbf{Note:} \texttt{close()} releases the resource associated with a connection but does not necessarily close the connection immediately. If you want to close the connection in a timely fashion, call \texttt{shutdown()} before \texttt{close()}.
\end{quote}

\begin{verbatim}
socket.connect(address)
\end{verbatim}

Connect to a remote socket at \texttt{address}. (The format of \texttt{address} depends on the address family — see above.)

If the connection is interrupted by a signal, the method waits until the connection completes, or raise a \texttt{socket.timeout} on timeout, if the signal handler doesn’t raise an exception and the socket is blocking or has a timeout. For non-blocking sockets, the method raises an \texttt{InterruptedError} exception if the connection is interrupted by a signal (or the exception raised by the signal handler).

\textit{Changed in version 3.5:} The method now waits until the connection completes instead of raising an \texttt{InterruptedError} exception if the connection is interrupted by a signal, the signal handler doesn’t raise an exception and the socket is blocking or has a timeout (see the \texttt{PEP 475} for the rationale).

\begin{verbatim}
socket.connect_ex(address)
\end{verbatim}

Like \texttt{connect(address)}, but return an error indicator instead of raising an exception for errors returned by the C-level \texttt{connect()} call (other problems, such as “host not found,” can still raise exceptions). The error indicator is 0 if the operation succeeded,
otherwise the value of the errno variable. This is useful to support, for example, asynchronous connects.

socket\ndetach()\n
Put the socket object into closed state without actually closing the underlying file descriptor. The file descriptor is returned, and can be reused for other purposes.

\n\n\nNew in version 3.2.\n
socket\ndup()\n
Duplicate the socket.

The newly created socket is non-inheritable.

\n\n\nChanged in version 3.4: The socket is now non-inheritable.\n
socket\nfileno()\n
Return the socket’s file descriptor (a small integer). This is useful with select.select().

Under Windows the small integer returned by this method cannot be used where a file descriptor can be used (such as os.fdopen()). Unix does not have this limitation.

socket\nget_inheritable()\n
Get the inheritable flag of the socket’s file descriptor or socket’s handle: True if the socket can be inherited in child processes, False if it cannot.

\n\n\nNew in version 3.4.\n
socket\ngetpeervname()
Return the remote address to which the socket is connected. This is useful to find out the port number of a remote IPv4/v6 socket, for instance. (The format of the address returned depends on the address family — see above.) On some systems this function is not supported.

socket.getsockname()

Return the socket's own address. This is useful to find out the port number of an IPv4/v6 socket, for instance. (The format of the address returned depends on the address family — see above.)

socket.getsockopt(level, optname[, buflen])

Return the value of the given socket option (see the Unix man page getsockopt(2)). The needed symbolic constants (SO_* etc.) are defined in this module. If buflen is absent, an integer option is assumed and its integer value is returned by the function. If buflen is present, it specifies the maximum length of the buffer used to receive the option in, and this buffer is returned as a bytes object. It is up to the caller to decode the contents of the buffer (see the optional built-in module struct for a way to decode C structures encoded as byte strings).

socket.gettimeout()

Return the timeout in seconds (float) associated with socket operations, or None if no timeout is set. This reflects the last call to setblocking() or settimeout().

socket.ioctl(control, option)

The ioctl() method is a limited interface to the WSAIoctl system interface. Please refer to the Win32 documentation for more
information.

On other platforms, the generic `fcntl.fcntl()` and `fcntl.ioctl()` functions may be used; they accept a socket object as their first argument.

```
socket.listen([backlog])
```

Enable a server to accept connections. If `backlog` is specified, it must be at least 0 (if it is lower, it is set to 0); it specifies the number of unaccepted connections that the system will allow before refusing new connections. If not specified, a default reasonable value is chosen.

*Changed in version 3.5:* The `backlog` parameter is now optional.

```
socket.makefile(mode='r', buffering=None, *, encoding=None, errors=None, newline=None)
```

Return a file object associated with the socket. The exact returned type depends on the arguments given to `makefile()`. These arguments are interpreted the same way as by the built-in `open()` function.

The socket must be in blocking mode; it can have a timeout, but the file object’s internal buffer may end up in an inconsistent state if a timeout occurs.

Closing the file object returned by `makefile()` won't close the original socket unless all other file objects have been closed and `socket.close()` has been called on the socket object.

**Note:** On Windows, the file-like object created by `makefile()` cannot be used where a file object with a file descriptor is
expected, such as the stream arguments of `subprocess.Popen()`.

socket.\texttt{recv}(\texttt{bufsize[, flags]})

Receive data from the socket. The return value is a bytes object representing the data received. The maximum amount of data to be received at once is specified by \texttt{bufsize}. See the Unix manual page \texttt{recv(2)} for the meaning of the optional argument \texttt{flags}; it defaults to zero.

\textbf{Note:} For best match with hardware and network realities, the value of \texttt{bufsize} should be a relatively small power of 2, for example, 4096.

\textit{Changed in version 3.5:} If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an \texttt{InterruptedError} exception (see PEP 475 for the rationale).

socket.\texttt{recvfrom}(\texttt{bufsize[, flags]})

Receive data from the socket. The return value is a pair (\texttt{bytes, address}) where \texttt{bytes} is a bytes object representing the data received and \texttt{address} is the address of the socket sending the data. See the Unix manual page \texttt{recv(2)} for the meaning of the optional argument \texttt{flags}; it defaults to zero. (The format of \texttt{address} depends on the address family — see above.)

\textit{Changed in version 3.5:} If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an \texttt{InterruptedError} exception (see PEP 475 for the rationale).
socket.recvmsg(bufsize[, ancbufsize[, flags]])

Receive normal data (up to bufsize bytes) and ancillary data from the socket. The ancbufsize argument sets the size in bytes of the internal buffer used to receive the ancillary data; it defaults to 0, meaning that no ancillary data will be received. Appropriate buffer sizes for ancillary data can be calculated using CMSG_SPACE() or CMSG_LEN(), and items which do not fit into the buffer might be truncated or discarded. The flags argument defaults to 0 and has the same meaning as for recv().

The return value is a 4-tuple: (data, ancdata, msg_flags, address). The data item is a bytes object holding the non-ancillary data received. The ancdata item is a list of zero or more tuples (cmsg_level, cmsg_type, cmsg_data) representing the ancillary data (control messages) received: cmsg_level and cmsg_type are integers specifying the protocol level and protocol-specific type respectively, and cmsg_data is a bytes object holding the associated data. The msg_flags item is the bitwise OR of various flags indicating conditions on the received message; see your system documentation for details. If the receiving socket is unconnected, address is the address of the sending socket, if available; otherwise, its value is unspecified.

On some systems, sendmsg() and recvmsg() can be used to pass file descriptors between processes over an AF_UNIX socket. When this facility is used (it is often restricted to SOCK_STREAM sockets), recvmsg() will return, in its ancillary data, items of the form (socket.SOL_SOCKET, socket.SCM_RIGHTS, fds), where fds is a bytes object representing the new file descriptors as a binary array of the native C int type. If recvmsg() raises an exception after the system call returns, it will first attempt to close
any file descriptors received via this mechanism.

Some systems do not indicate the truncated length of ancillary data items which have been only partially received. If an item appears to extend beyond the end of the buffer, `recvmsg()` will issue a `RuntimeWarning`, and will return the part of it which is inside the buffer provided it has not been truncated before the start of its associated data.

On systems which support the SCM_RIGHTS mechanism, the following function will receive up to `maxfds` file descriptors, returning the message data and a list containing the descriptors (while ignoring unexpected conditions such as unrelated control messages being received). See also `sendmsg()`.

```python
import socket, array

def recv_fds(sock, msglen, maxfds):
    fds = array.array("i")  # Array of ints
    msg, ancdata, flags, addr = sock.recvmsg(msglen)
    for cmsg_level, cmsg_type, cmsg_data in ancdata:
        if (cmsg_level == socket.SOL_SOCKET and cmsg_type == SCM_RIGHTS):
            # Append data, ignoring any truncated integers
            fds.fromstring(cmsg_data[:len(cmsg_data)])
    return msg, list(fds)
```

Availability: most Unix platforms, possibly others.

*New in version 3.3.*

*Changed in version 3.5:* If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an `InterruptedError`
exception (see PEP 475 for the rationale).

```python
socket.recvmsg_into(buffers[, ancbufsize[, flags]])
```

Receive normal data and ancillary data from the socket, behaving as `recvmsg()` would, but scatter the non-ancillary data into a series of buffers instead of returning a new bytes object. The `buffers` argument must be an iterable of objects that export writable buffers (e.g. `bytearray` objects); these will be filled with successive chunks of the non-ancillary data until it has all been written or there are no more buffers. The operating system may set a limit (`sysconf()` value `SC_IOV_MAX`) on the number of buffers that can be used. The `ancbufsize` and `flags` arguments have the same meaning as for `recvmsg()`.

The return value is a 4-tuple: `( nbytes, ancdata, msg_flags, address )`, where `nbytes` is the total number of bytes of non-ancillary data written into the buffers, and `ancdata`, `msg_flags` and `address` are the same as for `recvmsg()`.

Example:

```python
>>> import socket
>>> s1, s2 = socket.socketpair()
>>> b1 = bytearray(b'----')
>>> b2 = bytearray(b'0123456789')
>>> b3 = bytearray(b'--------------')
>>> s1.send(b'Mary had a little lamb')
22
>>> s2.recvmsg_into([b1, memoryview(b2)[2:9], b3])
(22, [ ], 0, None)
>>> [b1, b2, b3]
[bytearray(b'Mary'), bytearray(b'01 had a 9'), bytearray(b'little lamb---')]
```
Availability: most Unix platforms, possibly others.

New in version 3.3.

socket.recvfrom_into(buffer[, nbytes[, flags]])

Receive data from the socket, writing it into buffer instead of creating a new bytestring. The return value is a pair (nbytes, address) where nbytes is the number of bytes received and address is the address of the socket sending the data. See the Unix manual page recv(2) for the meaning of the optional argument flags; it defaults to zero. (The format of address depends on the address family — see above.)

socket.recv_into(buffer[, nbytes[, flags]])

Receive up to nbytes bytes from the socket, storing the data into a buffer rather than creating a new bytestring. If nbytes is not specified (or 0), receive up to the size available in the given buffer. Returns the number of bytes received. See the Unix manual page recv(2) for the meaning of the optional argument flags; it defaults to zero.

socket.send(bytes[, flags])

Send data to the socket. The socket must be connected to a remote socket. The optional flags argument has the same meaning as for recv() above. Returns the number of bytes sent. Applications are responsible for checking that all data has been sent; if only some of the data was transmitted, the application needs to attempt delivery of the remaining data. For further information on this topic, consult the Socket Programming HOWTO.

Changed in version 3.5: If the system call is interrupted and the
signal handler does not raise an exception, the method now retries the system call instead of raising an InterruptedError exception (see PEP 475 for the rationale).

```python
socket.sendall(bytes[, flags])
```

Send data to the socket. The socket must be connected to a remote socket. The optional `flags` argument has the same meaning as for `recv()` above. Unlike `send()`, this method continues to send data from `bytes` until either all data has been sent or an error occurs. None is returned on success. On error, an exception is raised, and there is no way to determine how much data, if any, was successfully sent.

*Changed in version 3.5:* The socket timeout is no more reset each time data is sent successfully. The socket timeout is now the maximum total duration to send all data.

```python
socket.sendto(bytes, address)
socket.sendto(bytes, flags, address)
```

Send data to the socket. The socket should not be connected to a remote socket, since the destination socket is specified by `address`. The optional `flags` argument has the same meaning as for `recv()` above. Return the number of bytes sent. (The format of `address` depends on the address family — see above.)

*Changed in version 3.5:* If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an InterruptedError exception (see PEP 475 for the rationale).
the system call instead of raising an `InterruptedError`
exception (see PEP 475 for the rationale).

```python
socket.sendmsg(buffers[, ancdata[, flags[, address]]])
```

Send normal and ancillary data to the socket, gathering the non-
ancillary data from a series of buffers and concatenating it into a
single message. The `buffers` argument specifies the non-ancillary
data as an iterable of `bytes-like objects` (e.g. `bytes` objects); the
operating system may set a limit (`sysconf()` value `SC_IOV_MAX`)
on the number of buffers that can be used. The `ancdata` argument
specifies the ancillary data (control messages) as an iterable of
zero or more tuples `(cmsg_level, cmsg_type, cmsg_data)`,
where `cmsg_level` and `cmsg_type` are integers specifying the
protocol level and protocol-specific type respectively, and
`cmsg_data` is a bytes-like object holding the associated data. Note
that some systems (in particular, systems without `CMSG_SPACE()`)might support sending only one control message per call. The `flags`
argument defaults to 0 and has the same meaning as for `send()`. If
`address` is supplied and not None, it sets a destination address
for the message. The return value is the number of bytes of non-
ancillary data sent.

The following function sends the list of file descriptors `fds` over an
`AF_UNIX` socket, on systems which support the SCM_RIGHTS
mechanism. See also `recvmsg()`.

```python
import socket, array

def send_fds(sock, msg, fds):
    return sock.sendmsg([[msg], [(socket.SOL_SOCKET,
```
Availability: most Unix platforms, possibly others.

*New in version 3.3.*

*Changed in version 3.5:* If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an `InterruptedError` exception (see [PEP 475](https://www.python.org/dev/peps/pep-0475/) for the rationale).

**socket.sendfile(file, offset=0, count=None)**

Send a file until EOF is reached by using high-performance `os.sendfile` and return the total number of bytes which were sent. `file` must be a regular file object opened in binary mode. If `os.sendfile` is not available (e.g. Windows) or `file` is not a regular file `send()` will be used instead. `offset` tells from where to start reading the file. If specified, `count` is the total number of bytes to transmit as opposed to sending the file until EOF is reached. File position is updated on return or also in case of error in which case `file.tell()` can be used to figure out the number of bytes which were sent. The socket must be of `SOCK_STREAM` type. Non-blocking sockets are not supported.

*New in version 3.5.*

**socket.set_inheritable(inheritable)**

Set the inheritable flag of the socket's file descriptor or socket's handle.

*New in version 3.4.*

**socket.setblocking(flag)**

Set blocking or non-blocking mode of the socket: if `flag` is false, the socket is set to non-blocking, else to blocking mode.
This method is a shorthand for certain `settimeout()` calls:

- `sock.setblocking(True)` is equivalent to `sock.settimeout(None)`
- `sock.setblocking(False)` is equivalent to `sock.settimeout(0.0)`

**socket.settimeout(value)**
Set a timeout on blocking socket operations. The `value` argument can be a nonnegative floating point number expressing seconds, or None. If a non-zero value is given, subsequent socket operations will raise a `timeout` exception if the timeout period `value` has elapsed before the operation has completed. If zero is given, the socket is put in non-blocking mode. If None is given, the socket is put in blocking mode.

For further information, please consult the notes on socket timeouts.

**socket.setsockopt(level, optname, value)**
Set the value of the given socket option (see the Unix manual page `setsockopt(2)`). The needed symbolic constants are defined in the `socket` module (SO_* etc.). The value can be an integer or a bytes-like object representing a buffer. In the latter case it is up to the caller to ensure that the bytestring contains the proper bits (see the optional built-in module `struct` for a way to encode C structures as bytestrings).

**socket.shutdown(how)**
Shut down one or both halves of the connection. If `how` is SHUT_RD, further receives are disallowed. If `how` is SHUT_WR, further sends are disallowed. If `how` is SHUT_RDWR, further sends
and receives are disallowed.

socket.share(process_id)

Duplicate a socket and prepare it for sharing with a target process. The target process must be provided with process_id. The resulting bytes object can then be passed to the target process using some form of interprocess communication and the socket can be recreated there using fromshare(). Once this method has been called, it is safe to close the socket since the operating system has already duplicated it for the target process.

Availability: Windows.

New in version 3.3.

Note that there are no methods read() or write(); use recv() and send() without flags argument instead.

Socket objects also have these (read-only) attributes that correspond to the values given to the socket constructor.

socket.family

The socket family.

socket.type

The socket type.

socket.proto

The socket protocol.
18.1.4. Notes on socket timeouts

A socket object can be in one of three modes: blocking, non-blocking, or timeout. Sockets are by default always created in blocking mode, but this can be changed by calling `setdefaulttimeout()`.

- In **blocking mode**, operations block until complete or the system returns an error (such as connection timed out).
- In **non-blocking mode**, operations fail (with an error that is unfortunately system-dependent) if they cannot be completed immediately: functions from the `select` can be used to know when and whether a socket is available for reading or writing.
- In **timeout mode**, operations fail if they cannot be completed within the timeout specified for the socket (they raise a `timeout` exception) or if the system returns an error.

**Note:** At the operating system level, sockets in **timeout mode** are internally set in non-blocking mode. Also, the blocking and timeout modes are shared between file descriptors and socket objects that refer to the same network endpoint. This implementation detail can have visible consequences if e.g. you decide to use the `fileno()` of a socket.

18.1.4.1. Timeouts and the connect method

The `connect()` operation is also subject to the timeout setting, and in general it is recommended to call `settimeout()` before calling `connect()` or pass a timeout parameter to `create_connection()`. However, the system network stack may also return a connection timeout error of its own regardless of any Python socket timeout setting.
18.1.4.2. Timeouts and the accept method

If `getdefaulttimeout()` is not `None`, sockets returned by the `accept()` method inherit that timeout. Otherwise, the behaviour depends on settings of the listening socket:

- if the listening socket is in *blocking mode* or in *timeout mode*, the socket returned by `accept()` is in *blocking mode*;
- if the listening socket is in *non-blocking mode*, whether the socket returned by `accept()` is in blocking or non-blocking mode is operating system-dependent. If you want to ensure cross-platform behaviour, it is recommended you manually override this setting.
18.1.5. Example

Here are four minimal example programs using the TCP/IP protocol: a server that echoes all data that it receives back (servicing only one client), and a client using it. Note that a server must perform the sequence `socket()`, `bind()`, `listen()`, `accept()` (possibly repeating the `accept()` to service more than one client), while a client only needs the sequence `socket()`, `connect()`. Also note that the server does not use `sendall()`, `recv()` on the socket it is listening on but on the new socket returned by `accept()`.

The first two examples support IPv4 only.

```python
# Echo server program
import socket

HOST = ''       # Symbolic name meaning all available interfaces
PORT = 50007    # Arbitrary non-privileged port

s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.bind((HOST, PORT))
s.listen(1)
conn, addr = s.accept()
print('Connected by', addr)
while True:
    data = conn.recv(1024)
    if not data: break
    conn.sendall(data)
conn.close()

# Echo client program
import socket

HOST = 'daring.cwi.nl'      # The remote host
```
PORT = 50007  # The same port as used by the server
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.connect((HOST, PORT))
s.sendall(b'Hello, world')
data = s.recv(1024)
s.close()
print('Received', repr(data))

The next two examples are identical to the above two, but support both IPv4 and IPv6. The server side will listen to the first address family available (it should listen to both instead). On most of IPv6-ready systems, IPv6 will take precedence and the server may not accept IPv4 traffic. The client side will try to connect to the all addresses returned as a result of the name resolution, and sends traffic to the first one connected successfully.

# Echo server program
import socket
import sys

HOST = None  # Symbolic name meaning all available interfaces
PORT = 50007  # Arbitrary non-privileged port
s = None
for res in socket.getaddrinfo(HOST, PORT, socket.AF_UNSPEC,
                               socket.SOCK_STREAM, 0,
                               socket.IPPROTO_TCP):
    af, socktype, proto, canonname, sa = res
    try:
        s = socket.socket(af, socktype, proto)
    except OSError as msg:
        s = None
        continue
    try:
        s.bind(sa)
        s.listen(1)
    except OSError as msg:
s.close()
    s = None
    continue
  break
if s is None:
  print('could not open socket')
  sys.exit(1)
conn, addr = s.accept()
print('Connected by', addr)
while True:
  data = conn.recv(1024)
  if not data: break
  conn.send(data)
conn.close()

# Echo client program
import socket
import sys

HOST = 'daring.cwi.nl'  # The remote host
PORT = 50007            # The same port as used by
s = None
for res in socket.getaddrinfo(HOST, PORT, socket.AF_
   af, socktype, proto, canonname, sa = res
   try:
      s = socket.socket(af, socktype, proto)
   except OSError as msg:
      s = None
      continue
  try:
      s.connect(sa)
  except OSError as msg:
      s.close()
      s = None
      continue
break
if s is None:
    print('could not open socket')
    sys.exit(1)

s.sendall(b'Hello, world')

data = s.recv(1024)
s.close()

print('Received', repr(data))

The next example shows how to write a very simple network sniffer with raw sockets on Windows. The example requires administrator privileges to modify the interface:

```python
import socket

# the public network interface
HOST = socket.gethostbyname(socket.gethostname())

# create a raw socket and bind it to the public interface
s = socket.socket(socket.AF_INET, socket.SOCK_RAW, socket.IPPROTO_IP)
s.bind((HOST, 0))

# Include IP headers
s.setsockopt(socket.IPPROTO_IP, socket.IP_HDRINCL, 1)

# receive all packages
s.ioctl(socket.SIO_RCVALL, socket.RCVALL_ON)

# receive a package
print(s.recvfrom(65565))

# disabled promiscuous mode
s.ioctl(socket.SIO_RCVALL, socket.RCVALL_OFF)
```

The last example shows how to use the socket interface to communicate to a CAN network using the raw socket protocol. To use
CAN with the broadcast manager protocol instead, open a socket with:

```python
socket.socket(socket.AF_CAN, socket.SOCK_DGRAM, socket.CAN_RAW)
```

After binding (CAN_RAW) or connecting (CAN_BCM) the socket, you can use the `socket.send()` and the `socket.recv()` operations (and their counterparts) on the socket object as usual.

This example might require special privileges:

```python
import socket
import struct

# CAN frame packing/unpacking (see 'struct can_frame' in <linux/can.h>)
can_frame_fmt = '=IB3x8s'
can_frame_size = struct.calcsize(can_frame_fmt)

def build_can_frame(can_id, data):
    can_dlc = len(data)
    data = data.ljust(8, b'\x00')
    return struct.pack(can_frame_fmt, can_id, can_dlc)

def dissect_can_frame(frame):
    can_id, can_dlc, data = struct.unpack(can_frame_fmt, frame)
    return (can_id, can_dlc, data[:can_dlc])

# create a raw socket and bind it to the 'vcan0' interface
s = socket.socket(socket.AF_CAN, socket.SOCK_RAW, socket.CAN_RAW)
s.bind(('vcan0',))

while True:
    cf, addr = s.recvfrom(can_frame_size)
```
```python
print('Received: can_id=%x, can_dlc=%x, data=%s')
try:
    s.send(cf)
except OSError:
    print('Error sending CAN frame')
try:
    s.send(build_can_frame(0x01, b'\x01\x02\x03'))
except OSError:
    print('Error sending CAN frame')
```

Running an example several times with too small delay between executions, could lead to this error:

```plaintext
OSError: [Errno 98] Address already in use
```

This is because the previous execution has left the socket in a TIME_WAIT state, and can't be immediately reused.

There is a `socket` flag to set, in order to prevent this, `socket.SO_REUSEADDR`:

```python
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
s.bind((HOST, PORT))
```

the `SO_REUSEADDR` flag tells the kernel to reuse a local socket in TIME_WAIT state, without waiting for its natural timeout to expire.

**See also:** For an introduction to socket programming (in C), see the following papers:
The platform-specific reference material for the various socket-related system calls are also a valuable source of information on the details of socket semantics. For Unix, refer to the manual pages; for Windows, see the WinSock (or Winsock 2) specification. For IPv6-ready APIs, readers may want to refer to RFC 3493 titled Basic Socket Interface Extensions for IPv6.
18. Interprocess Communication and Networking
18.2. **ssl** — TLS/SSL wrapper for socket objects

**Source code:** Lib/ssl.py

This module provides access to Transport Layer Security (often known as “Secure Sockets Layer”) encryption and peer authentication facilities for network sockets, both client-side and server-side. This module uses the OpenSSL library. It is available on all modern Unix systems, Windows, Mac OS X, and probably additional platforms, as long as OpenSSL is installed on that platform.

**Note:** Some behavior may be platform dependent, since calls are made to the operating system socket APIs. The installed version of OpenSSL may also cause variations in behavior. For example, TLSv1.1 and TLSv1.2 come with openssl version 1.0.1.

**Warning:** Don’t use this module without reading the Security considerations. Doing so may lead to a false sense of security, as the default settings of the ssl module are not necessarily appropriate for your application.

This section documents the objects and functions in the ssl module; for more general information about TLS, SSL, and certificates, the reader is referred to the documents in the “See Also” section at the bottom.

This module provides a class, `ssl.sslSocket`, which is derived from the `socket.socket` type, and provides a socket-like wrapper that
also encrypts and decrypts the data going over the socket with SSL. It supports additional methods such as getpeercert(), which retrieves the certificate of the other side of the connection, and cipher(), which retrieves the cipher being used for the secure connection.

For more sophisticated applications, the ssl. SSLContext class helps manage settings and certificates, which can then be inherited by SSL sockets created through the SSLContext.wrap_socket() method.
18.2.1. Functions, Constants, and Exceptions

exception ssl.SSLError

Raised to signal an error from the underlying SSL implementation (currently provided by the OpenSSL library). This signifies some problem in the higher-level encryption and authentication layer that's superimposed on the underlying network connection. This error is a subtype of OSError. The error code and message of SSLError instances are provided by the OpenSSL library.

Changed in version 3.3: SSLError used to be a subtype of socket.error.

library

A string mnemonic designating the OpenSSL submodule in which the error occurred, such as SSL, PEM or X509. The range of possible values depends on the OpenSSL version.

New in version 3.3.

reason

A string mnemonic designating the reason this error occurred, for example CERTIFICATE_VERIFY_FAILED. The range of possible values depends on the OpenSSL version.

New in version 3.3.

exception ssl.SSLZeroReturnError

A subclass of SSLError raised when trying to read or write and the SSL connection has been closed cleanly. Note that this doesn’t
mean that the underlying transport (read TCP) has been closed.

*New in version 3.3.*

**exception ss1.** **SSLWantReadError**
A subclass of **SSLError** raised by a non-blocking SSL socket when trying to read or write data, but more data needs to be received on the underlying TCP transport before the request can be fulfilled.

*New in version 3.3.*

**exception ss1.** **SSLWantWriteError**
A subclass of **SSLError** raised by a non-blocking SSL socket when trying to read or write data, but more data needs to be sent on the underlying TCP transport before the request can be fulfilled.

*New in version 3.3.*

**exception ss1.** **SSLSyscallError**
A subclass of **SSLError** raised when a system error was encountered while trying to fulfill an operation on a SSL socket. Unfortunately, there is no easy way to inspect the original errno number.

*New in version 3.3.*

**exception ss1.** **SSLEOFError**
A subclass of **SSLError** raised when the SSL connection has been terminated abruptly. Generally, you shouldn’t try to reuse the underlying transport when this error is encountered.

*New in version 3.3.*
exception ssl.CertificateError

Raised to signal an error with a certificate (such as mismatching hostname). Certificate errors detected by OpenSSL, though, raise an SSLError.

18.2.1.1. Socket creation

The following function allows for standalone socket creation. Starting from Python 3.2, it can be more flexible to use SSLContext.wrap_socket() instead.

ssl.wrap_socket(sock, keyfile=None, certfile=None, server_side=False, cert_reqs=CERT_NONE, ssl_version={see docs}, ca_certs=None, do_handshake_on_connect=True, suppress_ragged_eofs=True, ciphers=None)

Takes an instance sock of socket.socket, and returns an instance of ssl.SSLSocket, a subtype of socket.socket, which wraps the underlying socket in an SSL context. sock must be a SOCK_STREAM socket; other socket types are unsupported.

For client-side sockets, the context construction is lazy; if the underlying socket isn’t connected yet, the context construction will be performed after connect() is called on the socket. For server-side sockets, if the socket has no remote peer, it is assumed to be a listening socket, and the server-side SSL wrapping is automatically performed on client connections accepted via the accept() method. wrap_socket() may raise SSLError.

The keyfile and certfile parameters specify optional files which contain a certificate to be used to identify the local side of the connection. See the discussion of Certificates for more information on how the certificate is stored in the certfile.
The parameter `server_side` is a boolean which identifies whether server-side or client-side behavior is desired from this socket.

The parameter `cert_reqs` specifies whether a certificate is required from the other side of the connection, and whether it will be validated if provided. It must be one of the three values `CERT_NONE` (certificates ignored), `CERT_OPTIONAL` (not required, but validated if provided), or `CERT_REQUIRED` (required and validated). If the value of this parameter is not `CERT_NONE`, then the `ca_certs` parameter must point to a file of CA certificates.

The `ca_certs` file contains a set of concatenated “certification authority” certificates, which are used to validate certificates passed from the other end of the connection. See the discussion of Certificates for more information about how to arrange the certificates in this file.

The parameter `ssl_version` specifies which version of the SSL protocol to use. Typically, the server chooses a particular protocol version, and the client must adapt to the server’s choice. Most of the versions are not interoperable with the other versions. If not specified, the default is `PROTOCOL_SSLv23`; it provides the most compatibility with other versions.

Here’s a table showing which versions in a client (down the side) can connect to which versions in a server (along the top):

```
<table>
<thead>
<tr>
<th>client / server</th>
<th>SSLv2</th>
<th>SSLv3</th>
<th>SSLv23</th>
<th>TLSv1</th>
<th>TLSv1.1</th>
<th>TLSv2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSLv2</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>SSLv3</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>
```
<table>
<thead>
<tr>
<th>Version</th>
<th>SSLv23</th>
<th>yes</th>
<th>yes</th>
<th>yes</th>
<th>yes</th>
<th>yes</th>
<th>yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLSv1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>TLSv1.1</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>TLSv1.2</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

**Note:** Which connections succeed will vary depending on the version of OpenSSL. For example, before OpenSSL 1.0.0, an SSLv23 client would always attempt SSLv2 connections.

The `ciphers` parameter sets the available ciphers for this SSL object. It should be a string in the OpenSSL cipher list format.

The parameter `do_handshake_on_connect` specifies whether to do the SSL handshake automatically after doing a `socket.connect()`, or whether the application program will call it explicitly, by invoking the `SSLSocket.do_handshake()` method. Calling `SSLSocket.do_handshake()` explicitly gives the program control over the blocking behavior of the socket I/O involved in the handshake.

The parameter `suppress_ragged_eofs` specifies how the `SSLSocket.recv()` method should signal unexpected EOF from the other end of the connection. If specified as `True` (the default), it returns a normal EOF (an empty bytes object) in response to unexpected EOF errors raised from the underlying socket; if `False`, it will raise the exceptions back to the caller.

*Changed in version 3.2:* New optional argument `ciphers`.

### 18.2.1.2. Context creation
A convenience function helps create SSLContext objects for common purposes.

ssl.create_default_context(purpose=Purpose.SERVER_AUTH, cafile=None, capath=None, cadata=None)

Return a new SSLContext object with default settings for the given purpose. The settings are chosen by the ssl module, and usually represent a higher security level than when calling the SSLContext constructor directly.

cafíle, capath, cadata represent optional CA certificates to trust for certificate verification, as in SSLContext.load_verify_locations(). If all three are None, this function can choose to trust the system’s default CA certificates instead.

The settings are: PROTOCOL_SSLv23, OP_NO_SSLv2, and OP_NO_SSLv3 with high encryption cipher suites without RC4 and without unauthenticated cipher suites. Passing SERVER_AUTH as purpose sets verify_mode to CERT_REQUIRED and either loads CA certificates (when at least one of cafíle, capath or cadata is given) or uses SSLContext.load_default_certs() to load default CA certificates.

---

**Note:** The protocol, options, cipher and other settings may change to more restrictive values anytime without prior deprecation. The values represent a fair balance between compatibility and security.

If your application needs specific settings, you should create a SSLContext and apply the settings yourself.
Note: If you find that when certain older clients or servers attempt to connect with a SSLContext created by this function that they get an error stating “Protocol or cipher suite mismatch”, it may be that they only support SSL3.0 which this function excludes using the OP_NO_SSLv3. SSL3.0 is widely considered to be completely broken. If you still wish to continue to use this function but still allow SSL 3.0 connections you can re-enable them using:

```python
ctx = ssl.create_default_context(Purpose.CLIENT_AUTH)
ctx.options &= ~ssl.OP_NO_SSLv3
```

*New in version 3.4.*

*Changed in version 3.4.4:* RC4 was dropped from the default cipher string.

### 18.2.1.3. Random generation

**ssl.RAND_bytes(num)**

Return `num` cryptographically strong pseudo-random bytes. Raises an SSLError if the PRNG has not been seeded with enough data or if the operation is not supported by the current RAND method. `RAND_status()` can be used to check the status of the PRNG and `RAND_add()` can be used to seed the PRNG.

For almost all applications `os.urandom()` is preferable.

Read the Wikipedia article, Cryptographically secure pseudorandom number generator (CSPRNG), to get the requirements of a cryptographically generator.
New in version 3.3.

**ssl.RAND_pseudo_bytes(num)**

Return (bytes, is_cryptographic): bytes are `num` pseudo-random bytes, `is_cryptographic` is True if the bytes generated are cryptographically strong. Raises an `SSLError` if the operation is not supported by the current RAND method.

Generated pseudo-random byte sequences will be unique if they are of sufficient length, but are not necessarily unpredictable. They can be used for non-cryptographic purposes and for certain purposes in cryptographic protocols, but usually not for key generation etc.

For almost all applications `os.urandom()` is preferable.

New in version 3.3.

**ssl.RAND_status()**

Return True if the SSL pseudo-random number generator has been seeded with ‘enough’ randomness, and False otherwise. You can use `ssl.RAND_egd()` and `ssl.RAND_add()` to increase the randomness of the pseudo-random number generator.

**ssl.RAND_egd(path)**

If you are running an entropy-gathering daemon (EGD) somewhere, and `path` is the pathname of a socket connection open to it, this will read 256 bytes of randomness from the socket, and add it to the SSL pseudo-random number generator to increase the security of generated secret keys. This is typically only necessary on systems without better sources of randomness.

sources of entropy-gathering daemons.

Availability: not available with LibreSSL.

ssl.RAND_add(bytes, entropy)
Mix the given bytes into the SSL pseudo-random number generator. The parameter entropy (a float) is a lower bound on the entropy contained in string (so you can always use 0.0). See RFC 1750 for more information on sources of entropy.

18.2.1.4. Certificate handling

ssl.match_hostname(cert, hostname)
Verify that cert (in decoded format as returned by SSLSocket.getpeercert()) matches the given hostname. The rules applied are those for checking the identity of HTTPS servers as outlined in RFC 2818 and RFC 6125. In addition to HTTPS, this function should be suitable for checking the identity of servers in various SSL-based protocols such as FTPS, IMAPS, POPS and others.

CertificateError is raised on failure. On success, the function returns nothing:

```python
>>> cert = {'subject': (((('commonName', 'example.com'),)
>>> ssl.match_hostname(cert, 'example.com')
>>> ssl.match_hostname(cert, 'example.org')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "/home/py3k/Lib/ssl.py", line 130, in match_hostname
ssl.CertificateError: hostname 'example.org' does not match 'example.com'
```
New in version 3.2.

Changed in version 3.3.3: The function now follows RFC 6125, section 6.4.3 and does neither match multiple wildcards (e.g. *.*.com or *a*.example.org) nor a wildcard inside an internationalized domain names (IDN) fragment. IDN A-labels such as www*.xn--pthon-kva.org are still supported, but x*.python.org no longer matches xn--tda.python.org.

Changed in version 3.5: Matching of IP addresses, when present in the subjectAltName field of the certificate, is now supported.

**ssl.cert_time_to_seconds(cert_time)**

Return the time in seconds since the Epoch, given the cert_time string representing the “notBefore” or “notAfter” date from a certificate in "%b %d %H:%M:%S %Y %Z" strptime format (C locale).

Here's an example:

```python
>>> import ssl
>>> timestamp = ssl.cert_time_to_seconds("Jan 5 09:34:43 2018 GMT")
>>> timestamp
1515144883
>>> from datetime import datetime
>>> print(datetime.utcfromtimestamp(timestamp))
2018-01-05 09:34:43
```

“notBefore” or “notAfter” dates must use GMT (RFC 5280).

Changed in version 3.5: Interpret the input time as a time in UTC as specified by ‘GMT’ timezone in the input string. Local timezone was used previously. Return an integer (no fractions of a second in
the input format)

ssl.get_server_certificate(addr,
ssl_version=PROTOCOL_SSLv23, ca_certs=None)

Given the address addr of an SSL-protected server, as a
(\textit{hostname}, \textit{port-number}) pair, fetches the server’s certificate, and
returns it as a PEM-encoded string. If \textit{ssl_version} is specified,
uses that version of the SSL protocol to attempt to connect to the
server. If \textit{ca_certs} is specified, it should be a file containing a list
of root certificates, the same format as used for the same
parameter in \texttt{wrap_socket()}. The call will attempt to validate the
server certificate against that set of root certificates, and will fail if
the validation attempt fails.

\textit{Changed in version 3.3}: This function is now IPv6-compatible.

\textit{Changed in version 3.5}: The default \textit{ssl_version} is changed from
\texttt{PROTOCOL_SSLv3} to \texttt{PROTOCOL_SSLv23} for maximum
compatibility with modern servers.

ssl.DER_cert_to_PEM_cert(DER_cert_bytes)

Given a certificate as a DER-encoded blob of bytes, returns a
PEM-encoded string version of the same certificate.

ssl.PEM_cert_to_DER_cert(PEM_cert_string)

Given a certificate as an ASCII PEM string, returns a DER-
encoded sequence of bytes for that same certificate.

ssl.get_default_verify_paths()

Returns a named tuple with paths to OpenSSL’s default cafile and
capath. The paths are the same as used by
\texttt{SSLContext.set_default_verify_paths()}. The return
value is a named tuple `DefaultVerifyPaths`:

- `cafile` - resolved path to cafile or None if the file doesn't exist,
- `capath` - resolved path to capath or None if the directory doesn't exist,
- `openssl_cafile_env` - OpenSSL's environment key that points to a cafile,
- `openssl_capath_env` - OpenSSL's environment key that points to a capath,
- `openssl_capath` - hard coded path to a capath directory

*New in version 3.4.*

```python
ssl.enum_certificates(store_name)
```

Retrieve certificates from Windows' system cert store. `store_name` may be one of CA, ROOT or MY. Windows may provide additional cert stores, too.

The function returns a list of (cert_bytes, encoding_type, trust) tuples. The encoding_type specifies the encoding of cert_bytes. It is either `x509_asn` for X.509 ASN.1 data or `pkcs_7_asn` for PKCS#7 ASN.1 data. Trust specifies the purpose of the certificate as a set of OIDS or exactly True if the certificate is trustworthy for all purposes.

Example:

```python
>>> ssl.enum_certificates("CA")
[(b'data...', 'x509_asn', {'1.3.6.1.5.5.7.3.1', '1.3.6.1.5.5.7.3.2'}),
 (b'data...', 'x509_asn', True)]
```
Availability: Windows.

New in version 3.4.

**ssl.enum_crls(store_name)**

Retrieve CRLs from Windows' system cert store. *store_name* may be one of CA, ROOT or MY. Windows may provide additional cert stores, too.

The function returns a list of (cert_bytes, encoding_type, trust) tuples. The encoding_type specifies the encoding of cert_bytes. It is either x509_asn for X.509 ASN.1 data or pkcs_7_asn for PKCS#7 ASN.1 data.

Availability: Windows.

New in version 3.4.

### 18.2.1.5. Constants

**ssl.CERT_NONE**

Possible value for `SSLContext.verify_mode`, or the `cert_reqs` parameter to `wrap_socket()`. In this mode (the default), no certificates will be required from the other side of the socket connection. If a certificate is received from the other end, no attempt to validate it is made.

See the discussion of Security considerations below.

**ssl.CERT_OPTIONAL**

Possible value for `SSLContext.verify_mode`, or the `cert_reqs` parameter to `wrap_socket()`. In this mode no certificates will be required from the other side of the socket connection.
connection; but if they are provided, validation will be attempted and an `SSLError` will be raised on failure.

Use of this setting requires a valid set of CA certificates to be passed, either to `SSLContext.load_verify_locations()` or as a value of the `ca_certs` parameter to `wrap_socket()`.

**ssl.CERT_REQUIRED**
Possible value for `SSLContext.verify_mode`, or the `cert_reqs` parameter to `wrap_socket()`. In this mode, certificates are required from the other side of the socket connection; an `SSLError` will be raised if no certificate is provided, or if its validation fails.

Use of this setting requires a valid set of CA certificates to be passed, either to `SSLContext.load_verify_locations()` or as a value of the `ca_certs` parameter to `wrap_socket()`.

**ssl VERIFY_DEFAULT**
Possible value for `SSLContext.verify_flags`. In this mode, certificate revocation lists (CRLs) are not checked. By default OpenSSL does neither require nor verify CRLs.

*New in version 3.4.*

**ssl VERIFY_CRL_CHECK_LEAF**
Possible value for `SSLContext.verify_flags`. In this mode, only the peer cert is check but non of the intermediate CA certificates. The mode requires a valid CRL that is signed by the peer cert’s issuer (its direct ancestor CA). If no proper has been loaded `SSLContext.load_verify_locations`, validation will fail.
New in version 3.4.

ssl. **VERIFY_CRL_CHECK_CHAIN**
Possible value for `SSLContext.verify_flags`. In this mode, CRLs of all certificates in the peer cert chain are checked.

New in version 3.4.

ssl. **VERIFY_X509 STRICT**
Possible value for `SSLContext.verify_flags` to disable workarounds for broken X.509 certificates.

New in version 3.4.

ssl. **VERIFY_X509_TRUSTED_FIRST**
Possible value for `SSLContext.verify_flags`. It instructs OpenSSL to prefer trusted certificates when building the trust chain to validate a certificate. This flag is enabled by default.

New in version 3.4.4.

ssl. **PROTOCOL_SSLv23**
Selects the highest protocol version that both the client and server support. Despite the name, this option can select “TLS” protocols as well as “SSL”.

ssl. **PROTOCOL_SSLv2**
Selects SSL version 2 as the channel encryption protocol.

This protocol is not available if OpenSSL is compiled with the OPENSSL_NO_SSL2 flag.

**Warning:** SSL version 2 is insecure. Its use is highly discouraged.
ssl. **PROTOCOL_SSLv3**
Selects SSL version 3 as the channel encryption protocol.

This protocol is not be available if OpenSSL is compiled with the OPENSSL_NO_SSLv3 flag.

**Warning:** SSL version 3 is insecure. Its use is highly discouraged.

ssl. **PROTOCOL_TLSv1**
Selects TLS version 1.0 as the channel encryption protocol.

ssl. **PROTOCOL_TLSv1_1**
Selects TLS version 1.1 as the channel encryption protocol. Available only with openssl version 1.0.1+.

*New in version 3.4.*

ssl. **PROTOCOL_TLSv1_2**
Selects TLS version 1.2 as the channel encryption protocol. This is the most modern version, and probably the best choice for maximum protection, if both sides can speak it. Available only with openssl version 1.0.1+.

*New in version 3.4.*

ssl. **OP_ALL**
Enables workarounds for various bugs present in other SSL implementations. This option is set by default. It does not necessarily set the same flags as OpenSSL’s SSL_OP_ALL constant.
New in version 3.2.

**ssl.OP_NO_SSLv2**
Prevents an SSLv2 connection. This option is only applicable in conjunction with `PROTOCOL_SSLv23`. It prevents the peers from choosing SSLv2 as the protocol version.

New in version 3.2.

**ssl.OP_NO_SSLv3**
Prevents an SSLv3 connection. This option is only applicable in conjunction with `PROTOCOL_SSLv23`. It prevents the peers from choosing SSLv3 as the protocol version.

New in version 3.2.

**ssl.OP_NO_TLSv1**
Prevents a TLSv1 connection. This option is only applicable in conjunction with `PROTOCOL_SSLv23`. It prevents the peers from choosing TLSv1 as the protocol version.

New in version 3.2.

**ssl.OP_NO_TLSv1_1**
Prevents a TLSv1.1 connection. This option is only applicable in conjunction with `PROTOCOL_SSLv23`. It prevents the peers from choosing TLSv1.1 as the protocol version. Available only with openssl version 1.0.1+.

New in version 3.4.

**ssl.OP_NO_TLSv1_2**
Prevents a TLSv1.2 connection. This option is only applicable in conjunction with `PROTOCOL_SSLv23`. It prevents the peers from
choosing TLSv1.2 as the protocol version. Available only with openssl version 1.0.1+.

*New in version 3.4.*

**ssl.** **OP_CIPHER_SERVER_PREFERENCE**

Use the server’s cipher ordering preference, rather than the client’s. This option has no effect on client sockets and SSLv2 server sockets.

*New in version 3.3.*

**ssl.** **OP_SINGLE_DH_USE**

Prevents re-use of the same DH key for distinct SSL sessions. This improves forward secrecy but requires more computational resources. This option only applies to server sockets.

*New in version 3.3.*

**ssl.** **OP_SINGLE_ECDH_USE**

Prevents re-use of the same ECDH key for distinct SSL sessions. This improves forward secrecy but requires more computational resources. This option only applies to server sockets.

*New in version 3.3.*

**ssl.** **OP_NO_COMPRESSION**

Disable compression on the SSL channel. This is useful if the application protocol supports its own compression scheme.

This option is only available with OpenSSL 1.0.0 and later.

*New in version 3.3.*

**ssl.** **HAS_ALPN**
Whether the OpenSSL library has built-in support for the Application-Layer Protocol Negotiation TLS extension as described in RFC 7301.

New in version 3.5.

ssl.HAS_ECDH

Whether the OpenSSL library has built-in support for Elliptic Curve-based Diffie-Hellman key exchange. This should be true unless the feature was explicitly disabled by the distributor.

New in version 3.3.

ssl.HAS_SNI

Whether the OpenSSL library has built-in support for the Server Name Indication extension (as defined in RFC 4366).

New in version 3.2.

ssl.HAS_NPN

Whether the OpenSSL library has built-in support for Next Protocol Negotiation as described in the NPN draft specification. When true, you can use the SSLContext.set_npn_protocols() method to advertise which protocols you want to support.

New in version 3.3.

ssl.CHANNEL_BINDING_TYPES

List of supported TLS channel binding types. Strings in this list can be used as arguments to SSLSocket.get_channel_binding().

New in version 3.3.
ssl.**OPENSSL_VERSION**
The version string of the OpenSSL library loaded by the interpreter:

```python
>>> ssl.OPENSSL_VERSION
'OpenSSL 0.9.8k 25 Mar 2009'
```

*New in version 3.2.*

ssl.**OPENSSL_VERSION_INFO**
A tuple of five integers representing version information about the OpenSSL library:

```python
>>> ssl.OPENSSL_VERSION_INFO
(0, 9, 8, 11, 15)
```

*New in version 3.2.*

ssl.**OPENSSL_VERSION_NUMBER**
The raw version number of the OpenSSL library, as a single integer:

```python
>>> ssl.OPENSSL_VERSION_NUMBER
9470143
>>> hex(ssl.OPENSSL_VERSION_NUMBER)
'0x9080bf'
```

*New in version 3.2.*

ssl.**ALERT_DESCRiPTION_HANDSHAKE_FAILURE**
ssl.**ALERT.DESCRIPTION_INTERNAL_ERROR**
ssl.**ALERT_DESCRIPTION_***

Alert Descriptions from RFC 5246 and others. The IANA TLS Alert Registry contains this list and references to the RFCs where their meaning is defined.
Used as the return value of the callback function in `SSLContext.set_servername_callback()`.

*New in version 3.4.*

**Purpose.** **SERVER_AUTH**

Option for `create_default_context()` and `SSLContext.load_default_certs()`. This value indicates that the context may be used to authenticate Web servers (therefore, it will be used to create client-side sockets).

*New in version 3.4.*

**Purpose.** **CLIENT_AUTH**

Option for `create_default_context()` and `SSLContext.load_default_certs()`. This value indicates that the context may be used to authenticate Web clients (therefore, it will be used to create server-side sockets).

*New in version 3.4.*
18.2.2. SSL Sockets

class ssl.SSLSocket(socket.socket)

SSL sockets provide the following methods of Socket Objects:

- accept()
- bind()
- close()
- connect()
- detach()
- fileno()
- getpeername(), getsockname()
- getsockopt(), setsockopt()
- gettimeout(), settimeout(), setblocking()
- listen()
- makefile()
- recv(), recv_into() (but passing a non-zero flags argument is not allowed)
- send(), sendall() (with the same limitation)
- sendfile() (but os.sendfile will be used for plain-text sockets only, else send() will be used)
- shutdown()

However, since the SSL (and TLS) protocol has its own framing atop of TCP, the SSL sockets abstraction can, in certain respects, diverge from the specification of normal, OS-level sockets. See especially the notes on non-blocking sockets.

Usually, SSLSocket are not created directly, but using the wrap_socket() function or the SSLContext.wrap_socket() method.
Changed in version 3.5: The sendfile() method was added.

Changed in version 3.5: The shutdown() does not reset the socket timeout each time bytes are received or sent. The socket timeout is now to maximum total duration of the shutdown.

SSL sockets also have the following additional methods and attributes:

SSLSocket.\texttt{read}(len=0, buffer=None)

Read up to \texttt{len} bytes of data from the SSL socket and return the result as a bytes instance. If \texttt{buffer} is specified, then read into the buffer instead, and return the number of bytes read.

Raise \texttt{SSLWantReadError} or \texttt{SSLWantWriteError} if the socket is non-blocking and the read would block.

As at any time a re-negotiation is possible, a call to \texttt{read()} can also cause write operations.

\textit{Changed in version 3.5:} The socket timeout is no more reset each time bytes are received or sent. The socket timeout is now to maximum total duration to read up to \texttt{len} bytes.

SSLSocket.\texttt{write}(buf)

Write \texttt{buf} to the SSL socket and return the number of bytes written. The \texttt{buf} argument must be an object supporting the buffer interface.

Raise \texttt{SSLWantReadError} or \texttt{SSLWantWriteError} if the socket is non-blocking and the write would block.

As at any time a re-negotiation is possible, a call to \texttt{write()} can also cause read operations.
Changed in version 3.5: The socket timeout is no more reset each time bytes are received or sent. The socket timeout is now to maximum total duration to write `buf`.

**Note:** The `read()` and `write()` methods are the low-level methods that read and write unencrypted, application-level data and decrypt/encrypt it to encrypted, wire-level data. These methods require an active SSL connection, i.e. the handshake was completed and `SSLSocket.unwrap()` was not called.

Normally you should use the socket API methods like `recv()` and `send()` instead of these methods.

`SSLSocket.do_handshake()`  
Perform the SSL setup handshake.

*Changed in version 3.4:* The handshake method also performs `match_hostname()` when the `check_hostname` attribute of the socket's `context` is true.

*Changed in version 3.5:* The socket timeout is no more reset each time bytes are received or sent. The socket timeout is now to maximum total duration of the handshake.

`SSLSocket.getpeercert(binary_form=False)`  
If there is no certificate for the peer on the other end of the connection, return None. If the SSL handshake hasn’t been done yet, raise `ValueError`.

If the `binary_form` parameter is `False`, and a certificate was received from the peer, this method returns a `dict` instance. If the certificate was not validated, the dict is empty. If the certificate was
validated, it returns a dict with several keys, amongst them subject (the principal for which the certificate was issued) and issuer (the principal issuing the certificate). If a certificate contains an instance of the Subject Alternative Name extension (see RFC 3280), there will also be a subjectAltName key in the dictionary.

The subject and issuer fields are tuples containing the sequence of relative distinguished names (RDNs) given in the certificate's data structure for the respective fields, and each RDN is a sequence of name-value pairs. Here is a real-world example:

```python
{'issuer': ((('countryName', 'IL'),),
            (('organizationName', 'StartCom Ltd.'),
             ('organizationalUnitName',
              'Secure Digital Certificate Signing
              'StartCom Class 2 Primary Intermediate'),
            ('notAfter': 'Nov 22 08:15:19 2013 GMT',
            'notBefore': 'Nov 21 03:09:52 2011 GMT',
            'serialNumber': '95F0',
            'subject': ((('description', '571208-SLe257oHY9f
            ('countryName', 'US'),),
             ('stateOrProvinceName', 'California
            ('localityName', 'San Francisco'),
             ('organizationName', 'Electronic Fr
             'commonName', '*.eff.org'),),
             ('emailAddress', 'hostmaster@eff.org'),
             'subjectAltName': ((('DNS', '*.eff.org'),
            ('DNS', 'version': 3})
```

**Note:** To validate a certificate for a particular service, you can use the `match_hostname()` function.
If the `binary_form` parameter is `True`, and a certificate was provided, this method returns the DER-encoded form of the entire certificate as a sequence of bytes, or `None` if the peer did not provide a certificate. Whether the peer provides a certificate depends on the SSL socket’s role:

- for a client SSL socket, the server will always provide a certificate, regardless of whether validation was required;
- for a server SSL socket, the client will only provide a certificate when requested by the server; therefore `getpeercert()` will return `None` if you used `CERT_NONE` (rather than `CERT_OPTIONAL` or `CERT_REQUIRED`).

*Changed in version 3.2:* The returned dictionary includes additional items such as `issuer` and `notBefore`.

*Changed in version 3.4:* `ValueError` is raised when the handshake isn’t done. The returned dictionary includes additional X509v3 extension items such as `crlDistributionPoints`, `caIssuers` and `OCSP URIs`.

**SSLSocket.cipher()**

Returns a three-value tuple containing the name of the cipher being used, the version of the SSL protocol that defines its use, and the number of secret bits being used. If no connection has been established, returns `None`.

**SSLSocket.shared_ciphers()**

Return the list of ciphers shared by the client during the handshake. Each entry of the returned list is a three-value tuple containing the name of the cipher, the version of the SSL protocol that defines its use, and the number of secret bits the cipher uses. `shared_ciphers()` returns `None` if no connection has been
established or the socket is a client socket.

*New in version 3.5.*

**SSLSocket**. *compression()*

Return the compression algorithm being used as a string, or None if the connection isn’t compressed.

If the higher-level protocol supports its own compression mechanism, you can use **OP_NO_COMPRESSION** to disable SSL-level compression.

*New in version 3.3.*

**SSLSocket**. *get_channel_binding(cb_type="tls-unique")*

Get channel binding data for current connection, as a bytes object. Returns None if not connected or the handshake has not been completed.

The *cb_type* parameter allow selection of the desired channel binding type. Valid channel binding types are listed in the CHANNEL_BINDING_TYPES list. Currently only the ‘tls-unique’ channel binding, defined by **RFC 5929**, is supported. **ValueError** will be raised if an unsupported channel binding type is requested.

*New in version 3.3.*

**SSLSocket**. *selected_alpn_protocol()*

Return the protocol that was selected during the TLS handshake. If **SSLContext.set_alpn_protocols()** was not called, if the other party does not support ALPN, if this socket does not support any of the client’s proposed protocols, or if the handshake has not happened yet, None is returned.
New in version 3.5.

**SSLSocket**. **selected_npn_protocol()**

Return the higher-level protocol that was selected during the TLS/SSL handshake. If **SSLContext.set_npn_protocols()** was not called, or if the other party does not support NPN, or if the handshake has not yet happened, this will return None.

New in version 3.3.

**SSLSocket**. **unwrap()**

Performs the SSL shutdown handshake, which removes the TLS layer from the underlying socket, and returns the underlying socket object. This can be used to go from encrypted operation over a connection to unencrypted. The returned socket should always be used for further communication with the other side of the connection, rather than the original socket.

**SSLSocket**. **version()**

Return the actual SSL protocol version negotiated by the connection as a string, or None is no secure connection is established. As of this writing, possible return values include "SSLv2", "SSLv3", "TLSv1", "TLSv1.1" and "TLSv1.2". Recent OpenSSL versions may define more return values.

New in version 3.5.

**SSLSocket**. **pending()**

Returns the number of already decrypted bytes available for read, pending on the connection.

**SSLSocket**. **context**

The **SSLContext** object this SSL socket is tied to. If the SSL
socket was created using the top-level \texttt{wrap\_socket()} function (rather than \texttt{SSLContext\_wrap\_socket()}), this is a custom context object created for this SSL socket.

\textit{New in version 3.2.}

\texttt{SSLSocket.server\_side}

A boolean which is \texttt{True} for server-side sockets and \texttt{False} for client-side sockets.

\textit{New in version 3.2.}

\texttt{SSLSocket.server\_hostname}

Hostname of the server: \texttt{str} type, or \texttt{None} for server-side socket or if the hostname was not specified in the constructor.

\textit{New in version 3.2.}
18.2.3. SSL Contexts

New in version 3.2.

An SSL context holds various data longer-lived than single SSL connections, such as SSL configuration options, certificate(s) and private key(s). It also manages a cache of SSL sessions for server-side sockets, in order to speed up repeated connections from the same clients.

```python
class ssl.SSLContext(protocol)
    Create a new SSL context. You must pass protocol which must be one of the PROTOCOL_* constants defined in this module. PROTOCOL_SSLv23 is currently recommended for maximum interoperability.

See also: create_default_context() lets the ssl module choose security settings for a given purpose.
```

SSLContext objects have the following methods and attributes:

SSLContext.cert_store_stats()
Get statistics about quantities of loaded X.509 certificates, count of X.509 certificates flagged as CA certificates and certificate revocation lists as dictionary.

Example for a context with one CA cert and one other cert:

```python
>>> context.cert_store_stats()
{'crl': 0, 'x509_ca': 1, 'x509': 2}
```

New in version 3.4.
SSLContext.load_cert_chain(certfile, keyfile=None, password=None)

Load a private key and the corresponding certificate. The certfile string must be the path to a single file in PEM format containing the certificate as well as any number of CA certificates needed to establish the certificate’s authenticity. The keyfile string, if present, must point to a file containing the private key. Otherwise the private key will be taken from certfile as well. See the discussion of Certificates for more information on how the certificate is stored in the certfile.

The password argument may be a function to call to get the password for decrypting the private key. It will only be called if the private key is encrypted and a password is necessary. It will be called with no arguments, and it should return a string, bytes, or bytearray. If the return value is a string it will be encoded as UTF-8 before using it to decrypt the key. Alternatively a string, bytes, or bytearray value may be supplied directly as the password argument. It will be ignored if the private key is not encrypted and no password is needed.

If the password argument is not specified and a password is required, OpenSSL’s built-in password prompting mechanism will be used to interactively prompt the user for a password.

An SSLError is raised if the private key doesn’t match with the certificate.

Changed in version 3.3: New optional argument password.

SSLContext.load_default_certs(purpose=Purpose.SERVEf

Load a set of default “certification authority” (CA) certificates from default locations. On Windows it loads CA certs from the CA and
ROOT system stores. On other systems it calls
SSLContext.set_default_verify_paths(). In the future the
method may load CA certificates from other locations, too.

The *purpose* flag specifies what kind of CA certificates are loaded.
The default settings `Purpose.SERVER_AUTH` loads certificates,
that are flagged and trusted for TLS web server authentication
(client side sockets). `Purpose.CLIENT_AUTH` loads CA
certificates for client certificate verification on the server side.

*New in version 3.4.*

SSLContext.load_verify_locations(*cafile=None, capath=None, cadata=None*)

Load a set of “certification authority” (CA) certificates used to
validate other peers’ certificates when `verify_mode` is other than
`CERT_NONE`. At least one of `cafile` or `capath` must be specified.

This method can also load certification revocation lists (CRLs) in
PEM or DER format. In order to make use of CRLs,
SSLContext.verify_flags must be configured properly.

The `cafile` string, if present, is the path to a file of concatenated CA
certificates in PEM format. See the discussion of Certificates for
more information about how to arrange the certificates in this file.

The `capath` string, if present, is the path to a directory containing
several CA certificates in PEM format, following an OpenSSL
specific layout.

The `cadata` object, if present, is either an ASCII string of one or
more PEM-encoded certificates or a bytes-like object of DER-
encoded certificates. Like with `capath` extra lines around PEM-
encoded certificates are ignored but at least one certificate must be present.

*Changed in version 3.4:* New optional argument *cadata*

**SSLContext**.get_ca_certs(binary_form=False)
Get a list of loaded “certification authority” (CA) certificates. If the binary_form parameter is *False* each list entry is a dict like the output of *SSLSocket.getpeercert()*. Otherwise the method returns a list of DER-encoded certificates. The returned list does not contain certificates from *capath* unless a certificate was requested and loaded by a SSL connection.

**Note:** Certificates in a capath directory aren’t loaded unless they have been used at least once.

*New in version 3.4.*

**SSLContext**.set_default_verify_paths()
Load a set of default “certification authority” (CA) certificates from a filesystem path defined when building the OpenSSL library. Unfortunately, there’s no easy way to know whether this method succeeds: no error is returned if no certificates are to be found. When the OpenSSL library is provided as part of the operating system, though, it is likely to be configured properly.

**SSLContext**.set_ciphers(ciphers)
Set the available ciphers for sockets created with this context. It should be a string in the *OpenSSL cipher list format*. If no cipher can be selected (because compile-time options or other configuration forbids use of all the specified ciphers), an *SSLError* will be raised.
SSLContext.set_alpn_protocols(protocols)

Specify which protocols the socket should advertise during the SSL/TLS handshake. It should be a list of ASCII strings, like ['http/1.1', 'spdy/2'], ordered by preference. The selection of a protocol will happen during the handshake, and will play out according to RFC 7301. After a successful handshake, the SSLSocket.selected_alpn_protocol() method will return the agreed-upon protocol.

This method will raise NotImplementedError if HAS_ALPN is False.

New in version 3.5.

SSLContext.set_npn_protocols(protocols)

Specify which protocols the socket should advertise during the SSL/TLS handshake. It should be a list of strings, like ['http/1.1', 'spdy/2'], ordered by preference. The selection of a protocol will happen during the handshake, and will play out according to the NPN draft specification. After a successful handshake, the SSLSocket.selected_npn_protocol() method will return the agreed-upon protocol.

This method will raise NotImplementedError if HAS_NPN is False.

New in version 3.3.

SSLContext.set_servername_callback(server_name_callback)
Register a callback function that will be called after the TLS Client Hello handshake message has been received by the SSL/TLS server when the TLS client specifies a server name indication. The server name indication mechanism is specified in RFC 6066 section 3 - Server Name Indication.

Only one callback can be set per SSLContext. If server_name_callback is None then the callback is disabled. Calling this function a subsequent time will disable the previously registered callback.

The callback function, server_name_callback, will be called with three arguments; the first being the ssl.SSLSocket, the second is a string that represents the server name that the client is intending to communicate (or None if the TLS Client Hello does not contain a server name) and the third argument is the original SSLContext. The server name argument is the IDNA decoded server name.

A typical use of this callback is to change the ssl.SSLSocket's SSLContext.context attribute to a new object of type SSLContext representing a certificate chain that matches the server name.

Due to the early negotiation phase of the TLS connection, only limited methods and attributes are usable like SSLSocket.selected_alpn_protocol() and SSLSocket.context. SSLSocket.getpeercert(), SSLSocket.getpeercert(), SSLSocket.cipher() and SSLSocket.compress() methods require that the TLS connection has progressed beyond the TLS Client Hello and therefore will not contain return meaningful values nor can they be
called safely.

The server_name_callback function must return None to allow the TLS negotiation to continue. If a TLS failure is required, a constant ALERT_DESCRIPTION_* can be returned. Other return values will result in a TLS fatal error with ALERT_DESCRIPTION_INTERNAL_ERROR.

If there is an IDNA decoding error on the server name, the TLS connection will terminate with an ALERT_DESCRIPTION_INTERNAL_ERROR fatal TLS alert message to the client.

If an exception is raised from the server_name_callback function the TLS connection will terminate with a fatal TLS alert message ALERT_DESCRIPTION_HANDSHAKE_FAILURE.

This method will raise NotImplementedError if the OpenSSL library had OPENSSL_NO_TLSEXT defined when it was built.

New in version 3.4.

SSLContext.load_dh_params(dhfile)

Load the key generation parameters for Diffie-Helman (DH) key exchange. Using DH key exchange improves forward secrecy at the expense of computational resources (both on the server and on the client). The dhfile parameter should be the path to a file containing DH parameters in PEM format.

This setting doesn’t apply to client sockets. You can also use the OP_SINGLE_DH_USE option to further improve security.

New in version 3.3.
SSLContext.set_ecdh_curve(curve_name)

Set the curve name for Elliptic Curve-based Diffie-Hellman (ECDH) key exchange. ECDH is significantly faster than regular DH while arguably as secure. The curve_name parameter should be a string describing a well-known elliptic curve, for example prime256v1 for a widely supported curve.

This setting doesn’t apply to client sockets. You can also use the OP_SINGLE_ECDH_USE option to further improve security.

This method is not available if HAS_ECDH is False.

New in version 3.3.

See also:
SSL/TLS & Perfect Forward Secrecy
Vincent Bernat.

SSLContext.wrap_socket(sock, server_side=False, do_handshake_on_connect=True, suppress_ragged_eofs=True, server_hostname=None)

Wrap an existing Python socket sock and return an SSLSocket object. sock must be a SOCK_STREAM socket; other socket types are unsupported.

The returned SSL socket is tied to the context, its settings and certificates. The parameters server_side, do_handshake_on_connect and suppress_ragged_eofs have the same meaning as in the top-level wrap_socket() function.

On client connections, the optional parameter server_hostname specifies the hostname of the service which we are connecting to.
This allows a single server to host multiple SSL-based services with distinct certificates, quite similarly to HTTP virtual hosts. Specifying server_hostname will raise a \texttt{ValueError} if \texttt{server_side} is true.

\textit{Changed in version 3.5:} Always allow a server_hostname to be passed, even if OpenSSL does not have SNI.

\texttt{SSLContext.wrap_bio}(incoming, outgoing, server_side=False, server_hostname=None)

Create a new \texttt{SSLObject} instance by wrapping the BIO objects \texttt{incoming} and \texttt{outgoing}. The SSL routines will read input data from the incoming BIO and write data to the outgoing BIO.

The \texttt{server_side} and \texttt{server_hostname} parameters have the same meaning as in \texttt{SSLContext.wrap_socket()}. 

\texttt{SSLContext.session_stats()}

Get statistics about the SSL sessions created or managed by this context. A dictionary is returned which maps the names of each piece of information to their numeric values. For example, here is the total number of hits and misses in the session cache since the context was created:

```
>>> stats = context.session_stats()
>>> stats['hits'], stats['misses']
(0, 0)
```

\texttt{SSLContext.check_hostname}

Whether to match the peer cert's hostname with \texttt{match_hostname()} in \texttt{SSLSocket.do_handshake()}. The context's \texttt{verify_mode} must be set to \texttt{CERT_OPTIONAL} or \texttt{CERT_REQUIRED}, and you must pass \texttt{server_hostname} to
wrap_socket() in order to match the hostname.

Example:

```python
import socket, ssl
context = ssl.SSLContext(ssl.PROTOCOL_TLSv1)
context.verify_mode = ssl.CERT_REQUIRED
context.check_hostname = True
context.load_default_certs()

s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
ssl_sock = context.wrap_socket(s, server_hostname='www.verisign.com', 443)
ssl_sock.connect(('www.verisign.com', 443))
```

*New in version 3.4.*

**Note:** This feature requires OpenSSL 0.9.8f or newer.

**SSLContext.options**

An integer representing the set of SSL options enabled on this context. The default value is `OP_ALL`, but you can specify other options such as `OP_NO_SSLv2` by ORing them together.

**Note:** With versions of OpenSSL older than 0.9.8m, it is only possible to set options, not to clear them. Attempting to clear an option (by resetting the corresponding bits) will raise a `ValueError`.

**SSLContext.protocol**

The protocol version chosen when constructing the context. This attribute is read-only.
SSLContext.**verify_flags**

The flags for certificate verification operations. You can set flags like `VERIFY_CRL_CHECK_LEAF` by ORing them together. By default OpenSSL does neither require nor verify certificate revocation lists (CRLs). Available only with openssl version 0.9.8+.

*New in version 3.4.*

SSLContext.**verify_mode**

Whether to try to verify other peers’ certificates and how to behave if verification fails. This attribute must be one of `CERT_NONE`, `CERT_OPTIONAL` or `CERT_REQUIRED`.

18.2.4. Certificates

Certificates in general are part of a public-key / private-key system. In this system, each *principal*, (which may be a machine, or a person, or an organization) is assigned a unique two-part encryption key. One part of the key is public, and is called the *public key*; the other part is kept secret, and is called the *private key*. The two parts are related, in that if you encrypt a message with one of the parts, you can decrypt it with the other part, and **only** with the other part.

A certificate contains information about two principals. It contains the name of a *subject*, and the subject’s public key. It also contains a statement by a second principal, the *issuer*, that the subject is who he claims to be, and that this is indeed the subject’s public key. The issuer’s statement is signed with the issuer’s private key, which only the issuer knows. However, anyone can verify the issuer’s statement by finding the issuer’s public key, decrypting the statement with it, and comparing it to the other information in the certificate. The certificate also contains information about the time period over which it is valid. This is expressed as two fields, called “notBefore” and “notAfter”.

In the Python use of certificates, a client or server can use a certificate to prove who they are. The other side of a network connection can also be required to produce a certificate, and that certificate can be validated to the satisfaction of the client or server that requires such validation. The connection attempt can be set to raise an exception if the validation fails. Validation is done automatically, by the underlying OpenSSL framework; the application need not concern itself with its mechanics. But the application does usually need to provide sets of certificates to allow this process to take place.

Python uses files to contain certificates. They should be formatted as
“PEM” (see RFC 1422), which is a base-64 encoded form wrapped with a header line and a footer line:

```plaintext
-----BEGIN CERTIFICATE-----
... (certificate in base64 PEM encoding) ...
-----END CERTIFICATE-----
```

18.2.4.1. Certificate chains

The Python files which contain certificates can contain a sequence of certificates, sometimes called a certificate chain. This chain should start with the specific certificate for the principal who “is” the client or server, and then the certificate for the issuer of that certificate, and then the certificate for the issuer of that certificate, and so on up the chain till you get to a certificate which is self-signed, that is, a certificate which has the same subject and issuer, sometimes called a root certificate. The certificates should just be concatenated together in the certificate file. For example, suppose we had a three certificate chain, from our server certificate to the certificate of the certification authority that signed our server certificate, to the root certificate of the agency which issued the certification authority’s certificate:

```plaintext
-----BEGIN CERTIFICATE-----
... (certificate for your server)...
-----END CERTIFICATE-----
-----BEGIN CERTIFICATE-----
... (the certificate for the CA)...
-----END CERTIFICATE-----
-----BEGIN CERTIFICATE-----
... (the root certificate for the CA's issuer)...
-----END CERTIFICATE-----
```

18.2.4.2. CA certificates
If you are going to require validation of the other side of the connection's certificate, you need to provide a “CA certs” file, filled with the certificate chains for each issuer you are willing to trust. Again, this file just contains these chains concatenated together. For validation, Python will use the first chain it finds in the file which matches. The platform’s certificates file can be used by calling `SSLContext.load_default_certs()`, this is done automatically with `create_default_context()`.

18.2.4.3. Combined key and certificate

Often the private key is stored in the same file as the certificate; in this case, only the `certfile` parameter to `SSLContext.load_cert_chain()` and `wrap_socket()` needs to be passed. If the private key is stored with the certificate, it should come before the first certificate in the certificate chain:

```
-----BEGIN RSA PRIVATE KEY-----
... (private key in base64 encoding) ...
-----END RSA PRIVATE KEY-----
-----BEGIN CERTIFICATE-----
... (certificate in base64 PEM encoding) ...
-----END CERTIFICATE-----
```

18.2.4.4. Self-signed certificates

If you are going to create a server that provides SSL-encrypted connection services, you will need to acquire a certificate for that service. There are many ways of acquiring appropriate certificates, such as buying one from a certification authority. Another common practice is to generate a self-signed certificate. The simplest way to do
this is with the OpenSSL package, using something like the following:

```bash
% openssl req -new -x509 -days 365 -nodes -out cert.pem
Generating a 1024 bit RSA private key
........+++++
.................................+++++
writing new private key to 'cert.pem'
-----
You are about to be asked to enter information that into your certificate request.
What you are about to enter is what is called a Distinguished Name. There are quite a few fields but you can leave some blank. For some fields there will be a default value, if you enter '.', the field will be left blank.
-----
Country Name (2 letter code) [AU]: US
State or Province Name (full name) [Some-State]: MyState
Locality Name (eg, city) []: Some City
Organization Name (eg, company) [Internet Widgits Pty Ltd]: My Organization
Organizational Unit Name (eg, section) []: My Group
Common Name (eg, YOUR name) []: myserver.mygroup.myorganization.com
Email Address []: ops@myserver.mygroup.myorganization.com
```

The disadvantage of a self-signed certificate is that it is its own root certificate, and no one else will have it in their cache of known (and trusted) root certificates.
18.2.5. Examples

18.2.5.1. Testing for SSL support

To test for the presence of SSL support in a Python installation, user code should use the following idiom:

```python
try:
    import ssl
except ImportError:
    pass
else:
    ... # do something that requires SSL support
```

18.2.5.2. Client-side operation

This example creates a SSL context with the recommended security settings for client sockets, including automatic certificate verification:

```python
>>> context = ssl.create_default_context()
```

If you prefer to tune security settings yourself, you might create a context from scratch (but beware that you might not get the settings right):

```python
>>> context = ssl.SSLContext(ssl.PROTOCOL_SSLv23)
>>> context.verify_mode = ssl.CERT_REQUIRED
>>> context.check_hostname = True
>>> context.load_verify_locations("/etc/ssl/certs/ca-bundle.crt")
```

(this snippet assumes your operating system places a bundle of all CA certificates in /etc/ssl/certs/ca-bundle.crt; if not, you'll get
an error and have to adjust the location)

When you use the context to connect to a server, `CERT_REQUIRED` validates the server certificate: it ensures that the server certificate was signed with one of the CA certificates, and checks the signature for correctness:

```python
>>> conn = context.wrap_socket(socket.socket(socket...
                  server_hostname="www.
>>> conn.connect(("www.python.org", 443))
```

You may then fetch the certificate:

```python
>>> cert = conn.getpeercert()
```

Visual inspection shows that the certificate does identify the desired service (that is, the HTTPS host `www.python.org`):

```python
>>> pprint.pprint(cert)
{'OCSP': ('http://ocsp.digicert.com',),
 'caIssuers': ('http://cacerts.digicert.com/DigiCert',
 'http://crl3.digicert.com/sha2-ev-server-g1.crl',
 'http://crl4.digicert.com/sha2-ev-server-g1.crl'),
 'crlDistributionPoints': ('http://crl3.digicert.com/sha2-ev-server-g1.crl',
 'http://crl4.digicert.com/sha2-ev-server-g1.crl'),
 'issuer': (((('countryName', 'US'),),
             ((organizationName', 'DigiCert Inc'),)),
             ((organizationalUnitName', 'www.digicert'),
                ('commonName', 'DigiCert SHA2 Extended Server CA'))),
 'notAfter': 'Sep 9 12:00:00 2016 GMT',
 'notBefore': 'Sep 5 00:00:00 2014 GMT',
 'serialNumber': '01BB6F00122B177F36CAB49CEA8B6B26',
 'subject': (((('businessCategory', 'Private Organization'),
              ('1.3.6.1.4.1.311.60.2.1.3', 'US'),),
              ('1.3.6.1.4.1.311.60.2.1.2', 'Delaware'),
              ('serialNumber', '3359300'),),
              ('streetAddress', '16 Allen Rd'),),
```
Now the SSL channel is established and the certificate verified, you can proceed to talk with the server:

```python
>>> conn.sendall(b"HEAD / HTTP/1.0\r\nHost: linuxfr.

>>> pprint.pprint(conn.recv(1024).split(b"\r\n"))
[b'HTTP/1.1 200 OK',
 b'Date: Sat, 18 Oct 2014 18:27:20 GMT',
 b'Server: nginx',
 b'Content-Type: text/html; charset=utf-8',
 b'X-Frame-Options: SAMEORIGIN',
 b'Content-Length: 45679',
 b'Accept-Ranges: bytes',
 b'Via: 1.1 varnish',
```
See the discussion of Security considerations below.

18.2.5.3. Server-side operation

For server operation, typically you'll need to have a server certificate, and private key, each in a file. You'll first create a context holding the key and the certificate, so that clients can check your authenticity. Then you'll open a socket, bind it to a port, call listen() on it, and start waiting for clients to connect:

```python
import socket, ssl

context = ssl.create_default_context(ssl.Purpose.CLIENT_AUTH)
context.load_cert_chain(certfile="mycertfile", keyfile="mykeyfile")

bindsocket = socket.socket()
bindsocket.bind(('myaddr.mydomain.com', 10023))
bindsocket.listen(5)
```

When a client connects, you'll call accept() on the socket to get the new socket from the other end, and use the context's SSLContext.wrap_socket() method to create a server-side SSL socket for the connection:
```
while True:
    newsocket, fromaddr = bindsocket.accept()
    connstream = context.wrap_socket(newsocket, server_side=True)
    try:
        deal_with_client(connstream)
    finally:
        connstream.shutdown(socket.SHUT_RDWR)
        connstream.close()
```

Then you'll read data from the connstream and do something with it till you are finished with the client (or the client is finished with you):

```
def deal_with_client(connstream):
    data = connstream.recv(1024)
    # empty data means the client is finished with us
    while data:
        if not do_something(connstream, data):
            # we'll assume do_something returns False
            # when we're finished with client
            break
        data = connstream.recv(1024)
        # finished with client
```

And go back to listening for new client connections (of course, a real server would probably handle each client connection in a separate thread, or put the sockets in non-blocking mode and use an event loop).
18.2.6. Notes on non-blocking sockets

SSL sockets behave slightly different than regular sockets in non-blocking mode. When working with non-blocking sockets, there are thus several things you need to be aware of:

- Most `SSLSocket` methods will raise either `SSLWantWriteError` or `SSLWantReadError` instead of `BlockingIOError` if an I/O operation would block. `SSLWantReadError` will be raised if a read operation on the underlying socket is necessary, and `SSLWantWriteError` for a write operation on the underlying socket. Note that attempts to `write` to an SSL socket may require `reading` from the underlying socket first, and attempts to `read` from the SSL socket may require a prior `write` to the underlying socket.

  *Changed in version 3.5:* In earlier Python versions, the `SSLSocket.send()` method returned zero instead of raising `SSLWantWriteError` or `SSLWantReadError`.

- Calling `select()` tells you that the OS-level socket can be read from (or written to), but it does not imply that there is sufficient data at the upper SSL layer. For example, only part of an SSL frame might have arrived. Therefore, you must be ready to handle `SSLSocket.recv()` and `SSLSocket.send()` failures, and retry after another call to `select()`.

- Conversely, since the SSL layer has its own framing, a SSL socket may still have data available for reading without `select()` being aware of it. Therefore, you should first call `SSLSocket.recv()` to drain any potentially available data, and
then only block on a `select()` call if still necessary.

(of course, similar provisions apply when using other primitives such as `poll()`, or those in the `selectors` module)

- The SSL handshake itself will be non-blocking: the `SSLSocket.do_handshake()` method has to be retried until it returns successfully. Here is a synopsis using `select()` to wait for the socket's readiness:

```python
while True:
    try:
        sock.do_handshake()
        break
    except ssl.SSLWantReadError:
        select.select([sock], [], [])
    except ssl.SSLWantWriteError:
        select.select([], [sock], [])
```

See also: The `asyncio` module supports non-blocking SSL sockets and provides a higher level API. It polls for events using the `selectors` module and handles `SSLWantWriteError`, `SSLWantReadError` and `BlockingIOError` exceptions. It runs the SSL handshake asynchronously as well.
18.2.7. Memory BIO Support

*New in version 3.5.*

Ever since the SSL module was introduced in Python 2.6, the `SSLSocket` class has provided two related but distinct areas of functionality:

- SSL protocol handling
- Network IO

The network IO API is identical to that provided by `socket.socket`, from which `SSLSocket` also inherits. This allows an SSL socket to be used as a drop-in replacement for a regular socket, making it very easy to add SSL support to an existing application.

Combining SSL protocol handling and network IO usually works well, but there are some cases where it doesn’t. An example is async IO frameworks that want to use a different IO multiplexing model than the “select/poll on a file descriptor” (readiness based) model that is assumed by `socket.socket` and by the internal OpenSSL socket IO routines. This is mostly relevant for platforms like Windows where this model is not efficient. For this purpose, a reduced scope variant of `SSLSocket` called `SSLObject` is provided.

```python
class ssl.SSLObject
    A reduced-scope variant of `SSLSocket` representing an SSL protocol instance that does not contain any network IO methods. This class is typically used by framework authors that want to implement asynchronous IO for SSL through memory buffers.
```

This class implements an interface on top of a low-level SSL object
as implemented by OpenSSL. This object captures the state of an SSL connection but does not provide any network IO itself. IO needs to be performed through separate “BIO” objects which are OpenSSL’s IO abstraction layer.

An `SSLObject` instance can be created using the `wrap_bio()` method. This method will create the `SSLObject` instance and bind it to a pair of BIOs. The `incoming` BIO is used to pass data from Python to the SSL protocol instance, while the `outgoing` BIO is used to pass data the other way around.

The following methods are available:

- `context`
- `server_side`
- `server_hostname`
- `read()`  
- `write()`  
- `getpeercert()`  
- `selected_npn_protocol()`  
- `cipher()`  
- `shared_ciphers()`  
- `compression()`  
- `pending()`  
- `do_handshake()`  
- `unwrap()`  
- `get_channel_binding()`

When compared to `SSLSocket`, this object lacks the following features:

- Any form of network IO including methods such as `recv()` and `send()`.
• There is no `do_handshake_on_connect` machinery. You must always manually call `do_handshake()` to start the handshake.

• There is no handling of `suppress_ragged_eofs`. All end-of-file conditions that are in violation of the protocol are reported via the `SSLEOFError` exception.

• The method `unwrap()` call does not return anything, unlike for an SSL socket where it returns the underlying socket.

• The `server_name_callback` callback passed to `SSLContext.set_servername_callback()` will get an `SSLObject` instance instead of a `SSLSocket` instance as its first parameter.

Some notes related to the use of `SSLObject`:

• All IO on an `SSLObject` is non-blocking. This means that for example `read()` will raise an `SSLWantReadError` if it needs more data than the incoming BIO has available.

• There is no module-level `wrap_bio()` call like there is for `wrap_socket()`. An `SSLObject` is always created via an `SSLContext`.

An `SSLObject` communicates with the outside world using memory buffers. The class `MemoryBIO` provides a memory buffer that can be used for this purpose. It wraps an OpenSSL memory BIO (Basic IO) object:

```python
class ssl.Mem
```roryBuffer

A memory buffer that can be used to pass data between Python and an SSL protocol instance.

**pending**

Return the number of bytes currently in the memory buffer.
**eof**
A boolean indicating whether the memory BIO is current at the end-of-file position.

**read**(\(n=-1\))
Read up to \(n\) bytes from the memory buffer. If \(n\) is not specified or negative, all bytes are returned.

**write**(\(buf\))
Write the bytes from \(buf\) to the memory BIO. The \(buf\) argument must be an object supporting the buffer protocol.

The return value is the number of bytes written, which is always equal to the length of \(buf\).

**write_eof()**
Write an EOF marker to the memory BIO. After this method has been called, it is illegal to call \texttt{write()}. The attribute \texttt{eof} will become true after all data currently in the buffer has been read.
18.2.8. Security considerations

18.2.8.1. Best defaults

For **client use**, if you don’t have any special requirements for your security policy, it is highly recommended that you use the `create_default_context()` function to create your SSL context. It will load the system’s trusted CA certificates, enable certificate validation and hostname checking, and try to choose reasonably secure protocol and cipher settings.

For example, here is how you would use the `smtplib.SMTP` class to create a trusted, secure connection to a SMTP server:

```python
>>> import ssl, smtplib
>>> smtp = smtplib.SMTP("mail.python.org", port=587)
>>> context = ssl.create_default_context()
>>> smtp.starttls(context=context)
(220, b'2.0.0 Ready to start TLS')
```

If a client certificate is needed for the connection, it can be added with `SSLContext.load_cert_chain()`.

By contrast, if you create the SSL context by calling the `SSLContext` constructor yourself, it will not have certificate validation nor hostname checking enabled by default. If you do so, please read the paragraphs below to achieve a good security level.

18.2.8.2. Manual settings

18.2.8.2.1. Verifying certificates
When calling the `SSLContext` constructor directly, `CERT_NONE` is the default. Since it does not authenticate the other peer, it can be insecure, especially in client mode where most of time you would like to ensure the authenticity of the server you're talking to. Therefore, when in client mode, it is highly recommended to use `CERT_REQUIRED`. However, it is in itself not sufficient; you also have to check that the server certificate, which can be obtained by calling `SSLSocket.getpeercert()`, matches the desired service. For many protocols and applications, the service can be identified by the hostname; in this case, the `match_hostname()` function can be used. This common check is automatically performed when `SSLContext.check_hostname` is enabled.

In server mode, if you want to authenticate your clients using the SSL layer (rather than using a higher-level authentication mechanism), you'll also have to specify `CERT_REQUIRED` and similarly check the client certificate.

**Note:** In client mode, `CERT_OPTIONAL` and `CERT_REQUIRED` are equivalent unless anonymous ciphers are enabled (they are disabled by default).

### 18.2.8.2.2. Protocol versions

SSL versions 2 and 3 are considered insecure and are therefore dangerous to use. If you want maximum compatibility between clients and servers, it is recommended to use `PROTOCOL_SSLv23` as the protocol version and then disable SSLv2 and SSLv3 explicitly using the `SSLContext.options` attribute:

```python
context = ssl.SSLContext(ssl.PROTOCOL_SSLv23)
```
context.options |= ssl.OP_NO_SSLv2
context.options |= ssl.OP_NO_SSLv3

The SSL context created above will only allow TLSv1 and later (if supported by your system) connections.

18.2.8.2.3. Cipher selection

If you have advanced security requirements, fine-tuning of the ciphers enabled when negotiating a SSL session is possible through the `SSLContext.set_ciphers()` method. Starting from Python 3.2.3, the ssl module disables certain weak ciphers by default, but you may want to further restrict the cipher choice. Be sure to read OpenSSL's documentation about the cipher list format. If you want to check which ciphers are enabled by a given cipher list, use the `openssl ciphers` command on your system.

18.2.8.3. Multi-processing

If using this module as part of a multi-processed application (using, for example the `multiprocessing` or `concurrent.futures` modules), be aware that OpenSSL's internal random number generator does not properly handle forked processes. Applications must change the PRNG state of the parent process if they use any SSL feature with `os.fork()`. Any successful call of `RAND_add()`, `RAND_bytes()` or `RAND_pseudo_bytes()` is sufficient.

See also:

Class `socket.socket`
   Documentation of underlying `socket` class

SSL/TLS Strong Encryption: An Introduction
Intro from the Apache webserver documentation

**RFC 1422: Privacy Enhancement for Internet Electronic Mail: Part II: Certificate-Based Key Management**
Steve Kent

**RFC 1750: Randomness Recommendations for Security**
D. Eastlake et. al.

**RFC 3280: Internet X.509 Public Key Infrastructure Certificate and CRL Profile**
Housley et. al.

**RFC 4366: Transport Layer Security (TLS) Extensions**
Blake-Wilson et. al.

T. Dierks et. al.

**RFC 6066: Transport Layer Security (TLS) Extensions**
D. Eastlake

**IANA TLS: Transport Layer Security (TLS) Parameters**
IANA
18.3. `select` — Waiting for I/O completion

This module provides access to the `select()` and `poll()` functions available in most operating systems, `devpoll()` available on Solaris and derivatives, `epoll()` available on Linux 2.5+ and `kqueue()` available on most BSD. Note that on Windows, it only works for sockets; on other operating systems, it also works for other file types (in particular, on Unix, it works on pipes). It cannot be used on regular files to determine whether a file has grown since it was last read.

**Note:** The `selectors` module allows high-level and efficient I/O multiplexing, built upon the `select` module primitives. Users are encouraged to use the `selectors` module instead, unless they want precise control over the OS-level primitives used.

The module defines the following:

*exception* `select.error`

A deprecated alias of `OSError`.

*Changed in version 3.3:* Following PEP 3151, this class was made an alias of `OSError`.

`select.devpoll()`

(Only supported on Solaris and derivatives.) Returns a `/dev/poll` polling object; see section `/dev/poll Polling Objects` below for the methods supported by devpoll objects.

`devpoll()` objects are linked to the number of file descriptors
allowed at the time of instantiation. If your program reduces this value, devpoll() will fail. If your program increases this value, devpoll() may return an incomplete list of active file descriptors.

The new file descriptor is non-inheritable.

New in version 3.3.

Changed in version 3.4: The new file descriptor is now non-inheritable.

```python
select.epoll(sizehint=-1, flags=0)
```

(Only supported on Linux 2.5.44 and newer.) Return an edge polling object, which can be used as Edge or Level Triggered interface for I/O events. `sizehint` is deprecated and completely ignored. `flags` can be set to EPOLL_CLOEXEC, which causes the epoll descriptor to be closed automatically when `os.execve()` is called.

See the Edge and Level Trigger Polling (epoll) Objects section below for the methods supported by epolling objects.

epoll objects support the context management protocol: when used in a `with` statement, the new file descriptor is automatically closed at the end of the block.

The new file descriptor is non-inheritable.

Changed in version 3.3: Added the `flags` parameter.

Changed in version 3.4: Support for the `with` statement was added. The new file descriptor is now non-inheritable.

```python
select.poll()
```
(Not supported by all operating systems.) Returns a polling object, which supports registering and unregistering file descriptors, and then polling them for I/O events; see section Polling Objects below for the methods supported by polling objects.

select.\texttt{kqueue()}

(Only supported on BSD.) Returns a kernel queue object; see section Kqueue Objects below for the methods supported by kqueue objects.

The new file descriptor is non-inheritable.

Changed in version 3.4: The new file descriptor is now non-inheritable.

select.\texttt{kevent}(ident, filter=KQ\_FILTER\_READ, flags=KQ\_EV\_ADD, fflags=0, data=0, udata=0)

(Only supported on BSD.) Returns a kernel event object; see section Kevent Objects below for the methods supported by kevent objects.

select.\texttt{select}(rlist, wlist, xlist[, timeout])

This is a straightforward interface to the Unix select() system call. The first three arguments are sequences of ‘waitable objects’: either integers representing file descriptors or objects with a parameterless method named \texttt{fileno()} returning such an integer:

- \texttt{rlist}: wait until ready for reading
- \texttt{wlist}: wait until ready for writing
- \texttt{xlist}: wait for an “exceptional condition” (see the manual page for what your system considers such a condition)

Empty sequences are allowed, but acceptance of three empty
sequences is platform-dependent. (It is known to work on Unix but not on Windows.) The optional *timeout* argument specifies a time-out as a floating point number in seconds. When the *timeout* argument is omitted the function blocks until at least one file descriptor is ready. A time-out value of zero specifies a poll and never blocks.

The return value is a triple of lists of objects that are ready: subsets of the first three arguments. When the time-out is reached without a file descriptor becoming ready, three empty lists are returned.

Among the acceptable object types in the sequences are Python *file objects* (e.g. `sys.stdin`, or objects returned by `open()` or `os.popen()`), socket objects returned by `socket.socket()`. You may also define a *wrapper* class yourself, as long as it has an appropriate `fileno()` method (that really returns a file descriptor, not just a random integer).

```
Note:  File objects on Windows are not acceptable, but sockets are. On Windows, the underlying select() function is provided by the WinSock library, and does not handle file descriptors that don't originate from WinSock.
```

*Changed in version 3.5:* The function is now retried with a recomputed time-out when interrupted by a signal, except if the signal handler raises an exception (see PEP 475 for the rationale), instead of raising `InterruptedError`.

**select.PIPE_BUF**

The minimum number of bytes which can be written without blocking to a pipe when the pipe has been reported as ready for writing by `select()`, `poll()` or another interface in this module.
This doesn't apply to other kind of file-like objects such as sockets.

This value is guaranteed by POSIX to be at least 512. Availability: Unix.

New in version 3.2.
18.3.1. /dev/poll Polling Objects

Solaris and derivatives have /dev/poll. While select() is O(highest file descriptor) and poll() is O(number of file descriptors), /dev/poll is O(active file descriptors).

/dev/poll behaviour is very close to the standard poll() object.

devpoll.close()
Close the file descriptor of the polling object.

*New in version 3.4.*

devpoll.closed
True if the polling object is closed.

*New in version 3.4.*

devpoll.fileno()
Return the file descriptor number of the polling object.

*New in version 3.4.*

devpoll.register(fd[, eventmask])
Register a file descriptor with the polling object. Future calls to the poll() method will then check whether the file descriptor has any pending I/O events. *fd* can be either an integer, or an object with a fileno() method that returns an integer. File objects implement fileno(), so they can also be used as the argument.

*eventmask* is an optional bitmask describing the type of events you want to check for. The constants are the same that with poll()
The default value is a combination of the constants \texttt{POLLIN}, \texttt{POLLPRI}, and \texttt{POLLOUT}.

**Warning:** Registering a file descriptor that’s already registered is not an error, but the result is undefined. The appropriate action is to unregister or modify it first. This is an important difference compared with \texttt{poll()}.  

\begin{verbatim}

devpoll.modify(fd[, eventmask])
\end{verbatim}

This method does an \texttt{unregister()} followed by a \texttt{register()}. It is (a bit) more efficient that doing the same explicitly.

\begin{verbatim}

devpoll.unregister(fd)
\end{verbatim}

Remove a file descriptor being tracked by a polling object. Just like the \texttt{register()} method, \texttt{fd} can be an integer or an object with a \texttt{fileno()} method that returns an integer.

Attempting to remove a file descriptor that was never registered is safely ignored.

\begin{verbatim}

devpoll.poll([timeout])
\end{verbatim}

Polls the set of registered file descriptors, and returns a possibly-empty list containing (\texttt{fd}, \texttt{event}) 2-tuples for the descriptors that have events or errors to report. \texttt{fd} is the file descriptor, and \texttt{event} is a bitmask with bits set for the reported events for that descriptor — \texttt{POLLIN} for waiting input, \texttt{POLLOUT} to indicate that the descriptor can be written to, and so forth. An empty list indicates that the call timed out and no file descriptors had any events to report. If \texttt{timeout} is given, it specifies the length of time in milliseconds which the system will wait for events before returning. If \texttt{timeout} is omitted, -1, or \texttt{None}, the call will block until there is an
event for this poll object.

*Changed in version 3.5:* The function is now retried with a recomputed timeout when interrupted by a signal, except if the signal handler raises an exception (see [PEP 475](https://www.python.org/dev/peps/pep-0475/) for the rationale), instead of raising `InterruptedError`.
18.3.2. Edge and Level Trigger Polling (epoll) Objects

http://linux.die.net/man/4/epoll

**eventmask**

<table>
<thead>
<tr>
<th>Constant</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPOLLIN</td>
<td>Available for read</td>
</tr>
<tr>
<td>EPOLLOUT</td>
<td>Available for write</td>
</tr>
<tr>
<td>EPOLLPRI</td>
<td>Urgent data for read</td>
</tr>
<tr>
<td>EPOLLERR</td>
<td>Error condition happened on the assoc. fd</td>
</tr>
<tr>
<td>EPOLLHUP</td>
<td>Hang up happened on the assoc. fd</td>
</tr>
<tr>
<td>EPOLLET</td>
<td>Set Edge Trigger behavior, the default is Level Trigger behavior</td>
</tr>
<tr>
<td>EPOLLONESHOT</td>
<td>Set one-shot behavior. After one event is pulled out, the fd is internally disabled</td>
</tr>
<tr>
<td>EPOLLRDINORM</td>
<td>Equivalent to EPOLLIN</td>
</tr>
<tr>
<td>EPPOLLRDBAND</td>
<td>Priority data band can be read.</td>
</tr>
<tr>
<td>EPOLLWRNORM</td>
<td>Equivalent to EPOLLOUT</td>
</tr>
<tr>
<td>EPPOLLWRBAND</td>
<td>Priority data may be written.</td>
</tr>
<tr>
<td>EPOLLMSG</td>
<td>Ignored.</td>
</tr>
</tbody>
</table>

**epoll.close()**

Close the control file descriptor of the epoll object.

**epoll.closed**
True if the epoll object is closed.

epoll.fileno()
    Return the file descriptor number of the control fd.

epoll.fromfd(fd)
    Create an epoll object from a given file descriptor.

epoll.register(fd[, eventmask])
    Register a fd descriptor with the epoll object.

epoll.modify(fd, eventmask)
    Modify a registered file descriptor.

epoll.unregister(fd)
    Remove a registered file descriptor from the epoll object.

epoll.poll(timeout=-1, maxevents=-1)
    Wait for events. timeout in seconds (float)

    Changed in version 3.5: The function is now retried with a recomputed timeout when interrupted by a signal, except if the signal handler raises an exception (see PEP 475 for the rationale), instead of raising InterruptedError.
18.3.3. Polling Objects

The **poll()** system call, supported on most Unix systems, provides better scalability for network servers that service many, many clients at the same time. **poll()** scales better because the system call only requires listing the file descriptors of interest, while **select()** builds a bitmap, turns on bits for the fds of interest, and then afterward the whole bitmap has to be linearly scanned again. **select()** is \(O(\text{highest file descriptor})\), while **poll()** is \(O(\text{number of file descriptors})\).

**poll.register\((fd[, \text{eventmask}])\)**

Register a file descriptor with the polling object. Future calls to the **poll()** method will then check whether the file descriptor has any pending I/O events. \(fd\) can be either an integer, or an object with a **fileno()** method that returns an integer. File objects implement **fileno()**, so they can also be used as the argument.

**eventmask** is an optional bitmask describing the type of events you want to check for, and can be a combination of the constants **POLLIN**, **POLLPRI**, and **POLLOUT**, described in the table below. If not specified, the default value used will check for all 3 types of events.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>POLLIN</td>
<td>There is data to read</td>
</tr>
<tr>
<td>POLLPRI</td>
<td>There is urgent data to read</td>
</tr>
<tr>
<td>POLLOUT</td>
<td>Ready for output: writing will not block</td>
</tr>
<tr>
<td>POLLERR</td>
<td>Error condition of some sort</td>
</tr>
<tr>
<td>POLLHUP</td>
<td>Hung up</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>POLLNVAL</td>
<td>Invalid request: descriptor not open</td>
</tr>
</tbody>
</table>

Registering a file descriptor that’s already registered is not an error, and has the same effect as registering the descriptor exactly once.

```python
poll.modify(fd, eventmask)
```

Modifies an already registered `fd`. This has the same effect as `register(fd, eventmask)`. Attempting to modify a file descriptor that was never registered causes an `OSError` exception with `errno` `ENOENT` to be raised.

```python
poll.unregister(fd)
```

Remove a file descriptor being tracked by a polling object. Just like the `register()` method, `fd` can be an integer or an object with a `fileno()` method that returns an integer.

Attempting to remove a file descriptor that was never registered causes a `KeyError` exception to be raised.

```python
poll.poll([timeout])
```

Polls the set of registered file descriptors, and returns a possibly-empty list containing `(fd, event)` 2-tuples for the descriptors that have events or errors to report. `fd` is the file descriptor, and `event` is a bitmask with bits set for the reported events for that descriptor — `POLLIN` for waiting input, `POLLOUT` to indicate that the descriptor can be written to, and so forth. An empty list indicates that the call timed out and no file descriptors had any events to report. If `timeout` is given, it specifies the length of time in milliseconds which the system will wait for events before returning. If `timeout` is omitted, negative, or `None`, the call will block until there is an event for this poll object.
*Changed in version 3.5:* The function is now retried with a recomputed timeout when interrupted by a signal, except if the signal handler raises an exception (see [PEP 475](https://www.python.org/dev/peps/pep-0475/) for the rationale), instead of raising `InterruptedError`.
18.3.4. Kqueue Objects

kqueue.close()

    Close the control file descriptor of the kqueue object.

kqueue.closed

    True if the kqueue object is closed.

kqueue.fileno()

    Return the file descriptor number of the control fd.

kqueue.fromfd(fd)

    Create a kqueue object from a given file descriptor.

kqueue.control(changelist, max_events[, timeout=None]) → eventlist

    Low level interface to kevent

    • changelist must be an iterable of kevent object or None
    • max_events must be 0 or a positive integer
    • timeout in seconds (floats possible)

Changed in version 3.5: The function is now retried with a recomputed timeout when interrupted by a signal, except if the signal handler raises an exception (see PEP 475 for the rationale), instead of raising InterruptedError.
18.3.5. Kevent Objects

http://www.freebsd.org/cgi/man.cgi?query=kqueue&sektion=2

kevent. **ident**

Value used to identify the event. The interpretation depends on the filter but it's usually the file descriptor. In the constructor ident can either be an int or an object with a `fileno()` method. kevent stores the integer internally.

kevent. **filter**

Name of the kernel filter.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>KQ_FILTER_READ</td>
<td>Takes a descriptor and returns whenever there is data available to read</td>
</tr>
<tr>
<td>KQ_FILTER_WRITE</td>
<td>Takes a descriptor and returns whenever there is data available to write</td>
</tr>
<tr>
<td>KQ_FILTER_AIO</td>
<td>AIO requests</td>
</tr>
<tr>
<td>KQ_FILTER_VNODE</td>
<td>Returns when one or more of the requested events watched in <code>flag</code> occurs</td>
</tr>
<tr>
<td>KQ_FILTER_PROC</td>
<td>Watch for events on a process id</td>
</tr>
<tr>
<td>KQ_FILTER_NETDEV</td>
<td>Watch for events on a network device [not available on Mac OS X]</td>
</tr>
<tr>
<td>KQ_FILTER_SIGNAL</td>
<td>Returns whenever the watched signal is delivered to the process</td>
</tr>
<tr>
<td>KQ_FILTER_TIMER</td>
<td>Establishes an arbitrary timer</td>
</tr>
</tbody>
</table>
**k事件** flags

Filter action.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>KQ_EV_ADD</td>
<td>Adds or modifies an event</td>
</tr>
<tr>
<td>KQ_EV_DELETE</td>
<td>Removes an event from the queue</td>
</tr>
<tr>
<td>KQ_EV_ENABLE</td>
<td>Permits control() to return the event</td>
</tr>
<tr>
<td>KQ_EV_DISABLE</td>
<td>Disable event</td>
</tr>
<tr>
<td>KQ_EV_ONESHOT</td>
<td>Removes event after first occurrence</td>
</tr>
<tr>
<td>KQ_EV_CLEAR</td>
<td>Reset the state after an event is retrieved</td>
</tr>
<tr>
<td>KQ_EV_SYSFLAGS</td>
<td>Internal event</td>
</tr>
<tr>
<td>KQ_EV_FLAG1</td>
<td>Internal event</td>
</tr>
<tr>
<td>KQ_EV_EOF</td>
<td>Filter specific EOF condition</td>
</tr>
<tr>
<td>KQ_EV_ERROR</td>
<td>See return values</td>
</tr>
</tbody>
</table>

**k事件** flags

Filter specific flags.

KQ_FILTER_READ and KQ_FILTER_WRITE filter flags:

<table>
<thead>
<tr>
<th>Constant</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>KQ_NOTE_LOWAT</td>
<td>Low water mark of a socket buffer</td>
</tr>
</tbody>
</table>

KQ_FILTER_VNODE filter flags:

<table>
<thead>
<tr>
<th>Constant</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>KQ_NOTE_DELETE</td>
<td><em>unlink()</em> was called</td>
</tr>
<tr>
<td>Constant</td>
<td>Meaning</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>KQ_NOTE_WRITE</td>
<td>a write occurred</td>
</tr>
<tr>
<td>KQ_NOTE_EXTEND</td>
<td>the file was extended</td>
</tr>
<tr>
<td>KQ_NOTE_ATTRIB</td>
<td>an attribute was changed</td>
</tr>
<tr>
<td>KQ_NOTE_LINK</td>
<td>the link count has changed</td>
</tr>
<tr>
<td>KQ_NOTE_RENAME</td>
<td>the file was renamed</td>
</tr>
<tr>
<td>KQ_NOTE_REVOKE</td>
<td>access to the file was revoked</td>
</tr>
</tbody>
</table>

**KQ_FILTER_PROC** filter flags:

<table>
<thead>
<tr>
<th>Constant</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>KQ_NOTE_EXIT</td>
<td>the process has exited</td>
</tr>
<tr>
<td>KQ_NOTE_FORK</td>
<td>the process has called <em>fork()</em></td>
</tr>
<tr>
<td>KQ_NOTE_EXEC</td>
<td>the process has executed a new process</td>
</tr>
<tr>
<td>KQ_NOTE_PCTRLMASK</td>
<td>internal filter flag</td>
</tr>
<tr>
<td>KQ_NOTE_PDATAMASK</td>
<td>internal filter flag</td>
</tr>
<tr>
<td>KQ_NOTE_TRACK</td>
<td>follow a process across <em>fork()</em></td>
</tr>
<tr>
<td>KQ_NOTE_CHILD</td>
<td>returned on the child process for <em>NOTE_TRACK</em></td>
</tr>
<tr>
<td>KQ_NOTE_TRACKERR</td>
<td>unable to attach to a child</td>
</tr>
</tbody>
</table>

**KQ_FILTER_NETDEV** filter flags (not available on Mac OS X):

<table>
<thead>
<tr>
<th>Constant</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>KQ_NOTE_LINKUP</td>
<td>link is up</td>
</tr>
<tr>
<td>KQ_NOTE_LINKDOWN</td>
<td>link is down</td>
</tr>
<tr>
<td>KQ_NOTE_LINKINV</td>
<td>link state is invalid</td>
</tr>
</tbody>
</table>
Filter specific data.

kevent.udata
User defined value.
18.4. **selectors** – High-level I/O multiplexing

*New in version 3.4.*
18.4.1. Introduction

This module allows high-level and efficient I/O multiplexing, built upon the `select` module primitives. Users are encouraged to use this module instead, unless they want precise control over the OS-level primitives used.

It defines a `BaseSelector` abstract base class, along with several concrete implementations (`KqueueSelector`, `EpollSelector`...), that can be used to wait for I/O readiness notification on multiple file objects. In the following, “file object” refers to any object with a `fileno()` method, or a raw file descriptor. See file object.

`DefaultSelector` is an alias to the most efficient implementation available on the current platform: this should be the default choice for most users.

**Note:** The type of file objects supported depends on the platform: on Windows, sockets are supported, but not pipes, whereas on Unix, both are supported (some other types may be supported as well, such as fifos or special file devices).

**See also:**

`select`

Low-level I/O multiplexing module.
18.4.2. Classes

Classes hierarchy:

```
BaseSelector
   +-- SelectSelector
   +-- PollSelector
   +-- EpollSelector
   +-- DevpollSelector
   +-- KqueueSelector
```

In the following, events is a bitwise mask indicating which I/O events should be waited for on a given file object. It can be a combination of the modules constants below:

<table>
<thead>
<tr>
<th>Constant</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVENT_READ</td>
<td>Available for read</td>
</tr>
<tr>
<td>EVENT_WRITE</td>
<td>Available for write</td>
</tr>
</tbody>
</table>

**class** selectors.SelectorKey

A SelectorKey is a namedtuple used to associate a file object to its underlying file descriptor, selected event mask and attached data. It is returned by several BaseSelector methods.

**fileobj**

File object registered.

**fd**

Underlying file descriptor.

**events**

Events that must be waited for on this file object.
**data**
Optional opaque data associated to this file object: for example, this could be used to store a per-client session ID.

**class selectors.BaseSelector**
A BaseSelector is used to wait for I/O event readiness on multiple file objects. It supports file stream registration, unregistration, and a method to wait for I/O events on those streams, with an optional timeout. It's an abstract base class, so cannot be instantiated. Use DefaultSelector instead, or one of SelectSelector, KqueueSelector etc. if you want to specifically use an implementation, and your platform supports it. BaseSelector and its concrete implementations support the context manager protocol.

**register(fileobj, events, data=None)**
Register a file object for selection, monitoring it for I/O events.

`fileobj` is the file object to monitor. It may either be an integer file descriptor or an object with a fileno() method. `events` is a bitwise mask of events to monitor. `data` is an opaque object.

This returns a new SelectorKey instance, or raises a ValueError in case of invalid event mask or file descriptor, or KeyError if the file object is already registered.

**unregister(fileobj)**
Unregister a file object from selection, removing it from monitoring. A file object shall be unregistered prior to being closed.

`fileobj` must be a file object previously registered.
This returns the associated `SelectorKey` instance, or raises a `KeyError` if `fileobj` is not registered. It will raise `ValueError` if `fileobj` is invalid (e.g. it has no `fileno()` method or its `fileno()` method has an invalid return value).

**modify**(`fileobj`, `events`, `data=None`)  
Change a registered file object's monitored events or attached data.

This is equivalent to `BaseSelector.unregister(fileobj)()` followed by `BaseSelector.register(fileobj, events, data)()`, except that it can be implemented more efficiently.

This returns a new `SelectorKey` instance, or raises a `ValueError` in case of invalid event mask or file descriptor, or `KeyError` if the file object is not registered.

**select**(`timeout=None`)  
Wait until some registered file objects become ready, or the timeout expires.

If `timeout > 0`, this specifies the maximum wait time, in seconds. If `timeout <= 0`, the call won’t block, and will report the currently ready file objects. If `timeout` is `None`, the call will block until a monitored file object becomes ready.

This returns a list of `(key, events)` tuples, one for each ready file object.

`key` is the `SelectorKey` instance corresponding to a ready file object. `events` is a bitmask of events ready on this file object.
Note: This method can return before any file object becomes ready or the timeout has elapsed if the current process receives a signal: in this case, an empty list will be returned.

Changed in version 3.5: The selector is now retried with a recomputed timeout when interrupted by a signal if the signal handler did not raise an exception (see PEP 475 for the rationale), instead of returning an empty list of events before the timeout.

close()
Close the selector.

This must be called to make sure that any underlying resource is freed. The selector shall not be used once it has been closed.

get_key(fileobj)
Return the key associated with a registered file object.

This returns the SelectorKey instance associated to this file object, or raises KeyError if the file object is not registered.

get_map()
Return a mapping of file objects to selector keys.

This returns a Mapping instance mapping registered file objects to their associated SelectorKey instance.

class selectors.DefaultSelector
The default selector class, using the most efficient implementation available on the current platform. This should be the default choice for most users.
class selectors.SelectSelector
    select.select()-based selector.

class selectors.PollSelector
    select.poll()-based selector.

class selectors.EpollSelector
    select.epoll()-based selector.

fileno()
This returns the file descriptor used by the underlying select.epoll() object.

class selectors.DevpollSelector
    select.devpoll()-based selector.

fileno()
This returns the file descriptor used by the underlying select.devpoll() object.

New in version 3.5.

class selectors.KqueueSelector
    select.kqueue()-based selector.

fileno()
This returns the file descriptor used by the underlying select.kqueue() object.
18.4.3. Examples

Here is a simple echo server implementation:

```python
import selectors
import socket

sel = selectors.DefaultSelector()

def accept(sock, mask):
    conn, addr = sock.accept()  # Should be ready
    print('accepted', conn, 'from', addr)
    conn.setblocking(False)
    sel.register(conn, selectors.EVENT_READ, read)

def read(conn, mask):
    data = conn.recv(1000)  # Should be ready
    if data:
        print('echoing', repr(data), 'to', conn)
        conn.send(data)  # Hope it won't block
    else:
        print('closing', conn)
        sel.unregister(conn)
        conn.close()

sock = socket.socket()
sock.bind(('localhost', 1234))
sock.listen(100)
sock.setblocking(False)
sel.register(sock, selectors.EVENT_READ, accept)

while True:
    events = sel.select()
    for key, mask in events:
        callback = key.data
```
callback(key.fileobj, mask)
18.5. asyncio – Asynchronous I/O, event loop, coroutines and tasks

**Note:** The asyncio package has been included in the standard library on a provisional basis. Backwards incompatible changes (up to and including removal of the module) may occur if deemed necessary by the core developers.

*New in version 3.4.*

**Source code:** Lib/asyncio/

This module provides infrastructure for writing single-threaded concurrent code using coroutines, multiplexing I/O access over sockets and other resources, running network clients and servers, and other related primitives. Here is a more detailed list of the package contents:

- a pluggable **event loop** with various system-specific implementations;
- **transport** and **protocol** abstractions (similar to those in **Twisted**);
- concrete support for TCP, UDP, SSL, subprocess pipes, delayed calls, and others (some may be system-dependent);
- a **Future** class that mimics the one in the **concurrent.futures** module, but adapted for use with the event loop;
- coroutines and tasks based on **yield from** ([PEP 380](https://www.python.org/dev/peps/pep-0380/)), to help write concurrent code in a sequential fashion;
- cancellation support for Futures and coroutines;
- synchronization primitives for use between coroutines in a single thread, mimicking those in the threading module;
- an interface for passing work off to a threadpool, for times when you absolutely, positively have to use a library that makes blocking I/O calls.

Asynchronous programming is more complex than classical “sequential” programming: see the Develop with asyncio page which lists common traps and explains how to avoid them. Enable the debug mode during development to detect common issues.

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See also: The asyncio module was designed in PEP 3156. For a motivational primer on transports and protocols, see PEP 3153.
18.5.1. Base Event Loop

The event loop is the central execution device provided by asyncio. It provides multiple facilities, including:

- Registering, executing and cancelling delayed calls (timeouts).
- Creating client and server transports for various kinds of communication.
- Launching subprocesses and the associated transports for communication with an external program.
- Delegating costly function calls to a pool of threads.

```
class asyncio.BaseEventLoop
Base class of event loops.
```

This class is not thread safe.
18.5.1.1. Run an event loop

BaseEventLoop.run_forever()
Run until stop() is called. If stop() is called before run_forever() is called, this polls the I/O selector once with a timeout of zero, runs all callbacks scheduled in response to I/O events (and those that were already scheduled), and then exits. If stop() is called while run_forever() is running, this will run the current batch of callbacks and then exit. Note that callbacks scheduled by callbacks will not run in that case; they will run the next time run_forever() is called.

Changed in version 3.5.1.

BaseEventLoop.run_until_complete(future)
Run until the Future is done.

If the argument is a coroutine object, it is wrapped by ensure_future().

Return the Future's result, or raise its exception.

BaseEventLoop.is_running()
Returns running status of event loop.

BaseEventLoop.stop()
Stop running the event loop.

This causes run_forever() to exit at the next suitable opportunity (see there for more details).

Changed in version 3.5.1.
BaseEventLoop.\texttt{is\_closed()}

Returns True if the event loop was closed.

\textit{New in version 3.4.2.}

BaseEventLoop.\texttt{close()}

Close the event loop. The loop must not be running. Pending callbacks will be lost.

This clears the queues and shuts down the executor, but does not wait for the executor to finish.

This is idempotent and irreversible. No other methods should be called after this one.
18.5.1.2. Calls

Most `asyncio` functions don’t accept keywords. If you want to pass keywords to your callback, use `functools.partial()`. For example, `loop.call_soon(functools.partial(print, "Hello", flush=True))` will call `print("Hello", flush=True)`.

**Note:** `functools.partial()` is better than lambda functions, because `asyncio` can inspect `functools.partial()` object to display parameters in debug mode, whereas lambda functions have a poor representation.

`BaseEventLoop.call_soon(callback, *args)`

Arrange for a callback to be called as soon as possible. The callback is called after `call_soon()` returns, when control returns to the event loop.

This operates as a FIFO queue, callbacks are called in the order in which they are registered. Each callback will be called exactly once.

Any positional arguments after the callback will be passed to the callback when it is called.

An instance of `asyncio.Handle` is returned, which can be used to cancel the callback.

Use `functools.partial` to pass keywords to the callback.

`BaseEventLoop.call_soon_threadsafe(callback, *args)`
Like `call_soon()`, but thread safe.

See the concurrency and multithreading section of the documentation.
18.5.1.3. Delayed calls

The event loop has its own internal clock for computing timeouts. Which clock is used depends on the (platform-specific) event loop implementation; ideally it is a monotonic clock. This will generally be a different clock than \texttt{time.time()}.

\begin{note}
Timeouts (relative \texttt{delay} or absolute \texttt{when}) should not exceed one day.
\end{note}

\texttt{BaseEventLoop.call\_later}(\texttt{delay}, \texttt{callback}, *\texttt{args})

Arrange for the \texttt{callback} to be called after the given \texttt{delay} seconds (either an int or float).

An instance of \texttt{asyncio.Handle} is returned, which can be used to cancel the callback.

\texttt{callback} will be called exactly once per call to \texttt{call\_later()}. If two callbacks are scheduled for exactly the same time, it is undefined which will be called first.

The optional positional \texttt{args} will be passed to the callback when it is called. If you want the callback to be called with some named arguments, use a closure or \texttt{functools.partial()}. Use \texttt{functools.partial} to pass keywords to the callback.

\texttt{BaseEventLoop.call\_at}(\texttt{when}, \texttt{callback}, *\texttt{args})

Arrange for the \texttt{callback} to be called at the given absolute timestamp \texttt{when} (an int or float), using the same time reference as \texttt{BaseEventLoop.time()}. 
This method’s behavior is the same as `call_later()`.

An instance of `asyncio.Handle` is returned, which can be used to cancel the callback.

Use `functools.partial` to pass keywords to the callback.

**BaseEventLoop.time()**

Return the current time, as a `float` value, according to the event loop’s internal clock.

**See also:** The `asyncio.sleep()` function.
18.5.1.4. Tasks

BaseEventLoop.create_task(coro)
Schedule the execution of a coroutine object: wrap it in a future. Return a Task object.

Third-party event loops can use their own subclass of Task for interoperability. In this case, the result type is a subclass of Task.

This method was added in Python 3.4.2. Use the async() function to support also older Python versions.

New in version 3.4.2.

BaseEventLoop.set_task_factory(factory)
Set a task factory that will be used by BaseEventLoop.create_task().

If factory is None the default task factory will be set.

If factory is a callable, it should have a signature matching (loop, coro), where loop will be a reference to the active event loop, coro will be a coroutine object. The callable must return an asyncio.Future compatible object.

New in version 3.4.4.

BaseEventLoop.get_task_factory()
Return a task factory, or None if the default one is in use.

New in version 3.4.4.
18.5.1.5. Creating connections

coroutine
BaseEventLoop.create_connection(protocol_factory,
host=None, port=None, *, ssl=None, family=0, proto=0, flags=0,
sock=None, local_addr=None, server_hostname=None)

Create a streaming transport connection to a given Internet host
and port: socket family AF_INET or AF_INET6 depending on host
(or family if specified), socket type SOCK_STREAM. protocol_factory
must be a callable returning a protocol instance.

This method is a coroutine which will try to establish the connection
in the background. When successful, the coroutine returns a
(transport, protocol) pair.

The chronological synopsis of the underlying operation is as
follows:

1. The connection is established, and a transport is created to
   represent it.
2. protocol_factory is called without arguments and must return a
   protocol instance.
3. The protocol instance is tied to the transport, and its
   connection_made() method is called.
4. The coroutine returns successfully with the (transport, protocol) pair.

The created transport is an implementation-dependent bidirectional
stream.

Note: protocol_factory can be any kind of callable, not
necessarily a class. For example, if you want to use a pre-
created protocol instance, you can pass lambda:
my_protocol.

Options allowing to change how the connection is created:

- **ssl**: if given and not false, a SSL/TLS transport is created (by default a plain TCP transport is created). If ssl is a `ssl.SSLContext` object, this context is used to create the transport; if ssl is `True`, a context with some unspecified default settings is used.
  
  **See also**: [SSL/TLS security considerations](#)

- **server_hostname**, is only for use together with ssl, and sets or overrides the hostname that the target server’s certificate will be matched against. By default the value of the `host` argument is used. If `host` is empty, there is no default and you must pass a value for `server_hostname`. If `server_hostname` is an empty string, hostname matching is disabled (which is a serious security risk, allowing for man-in-the-middle-attacks).

- **family, proto, flags** are the optional address family, protocol and flags to be passed through to `getaddrinfo()` for `host` resolution. If given, these should all be integers from the corresponding `socket` module constants.

- **sock**, if given, should be an existing, already connected `socket.socket` object to be used by the transport. If `sock` is given, none of `host`, `port`, `family`, `proto`, `flags` and `local_addr` should be specified.

- **local_addr**, if given, is a `(local_host, local_port)` tuple used to bind the socket to locally. The `local_host` and `local_port` are looked up using `getaddrinfo()`, similarly to `host`
and port.

Changed in version 3.5: On Windows with ProactorEventLoop, SSL/TLS is now supported.

See also: The open_connection() function can be used to get a pair of (StreamReader, StreamWriter) instead of a protocol.

coroutine
BaseEventLoop.create_datagram_endpoint(protocol_factory, local_addr=None, remote_addr=None, *, family=0, proto=0, flags=0, reuse_address=None, reuse_port=None, allow_broadcast=None, sock=None)

Create datagram connection: socket family AF_INET or AF_INET6 depending on host (or family if specified), socket type SOCK_DGRAM. protocol_factory must be a callable returning a protocol instance.

This method is a coroutine which will try to establish the connection in the background. When successful, the coroutine returns a (transport, protocol) pair.

Options changing how the connection is created:

- **local_addr**, if given, is a (local_host, local_port) tuple used to bind the socket to locally. The local_host and local_port are looked up using getaddrinfo().
- **remote_addr**, if given, is a (remote_host, remote_port) tuple used to connect the socket to a remote address. The remote_host and remote_port are looked up using getaddrinfo().
- **family**, **proto**, **flags** are the optional address family, protocol
and flags to be passed through to getaddrinfo() for host resolution. If given, these should all be integers from the corresponding socket module constants.

- **reuse_address** tells the kernel to reuse a local socket in TIME_WAIT state, without waiting for its natural timeout to expire. If not specified will automatically be set to True on UNIX.

- **reuse_port** tells the kernel to allow this endpoint to be bound to the same port as other existing endpoints are bound to, so long as they all set this flag when being created. This option is not supported on Windows and some UNIX's. If the SO_REUSEPORT constant is not defined then this capability is unsupported.

- **allow_broadcast** tells the kernel to allow this endpoint to send messages to the broadcast address.

- **sock** can optionally be specified in order to use a preexisting, already connected, socket.socket object to be used by the transport. If specified, local_addr and remote_addr should be omitted (must be None).

On Windows with ProactorEventLoop, this method is not supported.

See UDP echo client protocol and UDP echo server protocol examples.

```coroutine
BaseEventLoop.create_unix_connection(protocol_factory, path, *, ssl=None, sock=None, server_hostname=None)
```

Create UNIX connection: socket family AF_UNIX, socket type SOCK_STREAM. The AF_UNIX socket family is used to communicate between processes on the same machine efficiently.

This method is a coroutine which will try to establish the connection
in the background. When successful, the coroutine returns a (transport, protocol) pair.

See the `BaseEventLoop.create_connection()` method for parameters.

Availability: UNIX.
18.5.1.6. Creating listening connections

coroutine BaseEventLoop.\texttt{create_server}(\texttt{protocol\_factory},
host=None, port=None, *, family=socket.AF\_UNSPEC,
flags=socket.AI\_PASSIVE, sock=None, backlog=100, ssl=None,
reuse\_address=None, reuse\_port=None)

Create a TCP server (socket type S\texttt{OCK\_STREAM}) bound to host
and port.

Return a \texttt{Server} object, its \texttt{sockets} attribute contains created
sockets. Use the \texttt{Server.close()} method to stop the server:
close listening sockets.

Parameters:

- The \texttt{host} parameter can be a string, in that case the TCP
  server is bound to \texttt{host} and \texttt{port}. The \texttt{host} parameter can also
  be a sequence of strings and in that case the TCP server is
  bound to all hosts of the sequence. If \texttt{host} is an empty string or
  None, all interfaces are assumed and a list of multiple sockets
  will be returned (most likely one for IPv4 and another one for
  IPv6).
- \texttt{family} can be set to either \texttt{socket.AF\_INET} or \texttt{AF\_INET6} to
  force the socket to use IPv4 or IPv6. If not set it will be
determined from host (defaults to \texttt{socket.AF\_UNSPEC}).
- \texttt{flags} is a bitmask for \texttt{getaddrinfo()}.
- \texttt{sock} can optionally be specified in order to use a preexisting
  socket object. If specified, \texttt{host} and \texttt{port} should be omitted
  (must be \texttt{None}).
- \texttt{backlog} is the maximum number of queued connections
  passed to \texttt{listen()} (defaults to 100).
- \texttt{ssl} can be set to an \texttt{SSLContext} to enable SSL over the
  accepted connections.
- **reuse_address** tells the kernel to reuse a local socket in TIME_WAIT state, without waiting for its natural timeout to expire. If not specified will automatically be set to True on UNIX.

- **reuse_port** tells the kernel to allow this endpoint to be bound to the same port as other existing endpoints are bound to, so long as they all set this flag when being created. This option is not supported on Windows.

This method is a coroutine.

*Changed in version 3.5:* On Windows with **ProactorEventLoop**, SSL/TLS is now supported.

**See also:** The function **start_server()** creates a (**StreamReader**, **StreamWriter**) pair and calls back a function with this pair.

*Changed in version 3.5.1:* The **host** parameter can now be a sequence of strings.

**coroutine**

**BaseEventLoop**. **create_unix_server**(**protocol_factory**, **path=None**, *, **sock=None**, **backlog=100**, **ssl=None**)  

Similar to **BaseEventLoop.create_server()**, but specific to the socket family **AF_UNIX**.

This method is a coroutine.

**Availability:** UNIX.
18.5.1.7. Watch file descriptors

On Windows with SelectorEventLoop, only socket handles are supported (ex: pipe file descriptors are not supported).

On Windows with ProactorEventLoop, these methods are not supported.

BaseEventLoop.add_reader(fd, callback, *args)

Start watching the file descriptor for read availability and then call the callback with specified arguments.

Use functools.partial to pass keywords to the callback.

BaseEventLoop.remove_reader(fd)

Stop watching the file descriptor for read availability.

BaseEventLoop.add_writer(fd, callback, *args)

Start watching the file descriptor for write availability and then call the callback with specified arguments.

Use functools.partial to pass keywords to the callback.

BaseEventLoop.remove_writer(fd)

Stop watching the file descriptor for write availability.

The watch a file descriptor for read events example uses the low-level BaseEventLoop.add_reader() method to register the file descriptor of a socket.
18.5.1.8. Low-level socket operations

```python
coroutine BaseEventLoop.sock_recv(sock, nbytes)
```
Receive data from the socket. The return value is a bytes object representing the data received. The maximum amount of data to be received at once is specified by `nbytes`.

With `SelectorEventLoop` event loop, the socket `sock` must be non-blocking.

This method is a coroutine.

**See also:** The `socket.socket.recv()` method.

```python
coroutine BaseEventLoop.sock_sendall(sock, data)
```
Send data to the socket. The socket must be connected to a remote socket. This method continues to send data from `data` until either all data has been sent or an error occurs. None is returned on success. On error, an exception is raised, and there is no way to determine how much data, if any, was successfully processed by the receiving end of the connection.

With `SelectorEventLoop` event loop, the socket `sock` must be non-blocking.

This method is a coroutine.

**See also:** The `socket.socket.sendall()` method.

```python
coroutine BaseEventLoop.sock_connect(sock, address)
```
Connect to a remote socket at `address`. 
The address must be already resolved to avoid the trap of hanging the entire event loop when the address requires doing a DNS lookup. For example, it must be an IP address, not an hostname, for AF_INET and AF_INET6 address families. Use getaddrinfo() to resolve the hostname asynchronously.

With SelectorEventLoop event loop, the socket sock must be non-blocking.

This method is a coroutine.

**See also:** The BaseEventLoop.create_connection() method, the open_connection() function and the socket.socket.connect() method.

coroutine BaseEventLoop.**sock_accept**(sock)

Accept a connection. The socket must be bound to an address and listening for connections. The return value is a pair (conn, address) where conn is a new socket object usable to send and receive data on the connection, and address is the address bound to the socket on the other end of the connection.

The socket sock must be non-blocking.

This method is a coroutine.

**See also:** The BaseEventLoop.create_server() method, the start_server() function and the socket.socket.accept() method.
18.5.1.9. Resolve host name

coroutine BaseEventLoop.getaddrinfo(host, port, *, family=0, type=0, proto=0, flags=0)
   This method is a coroutine, similar to socket.getaddrinfo() function but non-blocking.

coroutine BaseEventLoop.getnameinfo(sockaddr, flags=0)
   This method is a coroutine, similar to socket.getnameinfo() function but non-blocking.
18.5.1.10. Connect pipes

On Windows with SelectorEventLoop, these methods are not supported. Use ProactorEventLoop to support pipes on Windows.

coroutine
BaseEventLoop.connect_read_pipe(protocol_factory, pipe)

Register read pipe in eventloop.

protocol_factory should instantiate object with Protocol interface. pipe is a file-like object. Return pair (transport, protocol), where transport supports the ReadTransport interface.

With SelectorEventLoop event loop, the pipe is set to non-blocking mode.

This method is a coroutine.

coroutine
BaseEventLoop.connect_write_pipe(protocol_factory, pipe)

Register write pipe in eventloop.

protocol_factory should instantiate object with BaseProtocol interface. pipe is file-like object. Return pair (transport, protocol), where transport supports WriteTransport interface.

With SelectorEventLoop event loop, the pipe is set to non-blocking mode.

This method is a coroutine.
See also: The `BaseEventLoop.subprocess_exec()` and `BaseEventLoop.subprocess_shell()` methods.
18.5.1.11. UNIX signals

Availability: UNIX only.

```
BaseEventLoop.add_signal_handler(signum, callback, *args)
```

Add a handler for a signal.

Raise `ValueError` if the signal number is invalid or uncatchable.
Raise `RuntimeError` if there is a problem setting up the handler.

Use `functools.partial` to pass keywords to the callback.

```
BaseEventLoop.remove_signal_handler(sig)
```

Remove a handler for a signal.

Return True if a signal handler was removed, False if not.

**See also:** The `signal` module.
18.5.1.12. Executor

Call a function in an Executor (pool of threads or pool of processes). By default, an event loop uses a thread pool executor (ThreadPoolExecutor).

coroutine BaseEventLoop.run_in_executor(executor, func, *args)

Arrange for a func to be called in the specified executor.

The executor argument should be an Executor instance. The default executor is used if executor is None.

Use functools.partial to pass keywords to the *func*.

This method is a coroutine.

BaseEventLoop.set_default_executor(executor)

Set the default executor used by run_in_executor().
18.5.1.13. Error Handling API

Allows to customize how exceptions are handled in the event loop.

**BaseEventLoop.set_exception_handler(handler)**

Set *handler* as the new event loop exception handler.

If *handler* is None, the default exception handler will be set.

If *handler* is a callable object, it should have a matching signature to *(loop, context)*, where *loop* will be a reference to the active event loop, *context* will be a dict object (see *call_exception_handler()* documentation for details about context).

**BaseEventLoop.default_exception_handler(context)**

Default exception handler.

This is called when an exception occurs and no exception handler is set, and can be called by a custom exception handler that wants to defer to the default behavior.

*context* parameter has the same meaning as in *call_exception_handler()*.

**BaseEventLoop.call_exception_handler(context)**

Call the current event loop exception handler.

*context* is a dict object containing the following keys (new keys may be introduced later):

- ‘message’: Error message;
- ‘exception’ (optional): Exception object;
- ‘future’ (optional): `asyncio.Future` instance;
- ‘handle’ (optional): `asyncio.Handle` instance;
- ‘protocol’ (optional): `Protocol` instance;
- ‘transport’ (optional): `Transport` instance;
- ‘socket’ (optional): `socket.socket` instance.

**Note:** Note: this method should not be overloaded in subclassed event loops. For any custom exception handling, use `set_exception_handler()` method.
18.5.1.14. Debug mode

BaseEventLoop.get_debug()  
Get the debug mode (bool) of the event loop.

The default value is True if the environment variable PYTHONASYNCIODEBUG is set to a non-empty string, False otherwise.

*New in version 3.4.2.*

BaseEventLoop.set_debug(enabled: bool)  
Set the debug mode of the event loop.

*New in version 3.4.2.*

See also: The debug mode of asyncio.
18.5.1.15. Server

```python
class asyncio.Server

Server listening on sockets.

Object created by the `BaseEventLoop.create_server()` method and the `start_server()` function. Don’t instantiate the class directly.
```

close()

Stop serving: close listening sockets and set the `sockets` attribute to None.

The sockets that represent existing incoming client connections are left open.

The server is closed asynchronously, use the `wait_closed()` coroutine to wait until the server is closed.

```python
coroutine wait_closed()

Wait until the `close()` method completes.
```

This method is a coroutine.

sockets

List of `socket.socket` objects the server is listening to, or None if the server is closed.
18.5.1.16. Handle

class asyncio.Handle
A callback wrapper object returned by
BaseEventLoop.call_soon(),
BaseEventLoop.call_soon_threadsafe(),
BaseEventLoop.call_later(), and
BaseEventLoop.call_at().

cancel()
Cancel the call. If the callback is already canceled or executed,
this method has no effect.
18.5.1.17. Event loop examples

18.5.1.17.1. Hello World with call_soon()

Example using the `BaseEventLoop.call_soon()` method to schedule a callback. The callback displays "Hello World" and then stops the event loop:

```python
import asyncio

def hello_world(loop):
    print('Hello World')
    loop.stop()

loop = asyncio.get_event_loop()

# Schedule a call to hello_world()
loop.call_soon(hello_world, loop)

# Blocking call interrupted by loop.stop()
loop.run_forever()
loop.close()
```

**See also:** The [Hello World coroutine example](#) uses a coroutine.

18.5.1.17.2. Display the current date with call_later()

Example of callback displaying the current date every second. The callback uses the `BaseEventLoop.call_later()` method to reschedule itself during 5 seconds, and then stops the event loop:

```python
import asyncio
```
import datetime

def display_date(end_time, loop):
    print(datetime.datetime.now())
    if (loop.time() + 1.0) < end_time:
        loop.call_later(1, display_date, end_time, loop)
    else:
        loop.stop()

loop = asyncio.get_event_loop()

# Schedule the first call to display_date()
end_time = loop.time() + 5.0
loop.call_soon(display_date, end_time, loop)

# Blocking call interrupted by loop.stop()
loop.run_forever()
loop.close()

See also: The coroutine displaying the current date example uses a coroutine.

18.5.1.17.3. Watch a file descriptor for read events

Wait until a file descriptor received some data using the BaseEventLoop.add_reader() method and then close the event loop:

import asyncio
try:
    from socket import socketpair
except ImportError:
    from asyncio.windows_utils import socketpair
Create a pair of connected file descriptors

```python
rsock, wsock = socketpair()
loop = asyncio.get_event_loop()
```

def reader():
    data = rsock.recv(100)
    print("Received:", data.decode())
    # We are done: unregister the file descriptor
    loop.remove_reader(rsock)
    # Stop the event loop
    loop.stop()

    # Register the file descriptor for read event
    loop.add_reader(rsock, reader)

    # Simulate the reception of data from the network
    loop.call_soon(wsock.send, 'abc'.encode())

    # Run the event loop
    loop.run_forever()

    # We are done, close sockets and the event loop
    rsock.close()
    wsock.close()
    loop.close()
```

See also: The register an open socket to wait for data using a protocol example uses a low-level protocol created by the `BaseEventLoop.create_connection()` method.

The register an open socket to wait for data using streams example uses high-level streams created by the `open_connection()` function in a coroutine.

18.5.1.17.4. Set signal handlers for SIGINT and
Register handlers for signals SIGINT and SIGTERM using the `BaseEventLoop.add_signal_handler()` method:

```python
import asyncio
import functools
import os
import signal

def ask_exit(signame):
    print("got signal %s: exit" % signame)
    loop.stop()

loop = asyncio.get_event_loop()
for signame in ('SIGINT', 'SIGTERM'):
    loop.add_signal_handler(getattr(signal, signame),
                            functools.partial(ask_exit))

print("Event loop running forever, press Ctrl+C to interrupt.")
print("pid %s: send SIGINT or SIGTERM to exit." % os.getpid())
try:
    loop.run_forever()
finally:
    loop.close()
```

This example only works on UNIX.
asyncio – Asynchronous I/O, event loop, coroutines and tasks
18.5.2. Event loops
18.5.2.1. Event loop functions

The following functions are convenient shortcuts to accessing the methods of the global policy. Note that this provides access to the default policy, unless an alternative policy was set by calling `set_event_loop_policy()` earlier in the execution of the process.

```python
asyncio.get_event_loop()
  Equivalent to calling
  get_event_loop_policy().get_event_loop().

asyncio.set_event_loop(loop)
  Equivalent to calling
  get_event_loop_policy().set_event_loop(loop).

asyncio.new_event_loop()
  Equivalent to calling
  get_event_loop_policy().new_event_loop().
```
18.5.2.2. Available event loops

asyncio currently provides two implementations of event loops: SelectorEventLoop and ProactorEventLoop.

**class asyncio.SelectorEventLoop**

Event loop based on the selectors module. Subclass of BaseEventLoop.

Use the most efficient selector available on the platform.

On Windows, only sockets are supported (ex: pipes are not supported): see the MSDN documentation of select.

**class asyncio.ProactorEventLoop**

Proactor event loop for Windows using “I/O Completion Ports” aka IOCP. Subclass of BaseEventLoop.

Availability: Windows.

**See also:** MSDN documentation on I/O Completion Ports.

Example to use a ProactorEventLoop on Windows:

```python
import asyncio, sys

if sys.platform == 'win32':
    loop = asyncio.ProactorEventLoop()
    asyncio.set_event_loop(loop)
```
18.5.2.3. Platform support

The asyncio module has been designed to be portable, but each platform still has subtle differences and may not support all asyncio features.

18.5.2.3.1. Windows

Common limits of Windows event loops:

- `create_unix_connection()` and `create_unix_server()` are not supported: the socket family `socket.AF_UNIX` is specific to UNIX
- `add_signal_handler()` and `remove_signal_handler()` are not supported
- `EventLoopPolicy.set_child_watcher()` is not supported. `ProactorEventLoop` supports subprocesses. It has only one implementation to watch child processes, there is no need to configure it.

`SelectorEventLoop` specific limits:

- `SelectSelector` is used which only supports sockets and is limited to 512 sockets.
- `add_reader()` and `add_writer()` only accept file descriptors of sockets
- Pipes are not supported (ex: `connect_read_pipe()`, `connect_write_pipe()`)
- Subprocesses are not supported (ex: `subprocess_exec()`, `subprocess_shell()`)

`ProactorEventLoop` specific limits:
- `create_datagram_endpoint()` (UDP) is not supported
- `add_reader()` and `add_writer()` are not supported

The resolution of the monotonic clock on Windows is usually around 15.6 msec. The best resolution is 0.5 msec. The resolution depends on the hardware (availability of HPET) and on the Windows configuration. See asyncio delayed calls.

*Changed in version 3.5:* ProactorEventLoop now supports SSL.

### 18.5.2.3.2. Mac OS X

Character devices like PTY are only well supported since Mavericks (Mac OS 10.9). They are not supported at all on Mac OS 10.5 and older.

On Mac OS 10.6, 10.7 and 10.8, the default event loop is SelectorEventLoop which uses `selectors.KqueueSelector`. `selectors.KqueueSelector` does not support character devices on these versions. The SelectorEventLoop can be used with SelectSelector or PollSelector to support character devices on these versions of Mac OS X. Example:

```python
import asyncio
import selectors

selector = selectors.SelectSelector()
loop = asyncio.SelectorEventLoop(selector)
asyncio.set_event_loop(loop)
```
18.5.2.4. Event loop policies and the default policy

Event loop management is abstracted with a policy pattern, to provide maximal flexibility for custom platforms and frameworks. Throughout the execution of a process, a single global policy object manages the event loops available to the process based on the calling context. A policy is an object implementing the AbstractEventLoopPolicy interface.

For most users of asyncio, policies never have to be dealt with explicitly, since the default global policy is sufficient.

The default policy defines context as the current thread, and manages an event loop per thread that interacts with asyncio. The module-level functions get_event_loop() and set_event_loop() provide convenient access to event loops managed by the default policy.
18.5.2.5. Event loop policy interface

An event loop policy must implement the following interface:

```python
class asyncio.AbstractEventLoopPolicy
  Event loop policy.
  
  get_event_loop()
    Get the event loop for the current context.
    
    Returns an event loop object implementing the BaseEventLoop interface.
    
    Raises an exception in case no event loop has been set for the current context and the current policy does not specify to create one. It must never return None.
  
  set_event_loop(loop)
    Set the event loop for the current context to loop.
  
  new_event_loop()
    Create and return a new event loop object according to this policy’s rules.
    
    If there’s need to set this loop as the event loop for the current context, set_event_loop() must be called explicitly.
```
18.5.2.6. Access to the global loop policy

```python
asyncio.get_event_loop_policy()
```
Get the current event loop policy.

```python
asyncio.set_event_loop_policy(policy)
```
Set the current event loop policy. If `policy` is None, the default policy is restored.
18.5.3. Tasks and coroutines
18.5.3.1. Coroutines

Coroutines used with asyncio may be implemented using the async def statement, or by using generators. The async def type of coroutine was added in Python 3.5, and is recommended if there is no need to support older Python versions.

Generator-based coroutines should be decorated with @asyncio.coroutine, although this is not strictly enforced. The decorator enables compatibility with async def coroutines, and also serves as documentation. Generator-based coroutines use the yield from syntax introduced in PEP 380, instead of the original yield syntax.

The word “coroutine”, like the word “generator”, is used for two different (though related) concepts:

- The function that defines a coroutine (a function definition using async def or decorated with @asyncio.coroutine). If disambiguation is needed we will call this a coroutine function (iscoroutinefunction() returns True).
- The object obtained by calling a coroutine function. This object represents a computation or an I/O operation (usually a combination) that will complete eventually. If disambiguation is needed we will call it a coroutine object (iscoroutine() returns True).

Things a coroutine can do:

- result = await future or result = yield from future – suspends the coroutine until the future is done, then returns the future’s result, or raises an exception, which will be
propagated. (If the future is cancelled, it will raise a CancelledError exception.) Note that tasks are futures, and everything said about futures also applies to tasks.

- `result = await coroutine` or `result = yield from coroutine` – wait for another coroutine to produce a result (or raise an exception, which will be propagated). The coroutine expression must be a `call` to another coroutine.
- `return expression` – produce a result to the coroutine that is waiting for this one using `await` or `yield from`.
- `raise exception` – raise an exception in the coroutine that is waiting for this one using `await` or `yield from`.

Calling a coroutine does not start its code running – the coroutine object returned by the call doesn’t do anything until you schedule its execution. There are two basic ways to start it running: call `await coroutine` or `yield from coroutine` from another coroutine (assuming the other coroutine is already running!), or schedule its execution using the `ensure_future()` function or the `BaseEventLoop.create_task()` method.

Coroutines (and tasks) can only run when the event loop is running.

@asyncio.coroutine

Decorator to mark generator-based coroutines. This enables the generator use `yield from` to call `async def` coroutines, and also enables the generator to be called by `async def` coroutines, for instance using an `await` expression.

There is no need to decorate `async def` coroutines themselves.

If the generator is not yielded from before it is destroyed, an error message is logged. See Detect coroutines never scheduled.
Note: In this documentation, some methods are documented as coroutines, even if they are plain Python functions returning a `Future`. This is intentional to have a freedom of tweaking the implementation of these functions in the future. If such a function is needed to be used in a callback-style code, wrap its result with `ensure_future()`.

18.5.3.1.1. Example: Hello World coroutine

Example of coroutine displaying "Hello World":

```python
import asyncio

async def hello_world():
    print("Hello World!")

loop = asyncio.get_event_loop()
# Blocking call which returns when the hello_world() coroutine is done
loop.run_until_complete(hello_world())
loop.close()
```

See also: The Hello World with `call_soon()` example uses the `BaseEventLoop.call_soon()` method to schedule a callback.

18.5.3.1.2. Example: Coroutine displaying the current date

Example of coroutine displaying the current date every second during 5 seconds using the `sleep()` function:

```python
import asyncio
```
```python
import datetime

async def display_date(loop):
    end_time = loop.time() + 5.0
    while True:
        print(datetime.datetime.now())
        if (loop.time() + 1.0) >= end_time:
            break
        await asyncio.sleep(1)

loop = asyncio.get_event_loop()
# Blocking call which returns when the display_date()
loop.run_until_complete(display_date(loop))
loop.close()
```

The same coroutine implemented using a generator:

```python
@asyncio.coroutine
def display_date(loop):
    end_time = loop.time() + 5.0
    while True:
        print(datetime.datetime.now())
        if (loop.time() + 1.0) >= end_time:
            break
        yield from asyncio.sleep(1)
```

See also: The display the current date with call_later() example uses a callback with the `BaseEventLoop.call_later()` method.

18.5.3.1.3. Example: Chain coroutines

Example chaining coroutines:

```python
import asyncio
```
async def compute(x, y):
    print("Compute %s + %s ..." % (x, y))
    await asyncio.sleep(1.0)
    return x + y

async def print_sum(x, y):
    result = await compute(x, y)
    print("%s + %s = %s" % (x, y, result))

loop = asyncio.get_event_loop()
loop.run_until_complete(print_sum(1, 2))
loop.close()

compute() is chained to print_sum(): print_sum() coroutine waits until compute() is completed before returning its result.

Sequence diagram of the example:

The "Task" is created by the BaseEventLoop.run_until_complete() method when it gets a coroutine object instead of a task.
The diagram shows the control flow, it does not describe exactly how things work internally. For example, the sleep coroutine creates an internal future which uses `BaseEventLoop.callLater()` to wake up the task in 1 second.
18.5.3.2. InvalidStateError

The operation is not allowed in this state.
18.5.3.3. TimeoutError

_exception asyncio.TimeoutError_

The operation exceeded the given deadline.

**Note:** This exception is different from the builtin `TimeoutError` exception!
18.5.3.4. Future

class asyncio.Future(*, loop=None)

This class is almost compatible with concurrent.futures.Future.

Differences:

- `result()` and `exception()` do not take a timeout argument and raise an exception when the future isn't done yet.
- Callbacks registered with `add_done_callback()` are always called via the event loop's `call_soon_threadsafe()`.
- This class is not compatible with the `wait()` and `as_completed()` functions in the concurrent.futures package.

This class is not thread safe.

cancel()

Cancel the future and schedule callbacks.

If the future is already done or cancelled, return False. Otherwise, change the future's state to cancelled, schedule the callbacks and return True.

cancelled()

Return True if the future was cancelled.

done()

Return True if the future is done.

Done means either that a result / exception are available, or
that the future was cancelled.

**result()**
Return the result this future represents.

If the future has been cancelled, raises `CancelledError`. If the future's result isn't yet available, raises `InvalidStateError`. If the future is done and has an exception set, this exception is raised.

**exception()**
Return the exception that was set on this future.

The exception (or None if no exception was set) is returned only if the future is done. If the future has been cancelled, raises `CancelledError`. If the future isn't done yet, raises `InvalidStateError`.

**add_done_callback(fn)**
Add a callback to be run when the future becomes done.

The callback is called with a single argument - the future object. If the future is already done when this is called, the callback is scheduled with `call_soon()`.

Use `functools.partial` to pass parameters to the callback. For example, `fut.add_done_callback(functools.partial(print, "Future:", flush=True))` will call `print("Future:", fut, flush=True)`.

**remove_done_callback(fn)**
Remove all instances of a callback from the “call when done”
list.

Returns the number of callbacks removed.

**set_result**(result)
Mark the future done and set its result.

If the future is already done when this method is called, raises `InvalidStateError`.

**set_exception**(exception)
Mark the future done and set an exception.

If the future is already done when this method is called, raises `InvalidStateError`.

### 18.5.3.4.1. Example: Future with run_until_complete()

Example combining a `Future` and a coroutine function:

```python
import asyncio

@asyncio.coroutine
def slow_operation(future):
    yield from asyncio.sleep(1)
    future.set_result('Future is done!')

loop = asyncio.get_event_loop()
future = asyncio.Future()
asyncio.ensure_future(slow_operation(future))
loop.run_until_complete(future)
print(future.result())
loop.close()
```
The coroutine function is responsible for the computation (which takes 1 second) and it stores the result into the future. The \texttt{run\_until\_complete()} method waits for the completion of the future.

\begin{verbatim}
Note: The \texttt{run\_until\_complete()} method uses internally the \texttt{add\_done\_callback()} method to be notified when the future is done.
\end{verbatim}

18.5.3.4.2. Example: Future with \texttt{run\_forever()}

The previous example can be written differently using the \texttt{Future.add\_done\_callback()} method to describe explicitly the control flow:

\begin{verbatim}
import asyncio
@asyncio.coroutine
def slow_operation(future):
    yield from asyncio.sleep(1)
    future.set_result('Future is done!')

def got_result(future):
    print(future.result())
    loop.stop()

loop = asyncio.get_event_loop()
future = asyncio.Future()
asyncio.ensure_future(slow_operation(future))
future.add_done_callback(got_result)
try:
    loop.run_forever()
finally:
    loop.close()
\end{verbatim}
In this example, the future is used to link `slow_operation()` to `got_result()`: when `slow_operation()` is done, `got_result()` is called with the result.
18.5.3.5. Task

class asyncio.Task(coro, *, loop=None)

Schedule the execution of a coroutine: wrap it in a future. A task is a subclass of Future.

A task is responsible for executing a coroutine object in an event loop. If the wrapped coroutine yields from a future, the task suspends the execution of the wrapped coroutine and waits for the completion of the future. When the future is done, the execution of the wrapped coroutine restarts with the result or the exception of the future.

Event loops use cooperative scheduling: an event loop only runs one task at a time. Other tasks may run in parallel if other event loops are running in different threads. While a task waits for the completion of a future, the event loop executes a new task.

The cancellation of a task is different from the cancelation of a future. Calling cancel() will throw a CancelledError to the wrapped coroutine. cancelled() only returns True if the wrapped coroutine did not catch the CancelledError exception, or raised a CancelledError exception.

If a pending task is destroyed, the execution of its wrapped coroutine did not complete. It is probably a bug and a warning is logged: see Pending task destroyed.

Don’t directly create Task instances: use the ensure_future() function or the BaseEventLoop.create_task() method.

This class is not thread safe.
class all_tasks(loop=None)
    Return a set of all tasks for an event loop.

    By default all tasks for the current event loop are returned.

classmethod current_task(loop=None)
    Return the currently running task in an event loop or None.

    By default the current task for the current event loop is returned.

    None is returned when called not in the context of a Task.

cancel()
    Request that this task cancel itself.

    This arranges for a CancelledError to be thrown into the
    wrapped coroutine on the next cycle through the event loop.
    The coroutine then has a chance to clean up or even deny the
    request using try/except/finally.

    Unlike Future.cancel(), this does not guarantee that the
    task will be cancelled: the exception might be caught and acted
    upon, delaying cancellation of the task or preventing
    cancellation completely. The task may also return a value or
    raise a different exception.

    Immediately after this method is called, cancelled() will not
    return True (unless the task was already cancelled). A task will
    be marked as cancelled when the wrapped coroutine
    terminates with a CancelledError exception (even if
    cancel() was not called).

get_stack(*, limit=None)
Return the list of stack frames for this task’s coroutine.

If the coroutine is not done, this returns the stack where it is suspended. If the coroutine has completed successfully or was cancelled, this returns an empty list. If the coroutine was terminated by an exception, this returns the list of traceback frames.

The frames are always ordered from oldest to newest.

The optional limit gives the maximum number of frames to return; by default all available frames are returned. Its meaning differs depending on whether a stack or a traceback is returned: the newest frames of a stack are returned, but the oldest frames of a traceback are returned. (This matches the behavior of the traceback module.)

For reasons beyond our control, only one stack frame is returned for a suspended coroutine.

```
print_stack(*, limit=None, file=None)
```

Print the stack or traceback for this task’s coroutine.

This produces output similar to that of the traceback module, for the frames retrieved by `get_stack()`. The limit argument is passed to `get_stack()`. The file argument is an I/O stream to which the output is written; by default output is written to `sys.stderr`.

### 18.5.3.5.1. Example: Parallel execution of tasks

Example executing 3 tasks (A, B, C) in parallel:
import asyncio

@asyncio.coroutine
def factorial(name, number):
    f = 1
    for i in range(2, number+1):
        print("Task %s: Compute factorial(%s)...") % (name, number)
        yield from asyncio.sleep(1)
        f *= i
        print("Task %s: factorial(%s) = %s" % (name, number, f))

loop = asyncio.get_event_loop()
tasks = [
    asyncio.ensure_future(factorial("A", 2)),
    asyncio.ensure_future(factorial("B", 3)),
    asyncio.ensure_future(factorial("C", 4))]
loop.run_until_complete(asyncio.wait(tasks))
loop.close()

Output:

Task A: Compute factorial(2)...
Task B: Compute factorial(2)...
Task C: Compute factorial(2)...
Task A: factorial(2) = 2
Task B: Compute factorial(3)...
Task C: Compute factorial(3)...
Task B: factorial(3) = 6
Task C: Compute factorial(4)...
Task C: factorial(4) = 24

A task is automatically scheduled for execution when it is created. The event loop stops when all tasks are done.
18.5.3.6. Task functions

**Note:** In the functions below, the optional `loop` argument allows to explicitly set the event loop object used by the underlying task or coroutine. If it’s not provided, the default event loop is used.

```python
asyncio.as_completed(fs, *, loop=None, timeout=None)
```

Return an iterator whose values, when waited for, are `Future` instances.

Raises `asyncio.TimeoutError` if the timeout occurs before all Futures are done.

Example:

```python
for f in asyncio.as_completed(fs):
    result = f  # The 'yield from' may raise
    # Use result
```

**Note:** The futures `f` are not necessarily members of `fs`.

```python
asyncio.ensure_future(coro_or_future, *, loop=None)
```

Schedule the execution of a coroutine object: wrap it in a future. Return a `Task` object.

If the argument is a `Future`, it is returned directly.

*New in version 3.4.4.*

**See also:** The `BaseEventLoop.create_task()` method.
asyncio.async(coro_or_future, *, loop=None)
    A deprecated alias to ensure_future().

    Deprecated since version 3.4.4.

asyncio.gather(*coros_or_futures, loop=None, return_exceptions=False)
    Return a future aggregating results from the given coroutine objects or futures.

    All futures must share the same event loop. If all the tasks are done successfully, the returned future’s result is the list of results (in the order of the original sequence, not necessarily the order of results arrival). If return_exceptions is True, exceptions in the tasks are treated the same as successful results, and gathered in the result list; otherwise, the first raised exception will be immediately propagated to the returned future.

    Cancellation: if the outer Future is cancelled, all children (that have not completed yet) are also cancelled. If any child is cancelled, this is treated as if it raised CancelledError – the outer Future is not cancelled in this case. (This is to prevent the cancellation of one child to cause other children to be cancelled.)

asyncio.iscoroutine(obj)
    Return True if obj is a coroutine object, which may be based on a generator or an async def coroutine.

asyncio.iscoroutinefunction(func)
    Return True if func is determined to be a coroutine function, which may be a decorated generator function or an async def function.

coroutine asyncio.sleep(delay, result=None, *, loop=None)
Create a coroutine that completes after a given time (in seconds). If result is provided, it is produced to the caller when the coroutine completes.

The resolution of the sleep depends on the granularity of the event loop.

This function is a coroutine.

```python
asyncio.shield(arg, *, loop=None)
```

Wait for a future, shielding it from cancellation.

The statement:

```python
res = yield from shield(something())
```

is exactly equivalent to the statement:

```python
res = yield from something()
```

except that if the coroutine containing it is cancelled, the task running in `something()` is not cancelled. From the point of view of `something()`, the cancellation did not happen. But its caller is still cancelled, so the yield-from expression still raises CancelledError. Note: If `something()` is cancelled by other means this will still cancel `shield()`.

If you want to completely ignore cancellation (not recommended) you can combine `shield()` with a try/except clause, as follows:

```python
try:
    res = yield from shield(something())
except CancelledError:
    res = None
```
coroutine asyncio.wait(futures, *, loop=None, timeout=None, return_when=ALL_COMPLETED)

Wait for the Futures and coroutine objects given by the sequence futures to complete. Coroutines will be wrapped in Tasks. Returns two sets of Future: (done, pending).

The sequence futures must not be empty.

timeout can be used to control the maximum number of seconds to wait before returning. timeout can be an int or float. If timeout is not specified or None, there is no limit to the wait time.

return_when indicates when this function should return. It must be one of the following constants of the concurrent.futures module:

<table>
<thead>
<tr>
<th>Constant</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRST_COMPLETED</td>
<td>The function will return when any future finishes or is cancelled.</td>
</tr>
<tr>
<td>FIRST_EXCEPTION</td>
<td>The function will return when any future finishes by raising an exception. If no future raises an exception then it is equivalent to ALL_COMPLETED.</td>
</tr>
<tr>
<td>ALL_COMPLETED</td>
<td>The function will return when all futures finish or are cancelled.</td>
</tr>
</tbody>
</table>

This function is a coroutine.

Usage:

done, pending = yield from asyncio.wait(fs)
```python
# Create a coroutine
coro = asyncio.sleep(1, result=3)
```

```python
asyncio.run_coroutine_threadsafe(coro, loop)
```

Submit a coroutine object to a given event loop.

This function is meant to be called from a different thread than the one where the event loop is running.

Usage:

```python
result = yield from asyncio.wait_for(fut, 60.0)
```

Changed in version 3.4.3: If the wait is cancelled, the future fut is now also cancelled.

**Note:** This does not raise `asyncio.TimeoutError`! Futures that aren't done when the timeout occurs are returned in the second set.

coroutine `asyncio.wait_for(fut, timeout, *, loop=None)`

Wait for the single Future or coroutine object to complete with timeout. If `timeout` is None, block until the future completes.

Coroutine will be wrapped in Task.

Returns result of the Future or coroutine. When a timeout occurs, it cancels the task and raises `asyncio.TimeoutError`. To avoid the task cancellation, wrap it in `shield()`.

If the wait is cancelled, the future `fut` is also cancelled.

This function is a coroutine, usage:
# Submit the coroutine to a given loop
future = asyncio.run_coroutine_threadsafe(coro, loop)

# Wait for the result with an optional timeout argument
assert future.result(timeout) == 3

If an exception is raised in the coroutine, the returned future will be notified. It can also be used to cancel the task in the event loop:

```
try:
    result = future.result(timeout)
except asyncio.TimeoutError:
    print('The coroutine took too long, cancelling...')
    future.cancel()
except Exception as exc:
    print('The coroutine raised an exception: {!r}'.format(exc))
else:
    print('The coroutine returned: {!r}'.format(result))
```

See the concurrency and multithreading section of the documentation.

**Note:** Unlike the functions above, `run_coroutine_threadsafe()` requires the `loop` argument to be passed explicitly.

*New in version 3.4.4:* 3.5.1
Created using Sphinx 1.3.1.
18.5.4. Transports and protocols (low-level API)
18.5.4.1. Transports

Transports are classes provided by asyncio in order to abstract various kinds of communication channels. You generally won’t instantiate a transport yourself; instead, you will call a `BaseEventLoop` method which will create the transport and try to initiate the underlying communication channel, calling you back when it succeeds.

Once the communication channel is established, a transport is always paired with a protocol instance. The protocol can then call the transport’s methods for various purposes.

asyncio currently implements transports for TCP, UDP, SSL, and subprocess pipes. The methods available on a transport depend on the transport’s kind.

The transport classes are not thread safe.

18.5.4.1.1. BaseTransport

class asyncio.BaseTransport

Base class for transports.

   close(self)

Close the transport. If the transport has a buffer for outgoing data, buffered data will be flushed asynchronously. No more data will be received. After all buffered data is flushed, the protocol’s `connection_lost()` method will be called with `None` as its argument.
is_closing(self)
Return True if the transport is closing or is closed.

New in version 3.5.1.

get_extra_info(name, default=None)
Return optional transport information. name is a string representing the piece of transport-specific information to get, default is the value to return if the information doesn’t exist.

This method allows transport implementations to easily expose channel-specific information.

- socket:
  - 'peername': the remote address to which the socket is connected, result of socket.socket.getpeername() (None on error)
  - 'socket': socket.socket instance
  - 'sockname': the socket's own address, result of socket.socket.getsockname()

- SSL socket:
  - 'compression': the compression algorithm being used as a string, or None if the connection isn't compressed; result of ssl.SSLSocket.compression()
  - 'cipher': a three-value tuple containing the name of the cipher being used, the version of the SSL protocol that defines its use, and the number of secret bits being used; result of ssl.SSLSocket.cipher()
  - 'peercert': peer certificate; result of ssl.SSLSocket.getpeercert()
ssl.SSLSocket instance

- pipe:
  - 'pipe': pipe object

- subprocess:
  - 'subprocess': subprocess.Popen instance

*Changed in version 3.5.1:* 'ssl_object' info was added to SSL sockets.

18.5.4.1.2. ReadTransport

*class* asyncio.ReadTransport

Interface for read-only transports.

**pause_reading()**

Pause the receiving end of the transport. No data will be passed to the protocol's data_received() method until resume_reading() is called.

**resume_reading()**

Resume the receiving end. The protocol's data_received() method will be called once again if some data is available for reading.

18.5.4.1.3. WriteTransport

*class* asyncio.WriteTransport

Interface for write-only transports.

**abort()**

Close the transport immediately, without waiting for pending
operations to complete. Buffered data will be lost. No more data will be received. The protocol’s connection_lost() method will eventually be called with None as its argument.

**can_write_eof()**

Return True if the transport supports write_eof(), False if not.

**get_write_buffer_size()**

Return the current size of the output buffer used by the transport.

**get_write_buffer_limits()**

Get the high- and low-water limits for write flow control. Return a tuple (low, high) where low and high are positive number of bytes.

Use set_write_buffer_limits() to set the limits.

*New in version 3.4.2.*

**set_write_buffer_limits(high=None, low=None)**

Set the high- and low-water limits for write flow control.

These two values control when call the protocol’s pause_writing() and resume_writing() methods are called. If specified, the low-water limit must be less than or equal to the high-water limit. Neither high nor low can be negative.

The defaults are implementation-specific. If only the high-water limit is given, the low-water limit defaults to an implementation-specific value less than or equal to the high-water limit. Setting
high to zero forces low to zero as well, and causes pause_writing() to be called whenever the buffer becomes non-empty. Setting low to zero causes resume_writing() to be called only once the buffer is empty. Use of zero for either limit is generally sub-optimal as it reduces opportunities for doing I/O and computation concurrently.

Use get_write_buffer_limits() to get the limits.

**write**(data)
Write some data bytes to the transport.

This method does not block; it buffers the data and arranges for it to be sent out asynchronously.

**writelines**(list_of_data)
Write a list (or any iterable) of data bytes to the transport. This is functionally equivalent to calling write() on each element yielded by the iterable, but may be implemented more efficiently.

**write_eof()**
Close the write end of the transport after flushing buffered data. Data may still be received.

This method can raise NotImplementedError if the transport (e.g. SSL) doesn’t support half-closes.

18.5.4.1.4. DatagramTransport

DatagramTransport.sendto**(data, addr=None)**
Send the data bytes to the remote peer given by addr (a transport-
dependent target address). If \textit{addr} is \texttt{None}, the data is sent to the
target address given on transport creation.

This method does not block; it buffers the data and arranges for it
to be sent out asynchronously.

\texttt{DatagramTransport.abort()}

Close the transport immediately, without waiting for pending
operations to complete. Buffered data will be lost. No more data will
be received. The protocol's \texttt{connection
\_lost()} method will eventually be called with \texttt{None} as its argument.

\textbf{18.5.4.1.5. BaseSubprocessTransport}

\texttt{class asyncio.BaseSubprocessTransport}

\texttt{get\_pid()}

Return the subprocess process id as an integer.

\texttt{get\_pipe\_transport(fd)}

Return the transport for the communication pipe corresponding
to the integer file descriptor \texttt{fd}:

- 0: readable streaming transport of the standard input
  (\textit{stdin}), or \texttt{None} if the subprocess was not created with
  \texttt{stdin=PIPE}
- 1: writable streaming transport of the standard output
  (\textit{stdout}), or \texttt{None} if the subprocess was not created with
  \texttt{stdout=PIPE}
- 2: writable streaming transport of the standard error
  (\textit{stderr}), or \texttt{None} if the subprocess was not created with
  \texttt{stderr=PIPE}
- other \texttt{fd}: \texttt{None}
get_returncode()
Return the subprocess returncode as an integer or None if it hasn't returned, similarly to the subprocess.Popen.returncode attribute.

kill(self)
Kill the subprocess, as in subprocess.Popen.kill().

On POSIX systems, the function sends SIGKILL to the subprocess. On Windows, this method is an alias for terminate().

send_signal(signal)
Send the signal number to the subprocess, as in subprocess.Popen.send_signal().

terminate()
Ask the subprocess to stop, as in subprocess.Popen.terminate(). This method is an alias for the close() method.

On POSIX systems, this method sends SIGTERM to the subprocess. On Windows, the Windows API function TerminateProcess() is called to stop the subprocess.

close()
Ask the subprocess to stop by calling the terminate() method if the subprocess hasn't returned yet, and close transports of all pipes (stdin, stdout and stderr).
18.5.4.2. Protocols

asyncio provides base classes that you can subclass to implement your network protocols. Those classes are used in conjunction with transports (see below): the protocol parses incoming data and asks for the writing of outgoing data, while the transport is responsible for the actual I/O and buffering.

When subclassing a protocol class, it is recommended you override certain methods. Those methods are callbacks: they will be called by the transport on certain events (for example when some data is received); you shouldn’t call them yourself, unless you are implementing a transport.

Note: All callbacks have default implementations, which are empty. Therefore, you only need to implement the callbacks for the events in which you are interested.

18.5.4.2.1. Protocol classes

class asyncio.Protocol
    The base class for implementing streaming protocols (for use with e.g. TCP and SSL transports).

class asyncio.DatagramProtocol
    The base class for implementing datagram protocols (for use with e.g. UDP transports).

class asyncio.SubprocessProtocol
    The base class for implementing protocols communicating with child processes (through a set of unidirectional pipes).
18.5.4.2.2. Connection callbacks

These callbacks may be called on Protocol, DatagramProtocol and SubprocessProtocol instances:

BaseProtocol.connection_made(transport)

Called when a connection is made.

The transport argument is the transport representing the connection. You are responsible for storing it somewhere (e.g. as an attribute) if you need to.

BaseProtocol.connection_lost(exc)

Called when the connection is lost or closed.

The argument is either an exception object or None. The latter means a regular EOF is received, or the connection was aborted or closed by this side of the connection.

connection_made() and connection_lost() are called exactly once per successful connection. All other callbacks will be called between those two methods, which allows for easier resource management in your protocol implementation.

The following callbacks may be called only on SubprocessProtocol instances:

SubprocessProtocol.pipe_data_received(fd, data)

Called when the child process writes data into its stdout or stderr pipe. fd is the integer file descriptor of the pipe. data is a non-empty bytes object containing the data.

SubprocessProtocol.pipe_connection_lost(fd, exc)
Called when one of the pipes communicating with the child process is closed. `fd` is the integer file descriptor that was closed.

SubprocessProtocol.`process_exited()`
Called when the child process has exited.

### 18.5.4.2.3. Streaming protocols

The following callbacks are called on `Protocol` instances:

- **Protocol.`data_received`(data)**
  Called when some data is received. `data` is a non-empty bytes object containing the incoming data.

  **Note:** Whether the data is buffered, chunked or reassembled depends on the transport. In general, you shouldn’t rely on specific semantics and instead make your parsing generic and flexible enough. However, data is always received in the correct order.

- **Protocol.`eof_received`()**
  Calls when the other end signals it won’t send any more data (for example by calling `write_eof()`, if the other end also uses asyncio).

  This method may return a false value (including None), in which case the transport will close itself. Conversely, if this method returns a true value, closing the transport is up to the protocol. Since the default implementation returns None, it implicitly closes the connection.

  **Note:** Some transports such as SSL don’t support half-closed...
connections, in which case returning true from this method will not prevent closing the connection.

data_received() can be called an arbitrary number of times during a connection. However, eof_received() is called at most once and, if called, data_received() won't be called after it.

State machine:

```
start -> connection_made() [-> data_received() *][->
eof_received() ?] -> connection_lost() -> end
```

18.5.4.2.4. Datagram protocols

The following callbacks are called on DatagramProtocol instances.

DatagramProtocol.\texttt{datagram\_received}(data, addr)

Called when a datagram is received. \texttt{data} is a bytes object containing the incoming data. \texttt{addr} is the address of the peer sending the data; the exact format depends on the transport.

DatagramProtocol.\texttt{error\_received}(exc)

Called when a previous send or receive operation raises an OSError. \texttt{exc} is the OSError instance.

This method is called in rare conditions, when the transport (e.g. UDP) detects that a datagram couldn’t be delivered to its recipient. In many conditions though, undeliverable datagrams will be silently dropped.

18.5.4.2.5. Flow control callbacks
These callbacks may be called on `Protocol`, `DatagramProtocol` and `SubprocessProtocol` instances:

**BaseProtocol.pause_writing()**

Called when the transport's buffer goes over the high-water mark.

**BaseProtocol.resume_writing()**

Called when the transport's buffer drains below the low-water mark.

`pause_writing()` and `resume_writing()` calls are paired – `pause_writing()` is called once when the buffer goes strictly over the high-water mark (even if subsequent writes increases the buffer size even more), and eventually `resume_writing()` is called once when the buffer size reaches the low-water mark.

**Note:** If the buffer size equals the high-water mark, `pause_writing()` is not called – it must go strictly over. Conversely, `resume_writing()` is called when the buffer size is equal or lower than the low-water mark. These end conditions are important to ensure that things go as expected when either mark is zero.

**Note:** On BSD systems (OS X, FreeBSD, etc.) flow control is not supported for `DatagramProtocol`, because send failures caused by writing too many packets cannot be detected easily. The socket always appears ‘ready’ and excess packets are dropped; an `OSError` with errno set to `errno.ENOBUFS` may or may not be raised; if it is raised, it will be reported to `DatagramProtocol.error_received()` but otherwise ignored.

18.5.4.2.6. Coroutines and protocols
Coroutines can be scheduled in a protocol method using `ensure_future()`, but there is no guarantee made about the execution order. Protocols are not aware of coroutines created in protocol methods and so will not wait for them.

To have a reliable execution order, use stream objects in a coroutine with `yield from`. For example, the `StreamWriter.drain()` coroutine can be used to wait until the write buffer is flushed.
18.5.4.3. Protocol examples

18.5.4.3.1. TCP echo client protocol

TCP echo client using the `BaseEventLoop.create_connection()` method, send data and wait until the connection is closed:

```python
import asyncio

class EchoClientProtocol(asyncio.Protocol):
    def __init__(self, message, loop):
        self.message = message
        self.loop = loop

    def connection_made(self, transport):
        transport.write(self.message.encode())
        print('Data sent: {!r}'.format(self.message))

    def data_received(self, data):
        print('Data received: {!r}'.format(data.decode()))

    def connection_lost(self, exc):
        print('The server closed the connection')
        print('Stop the event loop')
        self.loop.stop()

loop = asyncio.get_event_loop()
message = 'Hello World!

loop.run_until_complete(asyncio.wait([loop.create_connection(lambda: EchoClientProtocol, '127.0.0.1', 8888)]))
loop.run_forever()
loop.close()
```
The event loop is running twice. The `run_until_complete()` method is preferred in this short example to raise an exception if the server is not listening, instead of having to write a short coroutine to handle the exception and stop the running loop. At `run_until_complete()` exit, the loop is no longer running, so there is no need to stop the loop in case of an error.

**See also:** The TCP echo client using streams example uses the `asyncio.open_connection()` function.

### 18.5.4.3.2. TCP echo server protocol

TCP echo server using the `BaseEventLoop.create_server()` method, send back received data and close the connection:

```python
import asyncio

class EchoServerClientProtocol(asyncio.Protocol):
    def connection_made(self, transport):
        peername = transport.get_extra_info('peername')
        print(f'Connection from {peername}')
        self.transport = transport

    def data_received(self, data):
        message = data.decode()
        print(f'Data received: {message!r}')
        print(f'Send: {message!r}')
        self.transport.write(data)

        print('Close the client socket')
        self.transport.close()

loop = asyncio.get_event_loop()
```
# Each client connection will create a new protocol

coro = loop.create_server(EchoServerClientProtocol,
server = loop.run_until_complete(coro)

# Serve requests until Ctrl+C is pressed
print('Serving on {}' .format(serversockets[0] .getsockname)

try:
    loop.run_forever()
except KeyboardInterrupt:
    pass

# Close the server
server .close()
loop.run_until_complete(server .wait_closed())
loop .close()

Transport.close() can be called immediately after WriteTransport.write() even if data are not sent yet on the socket: both methods are asynchronous. yield from is not needed because these transport methods are not coroutines.

See also: The TCP echo server using streams example uses the asyncio .start_server() function.

18.5.4.3.3. UDP echo client protocol

UDP echo client using the BaseEventLoop .create_datagram_endpoint() method, send data and close the transport when we received the answer:

import asyncio
class EchoClientProtocol:
```python
def __init__(self, message, loop):
    self.message = message
    self.loop = loop
    self.transport = None

def connection_made(self, transport):
    self.transport = transport
    print('Send:', self.message)
    self.transport.sendto(self.message.encode())

def datagram_received(self, data, addr):
    print("Received:", data.decode())
    print("Close the socket")
    self.transport.close()

def error_received(self, exc):
    print('Error received:', exc)

def connection_lost(self, exc):
    print("Socket closed, stop the event loop")
    loop = asyncio.get_event_loop()
    loop.stop()

loop = asyncio.get_event_loop()
message = "Hello World!"
connect = loop.create_datagram_endpoint(
    lambda: EchoClientProtocol(message, loop),
    remote_addr=('127.0.0.1', 9999))
transport, protocol = loop.run_until_complete(connect)
loop.run_forever()
transport.close()
loop.close()
```

18.5.4.3.4. UDP echo server protocol
UDP echo server using the `BaseEventLoop.create_datagram_endpoint()` method, send back received data:

```python
import asyncio

class EchoServerProtocol:
    def connection_made(self, transport):
        self.transport = transport

    def datagram_received(self, data, addr):
        message = data.decode()
        print('Received %r from %s' % (message, addr))
        print('Send %r to %s' % (message, addr))
        self.transport.sendto(data, addr)

loop = asyncio.get_event_loop()
print("Starting UDP server")
# One protocol instance will be created to serve all
listen = loop.create_datagram_endpoint(
    EchoServerProtocol, local_addr=('127.0.0.1', 9999))
transport, protocol = loop.run_until_complete(listen)

try:
    loop.run_forever()
except KeyboardInterrupt:
    pass

transport.close()
loop.close()
```

18.5.4.3.5. Register an open socket to wait for data using a protocol
Wait until a socket receives data using the `BaseEventLoop.create_connection()` method with a protocol, and then close the event loop

```python
import asyncio
try:
    from socket import socketpair
except ImportError:
    from asyncio.windows_utils import socketpair

# Create a pair of connected sockets
rsock, wsock = socketpair()
loop = asyncio.get_event_loop()

class MyProtocol(asyncio.Protocol):
    transport = None

    def connection_made(self, transport):
        self.transport = transport

    def data_received(self, data):
        print("Received:", data.decode())

        # We are done: close the transport (it will
        self.transport.close()

    def connection_lost(self, exc):
        # The socket has been closed, stop the event
        loop.stop()

# Register the socket to wait for data
connect_coro = loop.create_connection(MyProtocol, sock
transport, protocol = loop.run_until_complete(connect_coro)

# Simulate the reception of data from the network
loop.call_soon(wsock.send, 'abc'.encode())
```
# Run the event loop
loop.run_forever()

# We are done, close sockets and the event loop
rsock.close()
wsock.close()
loop.close()

See also: The watch a file descriptor for read events example uses the low-level `BaseEventLoop.add_reader()` method to register the file descriptor of a socket.

The register an open socket to wait for data using streams example uses high-level streams created by the `open_connection()` function in a coroutine.
18.5. asyncio – Asynchronous I/O, event loop, coroutines and tasks
18.5.5. Streams (high-level API)
18.5.5.1. Stream functions

**Note:** The top-level functions in this module are meant convenience wrappers only; there's really nothing special there, and if they don't do exactly what you want, feel free to copy their code.

coroutine asyncio.open_connection(host=host, port=port, *, loop=loop, limit=limit, **kwds)

A wrapper for `create_connection()` returning a (reader, writer) pair.

The reader returned is a `StreamReader` instance; the writer is a `StreamWriter` instance.

The arguments are all the usual arguments to `BaseEventLoop.create_connection()` except `protocol_factory`; most common are positional host and port, with various optional keyword arguments following.

Additional optional keyword arguments are `loop` (to set the event loop instance to use) and `limit` (to set the buffer limit passed to the `StreamReader`).

This function is a coroutine.

coroutine asyncio.start_server(client_connected_cb, host=host, port=port, *, loop=loop, limit=limit, **kwds)

Start a socket server, with a callback for each client connected. The return value is the same as `create_server()`.

The `client_connected_cb` parameter is called with two parameters: `client_reader`, `client_writer`. `client_reader` is a `StreamReader`
object, while client_writer is a StreamWriter object. The client_connected_cb parameter can either be a plain callback function or a coroutine function; if it is a coroutine function, it will be automatically converted into a Task.

The rest of the arguments are all the usual arguments to create_server() except protocol_factory; most common are positional host and port, with various optional keyword arguments following.

Additional optional keyword arguments are loop (to set the event loop instance to use) and limit (to set the buffer limit passed to the StreamReader).

This function is a coroutine.

coroutine asyncio.open_unix_connection(path=None, *, loop=None, limit=None, **kwds)
A wrapper for create_unix_connection() returning a (reader, writer) pair.

See open_connection() for information about return value and other details.

This function is a coroutine.

Availability: UNIX.

coroutine asyncio.start_unix_server(client_connected_cb, path=None, *, loop=None, limit=None, **kwds)
Start a UNIX Domain Socket server, with a callback for each client connected.

See start_server() for information about return value and
other details.

This function is a coroutine.

Availability: UNIX.
18.5.5.2. StreamReader

class asyncio.StreamReader(limit=None, loop=None)
   This class is not thread safe.

exception()
   Get the exception.

feed_eof()
   Acknowledge the EOF.

feed_data(data)
   Feed data bytes in the internal buffer. Any operations waiting for the data will be resumed.

set_exception(exc)
   Set the exception.

set_transport(transport)
   Set the transport.

coroutine read(n=-1)
   Read up to n bytes. If n is not provided, or set to -1, read until EOF and return all read bytes.

   If the EOF was received and the internal buffer is empty, return an empty bytes object.

   This method is a coroutine.

coroutine readline()
   Read one line, where “line” is a sequence of bytes ending with
If EOF is received, and \n was not found, the method will return the partial read bytes.

If the EOF was received and the internal buffer is empty, return an empty bytes object.

This method is a coroutine.

coroutine **readexactly**(n)
Read exactly n bytes. Raise an *IncompleteReadError* if the end of the stream is reached before n can be read, the *IncompleteReadError.partial* attribute of the exception contains the partial read bytes.

This method is a coroutine.

**at_eof()**
Return True if the buffer is empty and *feed_eof()* was called.
18.5.5.3. StreamWriter

class asyncio.StreamWriter(transport, protocol, reader, loop)
    Wraps a Transport.

    This exposes write(), writelines(), can_write_eof(),
    write_eof(), get_extra_info() and close(). It adds
drain() which returns an optional Future on which you can wait
for flow control. It also adds a transport attribute which references
the Transport directly.

    This class is not thread safe.

    transport
        Transport.

    can_write_eof()
        Return True if the transport supports write_eof(), False if
        not. See WriteTransport.can_write_eof().

    close()
        Close the transport: see BaseTransport.close().

    coroutine drain()
        Let the write buffer of the underlying transport a chance to be
        flushed.

        The intended use is to write:

        ```python
        w.write(data)
yield from w.drain()
        ```
When the size of the transport buffer reaches the high-water limit (the protocol is paused), block until the size of the buffer is drained down to the low-water limit and the protocol is resumed. When there is nothing to wait for, the yield-from continues immediately.

Yielding from `drain()` gives the opportunity for the loop to schedule the write operation and flush the buffer. It should especially be used when a possibly large amount of data is written to the transport, and the coroutine does not yield-from between calls to `write()`.

This method is a coroutine.

`get_extra_info(name, default=None)`
Return optional transport information: see `BaseTransport.get_extra_info()`.

`write(data)`
Write some `data` bytes to the transport: see `WriteTransport.write()`.

`writelines(data)`
Write a list (or any iterable) of data bytes to the transport: see `WriteTransport.writelines()`.

`write_eof()`
Close the write end of the transport after flushing buffered data: see `WriteTransport.write_eof()`.
18.5.5.4. StreamReaderProtocol

class asyncio.StreamReaderProtocol(stream_reader, client_connected_cb=None, loop=None)

Trivial helper class to adapt between Protocol and StreamReader. Subclass of Protocol.

stream_reader is a StreamReader instance, client_connected_cb is an optional function called with (stream_reader, stream_writer) when a connection is made, loop is the event loop instance to use.

(This is a helper class instead of making StreamReader itself a Protocol subclass, because the StreamReader has other potential uses, and to prevent the user of the StreamReader from accidentally calling inappropriate methods of the protocol.)
18.5.5.5. IncompleteReadError

*exception* asyncio.**IncompleteReadError**

Incomplete read error, subclass of **EOFError**.

**expected**

Total number of expected bytes (**int**).

**partial**

Read bytes string before the end of stream was reached (**bytes**).
18.5.5.6. Stream examples

18.5.5.6.1. TCP echo client using streams

TCP echo client using the `asyncio.open_connection()` function:

```python
import asyncio

@asyncio.coroutine
def tcp_echo_client(message, loop):
    reader, writer = yield from asyncio.open_connection()

    print('Send: %r' % message)
    writer.write(message.encode())

    data = yield from reader.read(100)
    print('Received: %r' % data.decode())

    print('Close the socket')
    writer.close()

message = 'Hello World!'
loop = asyncio.get_event_loop()
loop.run_until_complete(tcp_echo_client(message, loop))
loop.close()
```

See also: The TCP echo client protocol example uses the `BaseEventLoop.create_connection()` method.

18.5.5.6.2. TCP echo server using streams

TCP echo server using the `asyncio.start_server()` function:
import asyncio

@asyncio.coroutine
def handle_echo(reader, writer):
    data = yield from reader.read(100)
    message = data.decode()
    addr = writer.get_extra_info('peername')
    print("Received %r from %r" % (message, addr))

    print("Send: %r" % message)
    writer.write(data)
    yield from writer.drain()

    print("Close the client socket")
    writer.close()

loop = asyncio.get_event_loop()
coro = asyncio.start_server(handle_echo, '127.0.0.1')
server = loop.run_until_complete(coro)

# Serve requests until Ctrl+C is pressed
print('Serving on {}' .format(serversockets[0].getsockname()))
try:
    loop.run_forever()
except KeyboardInterrupt:
    pass

# Close the server
server.close()
loop.run_until_complete(server.wait_closed())
loop.close()

See also: The TCP echo server protocol example uses the BaseEventLoop.create_server() method.
18.5.5.6.3. Get HTTP headers

Simple example querying HTTP headers of the URL passed on the command line:

```python
import asyncio
import urllib.parse
import sys

@asyncio.coroutine
def print_http_headers(url):
    url = urllib.parse.urlsplit(url)
    if url.scheme == 'https':
        connect = asyncio.open_connection(url.hostname)
    else:
        connect = asyncio.open_connection(url.hostname)
    reader, writer = yield from connect
    query = ('HEAD {path} HTTP/1.0\r\n'  
             'Host: {hostname}\r\n'  
             '\r\n').format(path=url.path or '/', hostname=url.hostname)
    writer.write(query.encode('latin-1'))
    while True:
        line = yield from reader.readline()
        if not line:
            break
        line = line.decode('latin1').rstrip()
        if line:
            print('HTTP header> %s' % line)

    # Ignore the body, close the socket
    writer.close()

url = sys.argv[1]
loop = asyncio.get_event_loop()
task = asyncio.ensure_future(print_http_headers(url))
loop.run_until_complete(task)
```
18.5.5.6.4. Register an open socket to wait for data using streams

Coroutine waiting until a socket receives data using the `open_connection()` function:

```python
import asyncio
try:
    from socket import socketpair
except ImportError:
    from asyncio.windows_utils import socketpair

@asyncio.coroutine
def wait_for_data(loop):
    # Create a pair of connected sockets
    rsock, wsock = socketpair()

    # Register the open socket to wait for data
    reader, writer = yield from asyncio.open_connection()

    # Simulate the reception of data from the network
    loop.call_soon(wsock.send, 'abc'.encode())
```
```python
# Wait for data
data = yield from reader.read(100)

# Got data, we are done: close the socket
print("Received:", data.decode())
writer.close()

# Close the second socket
wsock.close()

loop = asyncio.get_event_loop()
loop.run_until_complete(wait_for_data(loop))
loop.close()
```

See also: The register an open socket to wait for data using a protocol example uses a low-level protocol created by the `BaseEventLoop.create_connection()` method.

The watch a file descriptor for read events example uses the low-level `BaseEventLoop.add_reader()` method to register the file descriptor of a socket.
18. Interprocess Communication and Networking

18.5. asyncio – Asynchronous I/O, event loop, coroutines and tasks
18.5.6. Subprocess
18.5.6.1. Windows event loop

On Windows, the default event loop is `SelectorEventLoop` which does not support subprocesses. `ProactorEventLoop` should be used instead. Example to use it on Windows:

```python
import asyncio, sys

if sys.platform == 'win32':
    loop = asyncio.ProactorEventLoop()
    asyncio.set_event_loop(loop)
```

See also: Available event loops and Platform support.
18.5.6.2. Create a subprocess: high-level API using Process

Coroutine asyncio.create_subprocess_exec(*args, stdin=None, stdout=None, stderr=None, loop=None, limit=None, **kwds)

Create a subprocess.

The limit parameter sets the buffer limit passed to the StreamReader. See BaseEventLoop.subprocess_exec() for other parameters.

Return a Process instance.

This function is a coroutine.

Coroutine asyncio.create_subprocess_shell(cmd, stdin=None, stdout=None, stderr=None, loop=None, limit=None, **kwds)

Run the shell command cmd.

The limit parameter sets the buffer limit passed to the StreamReader. See BaseEventLoop.subprocess_shell() for other parameters.

Return a Process instance.

It is the application’s responsibility to ensure that all whitespace and metacharacters are quoted appropriately to avoid shell injection vulnerabilities. The shlex.quote() function can be used to properly escape whitespace and shell metacharacters in strings that are going to be used to construct shell commands.
This function is a coroutine.

Use the `BaseEventLoop.connect_read_pipe()` and `BaseEventLoop.connect_write_pipe()` methods to connect pipes.
18.5.6.3. Create a subprocess: low-level API using subprocess.Popen

Run subprocesses asynchronously using the `subprocess` module.

```python
coroutine BaseEventLoop.subprocess_exec(protocol_factory, *args, stdin=subprocess.PIPE, stdout=subprocess.PIPE, stderr=subprocess.PIPE, **kwargs)
```

Create a subprocess from one or more string arguments (character strings or bytes strings encoded to the filesystem encoding), where the first string specifies the program to execute, and the remaining strings specify the program’s arguments. (Thus, together the string arguments form the `sys.argv` value of the program, assuming it is a Python script.) This is similar to the standard library `subprocess.Popen` class called with `shell=False` and the list of strings passed as the first argument; however, where `Popen` takes a single argument which is list of strings, `subprocess_exec()` takes multiple string arguments.

The `protocol_factory` must instantiate a subclass of the `asyncio.SubprocessProtocol` class.

Other parameters:

- `stdin`: Either a file-like object representing the pipe to be connected to the subprocess’s standard input stream using `connect_write_pipe()`, or the constant `subprocess.PIPE` (the default). By default a new pipe will be created and connected.
- `stdout`: Either a file-like object representing the pipe to be connected to the subprocess’s standard output stream using `connect_read_pipe()`, or the constant...
subprocess.PIPE (the default). By default a new pipe will be created and connected.

- **stderr**: Either a file-like object representing the pipe to be connected to the subprocess's standard error stream using `connect_read_pipe()`, or one of the constants `subprocess.PIPE` (the default) or `subprocess.STDOUT`. By default a new pipe will be created and connected. When `subprocess.STDOUT` is specified, the subprocess's standard error stream will be connected to the same pipe as the standard output stream.

- All other keyword arguments are passed to `subprocess.Popen` without interpretation, except for `bufsize`, `universal_newlines` and `shell`, which should not be specified at all.

Returns a pair of `(transport, protocol)`, where `transport` is an instance of `BaseSubprocessTransport`.

This method is a coroutine.

See the constructor of the `subprocess.Popen` class for parameters.

coroutine

```python
BaseEventLoop.subprocess_shell(protocol_factory, cmd, *, stdin=subprocess.PIPE, stdout=subprocess.PIPE, stderr=subprocess.PIPE, **kwargs)
```

Create a subprocess from `cmd`, which is a character string or a bytes string encoded to the filesystem encoding, using the platform's "shell" syntax. This is similar to the standard library `subprocess.Popen` class called with `shell=True`.

The `protocol_factory` must instanciate a subclass of the `asyncio.SubprocessProtocol` class.
See `subprocess_exec()` for more details about the remaining arguments.

Returns a pair of `(transport, protocol)`, where `transport` is an instance of `BaseSubprocessTransport`.

It is the application's responsibility to ensure that all whitespace and metacharacters are quoted appropriately to avoid shell injection vulnerabilities. The `shlex.quote()` function can be used to properly escape whitespace and shell metacharacters in strings that are going to be used to construct shell commands.

This method is a coroutine.

**See also:** The `BaseEventLoop.connect_read_pipe()` and `BaseEventLoop.connect_write_pipe()` methods.
18.5.6.4. Constants

asyncio.subprocess.PIPE
Special value that can be used as the stdin, stdout or stderr argument to create_subprocess_shell() and create_subprocess_exec() and indicates that a pipe to the standard stream should be opened.

asyncio.subprocess.STDOUT
Special value that can be used as the stderr argument to create_subprocess_shell() and create_subprocess_exec() and indicates that standard error should go into the same handle as standard output.

asyncio.subprocess.DEVNULL
Special value that can be used as the stdin, stdout or stderr argument to create_subprocess_shell() and create_subprocess_exec() and indicates that the special file os.devnull will be used.
18.5.6.5. Process

class asyncio.subprocess.Process

A subprocess created by the create_subprocess_exec() or the create_subprocess_shell() function.

The API of the Process class was designed to be close to the API of the subprocess.Popen class, but there are some differences:

- There is no explicit poll() method
- The communicate() and wait() methods don’t take a timeout parameter: use the wait_for() function
- The universal_newlines parameter is not supported (only bytes strings are supported)
- The wait() method of the Process class is asynchronous whereas the wait() method of the Popen class is implemented as a busy loop.

This class is not thread safe. See also the Subprocess and threads section.

coroutine wait()

Wait for child process to terminate. Set and return returncode attribute.

This method is a coroutine.

Note: This will deadlock when using stdout=PIPE or stderr=PIPE and the child process generates enough output to a pipe such that it blocks waiting for the OS pipe buffer to accept more data. Use the communicate() method when using pipes to avoid that.
**coroutine** `communicate(input=None)`

Interact with process: Send data to stdin. Read data from stdout and stderr, until end-of-file is reached. Wait for process to terminate. The optional `input` argument should be data to be sent to the child process, or None, if no data should be sent to the child. The type of `input` must be bytes.

`communicate()` returns a tuple `(stdout_data, stderr_data)`.

If a `BrokenPipeError` or `ConnectionResetError` exception is raised when writing `input` into stdin, the exception is ignored. It occurs when the process exits before all data are written into stdin.

Note that if you want to send data to the process's stdin, you need to create the Process object with `stdin=PIPE`. Similarly, to get anything other than None in the result tuple, you need to give `stdout=PIPE` and/or `stderr=PIPE` too.

This method is a **coroutine**.

---

**Note:** The data read is buffered in memory, so do not use this method if the data size is large or unlimited.

*Changed in version 3.4.2:* The method now ignores `BrokenPipeError` and `ConnectionResetError`.

**send_signal**(signal)

Sends the signal `signal` to the child process.

---

**Note:** On Windows, SIGTERM is an alias for `terminate()`.
CTRL_C_EVENT and CTRL_BREAK_EVENT can be sent to processes started with a `creationflags` parameter which includes CREATE_NEW_PROCESS_GROUP.

**terminate()**
Stop the child. On Posix OSs the method sends `signal.SIGTERM` to the child. On Windows the Win32 API function `TerminateProcess()` is called to stop the child.

**kill()**
Kills the child. On Posix OSs the function sends SIGKILL to the child. On Windows `kill()` is an alias for `terminate()`.

**stdin**
Standard input stream (`StreamWriter`), None if the process was created with `stdin=None`.

**stdout**
Standard output stream (`StreamReader`), None if the process was created with `stdout=None`.

**stderr**
Standard error stream (`StreamReader`), None if the process was created with `stderr=None`.

**Warning:** Use the `communicate()` method rather than `.stdin.write`, `.stdout.read` or `.stderr.read` to avoid deadlocks due to streams pausing reading or writing and blocking the child process.

**pid**
The identifier of the process.
Note that for processes created by the `create_subprocess_shell()` function, this attribute is the process identifier of the spawned shell.

**returncode**

Return code of the process when it exited. A None value indicates that the process has not terminated yet.

A negative value -N indicates that the child was terminated by signal N (Unix only).
18.5.6.6. Subprocess and threads

asyncio supports running subprocesses from different threads, but there are limits:

- An event loop must run in the main thread
- The child watcher must be instantiated in the main thread, before executing subprocesses from other threads. Call the `get_child_watcher()` function in the main thread to instantiate the child watcher.

The `asyncio.subprocess.Process` class is not thread safe.

See also: The Concurrency and multithreading in asyncio section.
18.5.6.7. Subprocess examples

18.5.6.7.1. Subprocess using transport and protocol

Example of a subprocess protocol using to get the output of a subprocess and to wait for the subprocess exit. The subprocess is created by the `BaseEventLoop.subprocess_exec()` method:

```python
import asyncio
import sys

class DateProtocol(asyncio.SubprocessProtocol):
    def __init__(self, exit_future):
        self.exit_future = exit_future
        self.output = bytearray()

    def pipe_data_received(self, fd, data):
        self.output.extend(data)

    def process_exited(self):
        self.exit_future.set_result(True)

@asyncio.coroutine
def get_date(loop):
    code = 'import datetime; print(datetime.datetime.now())
    exit_future = asyncio.Future(loop=loop)

    # Create the subprocess controlled by the protocol
    # redirect the standard output into a pipe
    create = loop.subprocess_exec(lambda: DateProtocol(),
                                    sys.executable, '-',
                                    stdin=None, stderr=None)

    transport, protocol = yield from create
```

```
```
18.5.6.7.2. Subprocess using streams

Example using the Process class to control the subprocess and the StreamReader class to read from the standard output. The subprocess is created by the create_subprocess_exec() function:

```python
import asyncio.subprocess
import sys

@asyncio.coroutine
def get_date():
    # Wait for the subprocess exit using the protocol of the protocol
    yield from exit_future

    # Close the stdout pipe
    transport.close()

    # Read the output which was collected by the pipe method of the protocol
    data = bytes(protocol.output)
    return data.decode('ascii').rstrip()

if sys.platform == "win32":
    loop = asyncio.ProactorEventLoop()
    asyncio.set_event_loop(loop)
else:
    loop = asyncio.get_event_loop()

date = loop.run_until_complete(get_date(loop))
print("Current date: %s" % date)
loop.close()
```
```python
code = 'import datetime; print(datetime.datetime.now())

# Create the subprocess, redirect the standard output into a pipe
create = asyncio.create_subprocess_exec(sys.executable, stdout=asyncio.subprocess.PIPE)
proc = yield from create

# Read one line of output
data = yield from proc.stdout.readline()
line = data.decode('ascii').rstrip()

# Wait for the subprocess exit
yield from proc.wait()
return line

if sys.platform == "win32":
    loop = asyncio.ProactorEventLoop()
    asyncio.set_event_loop(loop)
else:
    loop = asyncio.get_event_loop()

date = loop.run_until_complete(get_date())
print("Current date: \%s" % date)
loop.close()
```
18.5.7. Synchronization primitives

Locks:

- Lock
- Event
- Condition

Semaphores:

- Semaphore
- BoundedSemaphore

asyncio lock API was designed to be close to classes of the `threading` module (Lock, Event, Condition, Semaphore, BoundedSemaphore), but it has no `timeout` parameter. The `asyncio.wait_for()` function can be used to cancel a task after a timeout.
18.5.7.1. Locks

18.5.7.1.1. Lock

class asyncio.Lock(*, loop=None)

    Primitive lock objects.

A primitive lock is a synchronization primitive that is not owned by a particular coroutine when locked. A primitive lock is in one of two states, ‘locked’ or ‘unlocked’.

It is created in the unlocked state. It has two basic methods, acquire() and release(). When the state is unlocked, acquire() changes the state to locked and returns immediately. When the state is locked, acquire() blocks until a call to release() in another coroutine changes it to unlocked, then the acquire() call resets it to locked and returns. The release() method should only be called in the locked state; it changes the state to unlocked and returns immediately. If an attempt is made to release an unlocked lock, a RuntimeError will be raised.

When more than one coroutine is blocked in acquire() waiting for the state to turn to unlocked, only one coroutine proceeds when a release() call resets the state to unlocked; first coroutine which is blocked in acquire() is being processed.

acquire() is a coroutine and should be called with yield from.

Locks also support the context management protocol. (yield from lock) should be used as context manager expression.

This class is not thread safe.
Usage:

```python
lock = Lock()
...
yield from lock
try:
    ...
finally:
    lock.release()
```

Context manager usage:

```python
lock = Lock()
...
with (yield from lock):
    ...
```

Lock objects can be tested for locking state:

```python
if not lock.locked():
    yield from lock
else:
    # lock is acquired
    ...
```

`locked()`

Return True if the lock is acquired.

`coroutine acquire()`

Acquire a lock.

This method blocks until the lock is unlocked, then sets it to locked and returns True.

This method is a coroutine.
**release()**
Release a lock.

When the lock is locked, reset it to unlocked, and return. If any other coroutines are blocked waiting for the lock to become unlocked, allow exactly one of them to proceed.

When invoked on an unlocked lock, a `RuntimeError` is raised.

There is no return value.

---

### 18.5.7.1.2. Event

*class asyncio.Event(*, loop=None)*

An Event implementation, asynchronous equivalent to `threading.Event`.

Class implementing event objects. An event manages a flag that can be set to true with the `set()` method and reset to false with the `clear()` method. The `wait()` method blocks until the flag is true. The flag is initially false.

This class is **not thread safe**.

**clear()**
Reset the internal flag to false. Subsequently, coroutines calling `wait()` will block until `set()` is called to set the internal flag to true again.

**is_set()**
Return True if and only if the internal flag is true.
**set()**

Set the internal flag to true. All coroutines waiting for it to become true are awakened. Coroutine that call `wait()` once the flag is true will not block at all.

**coroutine `wait()`**

Block until the internal flag is true.

If the internal flag is true on entry, return True immediately. Otherwise, block until another coroutine calls `set()` to set the flag to true, then return True.

This method is a **coroutine**.

### 18.5.7.1.3. Condition

```python
class asyncio.Condition(lock=None, *, loop=None)
```

A Condition implementation, asynchronous equivalent to `threading.Condition`.

This class implements condition variable objects. A condition variable allows one or more coroutines to wait until they are notified by another coroutine.

If the `lock` argument is given and not None, it must be a `Lock` object, and it is used as the underlying lock. Otherwise, a new `Lock` object is created and used as the underlying lock.

This class is **not thread safe**.

**coroutine `acquire()`**

Acquire the underlying lock.
This method blocks until the lock is unlocked, then sets it to locked and returns True.

This method is a coroutine.

**notify\( (n=1) \)**

By default, wake up one coroutine waiting on this condition, if any. If the calling coroutine has not acquired the lock when this method is called, a `RuntimeError` is raised.

This method wakes up at most \( n \) of the coroutines waiting for the condition variable; it is a no-op if no coroutines are waiting.

**Note:** An awakened coroutine does not actually return from its `wait()` call until it can reacquire the lock. Since `notify()` does not release the lock, its caller should.

**locked()**

Return True if the underlying lock is acquired.

**notify_all()**

Wake up all coroutines waiting on this condition. This method acts like `notify()`, but wakes up all waiting coroutines instead of one. If the calling coroutine has not acquired the lock when this method is called, a `RuntimeError` is raised.

**release()**

Release the underlying lock.

When the lock is locked, reset it to unlocked, and return. If any other coroutines are blocked waiting for the lock to become unlocked, allow exactly one of them to proceed.
When invoked on an unlocked lock, a `RuntimeError` is raised.

There is no return value.

coroutine `wait()`

Wait until notified.

If the calling coroutine has not acquired the lock when this method is called, a `RuntimeError` is raised.

This method releases the underlying lock, and then blocks until it is awakened by a `notify()` or `notify_all()` call for the same condition variable in another coroutine. Once awakened, it re-acquires the lock and returns True.

This method is a coroutine.

coroutine `wait_for(predicate)`

Wait until a predicate becomes true.

The predicate should be a callable which result will be interpreted as a boolean value. The final predicate value is the return value.

This method is a coroutine.
18.5.7.2. Semaphores

18.5.7.2.1. Semaphore

class asyncio.Semaphore(value=1, *, loop=None)

A Semaphore implementation.

A semaphore manages an internal counter which is decremented by each acquire() call and incremented by each release() call. The counter can never go below zero; when acquire() finds that it is zero, it blocks, waiting until some other coroutine calls release().

Semaphores also support the context management protocol.

The optional argument gives the initial value for the internal counter; it defaults to 1. If the value given is less than 0, ValueError is raised.

This class is not thread safe.

coroutine acquire()

Acquire a semaphore.

If the internal counter is larger than zero on entry, decrement it by one and return True immediately. If it is zero on entry, block, waiting until some other coroutine has called release() to make it larger than 0, and then return True.

This method is a coroutine.

locked()
Returns True if semaphore can not be acquired immediately.

**release()**

Release a semaphore, incrementing the internal counter by one. When it was zero on entry and another coroutine is waiting for it to become larger than zero again, wake up that coroutine.

18.5.7.2.2. BoundedSemaphore

```python
class asyncio.BoundedSemaphore(value=1, *, loop=None)
```

A bounded semaphore implementation. Inherit from `Semaphore`.

This raises `ValueError` in `release()` if it would increase the value above the initial value.
18.5.8. Queues

Queues:

- Queue
- PriorityQueue
- LifoQueue

asyncio queue API was designed to be close to classes of the queue module (Queue, PriorityQueue, LifoQueue), but it has no timeout parameter. The asyncio.wait_for() function can be used to cancel a task after a timeout.
18.5.8.1. Queue

class asyncio.Queue(maxsize=0, *, loop=None)

A queue, useful for coordinating producer and consumer coroutines.

If `maxsize` is less than or equal to zero, the queue size is infinite. If it is an integer greater than 0, then `yield from put()` will block when the queue reaches `maxsize`, until an item is removed by `get()`.

Unlike the standard library `queue`, you can reliably know this Queue's size with `qsize()`, since your single-threaded asyncio application won't be interrupted between calling `qsize()` and doing an operation on the Queue.

This class is **not thread safe**.

*Changed in version 3.4.4:* New `join()` and `task_done()` methods.

`empty()`

Return True if the queue is empty, False otherwise.

`full()`

Return True if there are `maxsize` items in the queue.

**Note:** If the Queue was initialized with `maxsize=0` (the default), then `full()` is never True.

`coroutine get()`
Remove and return an item from the queue. If queue is empty, wait until an item is available.

This method is a coroutine.

**See also:** The `empty()` method.

**get_nowait()**
Remove and return an item from the queue.

Return an item if one is immediately available, else raise `QueueEmpty`.

**coroutine join()**
Block until all items in the queue have been gotten and processed.

The count of unfinished tasks goes up whenever an item is added to the queue. The count goes down whenever a consumer thread calls `task_done()` to indicate that the item was retrieved and all work on it is complete. When the count of unfinished tasks drops to zero, `join()` unblocks.

This method is a coroutine.

*New in version 3.4.4.*

**coroutine put(item)**
Put an item into the queue. If the queue is full, wait until a free slot is available before adding item.

This method is a coroutine.
See also: The full() method.

**put_nowait(item)**

Put an item into the queue without blocking.

If no free slot is immediately available, raise QueueFull.

**qsize()**

Number of items in the queue.

**task_done()**

Indicate that a formerly enqueued task is complete.

Used by queue consumers. For each get() used to fetch a task, a subsequent call to task_done() tells the queue that the processing on the task is complete.

If a join() is currently blocking, it will resume when all items have been processed (meaning that a task_done() call was received for every item that had been put() into the queue).

 Raises ValueError if called more times than there were items placed in the queue.

New in version 3.4.4.

**maxsize**

Number of items allowed in the queue.
18.5.8.2. PriorityQueue

```python
class asyncio.PriorityQueue
    A subclass of Queue; retrieves entries in priority order (lowest first).

    Entries are typically tuples of the form: (priority number, data).
```
18.5.8.3. LifoQueue

```python
class asyncio.LifoQueue
```

A subclass of Queue that retrieves most recently added entries first.

18.5.8.3.1. Exceptions

```python
exception asyncio.QueueEmpty

Exception raised when the get_nowait() method is called on a Queue object which is empty.
```

```python
exception asyncio.QueueFull

Exception raised when the put_nowait() method is called on a Queue object which is full.
```
18. Interprocess Communication and Networking » 18.5. asyncio – Asynchronous I/O, event loop, coroutines and tasks »
18.5.9. Develop with asyncio

Asynchronous programming is different than classical “sequential” programming. This page lists common traps and explains how to avoid them.
The implementation of asyncio has been written for performance. In order to ease the development of asynchronous code, you may wish to enable debug mode.

To enable all debug checks for an application:

- Enable the asyncio debug mode globally by setting the environment variable PYTHONASYNCIODEBUG to 1, or by calling BaseEventLoop.set_debug().
- Set the log level of the asyncio logger to logging.DEBUG. For example, call logging.basicConfig(level=logging.DEBUG) at startup.
- Configure the warnings module to display ResourceWarning warnings. For example, use the -Wdefault command line option of Python to display them.

Examples debug checks:

- Log coroutines defined but never “yielded from”
- call_soon() and call_at() methods raise an exception if they are called from the wrong thread.
- Log the execution time of the selector
- Log callbacks taking more than 100 ms to be executed. The BaseEventLoop.slow_callback_duration attribute is the minimum duration in seconds of “slow” callbacks.
- ResourceWarning warnings are emitted when transports and event loops are not closed explicitly.

See also: The BaseEventLoop.set_debug() method and the asyncio logger.
18.5.9.2. Cancellation

Cancellation of tasks is not common in classic programming. In asynchronous programming, not only it is something common, but you have to prepare your code to handle it.

Futures and tasks can be cancelled explicitly with their `Future.cancel()` method. The `wait_for()` function cancels the waited task when the timeout occurs. There are many other cases where a task can be cancelled indirectly.

Don't call `set_result()` or `set_exception()` method of `Future` if the future is cancelled: it would fail with an exception. For example, write:

```python
if not fut.cancelled():
    fut.set_result('done')
```

Don't schedule directly a call to the `set_result()` or the `set_exception()` method of a future with `BaseEventLoop.call_soon()`: the future can be cancelled before its method is called.

If you wait for a future, you should check early if the future was cancelled to avoid useless operations. Example:

```python
@coroutine
def slow_operation(fut):
    if fut.cancelled():
        return
    # ... slow computation ...
    yield from fut
    # ...
```
The `shield()` function can also be used to ignore cancellation.
18.5.9.3. Concurrency and multithreading

An event loop runs in a thread and executes all callbacks and tasks in the same thread. While a task is running in the event loop, no other task is running in the same thread. But when the task uses `yield from`, the task is suspended and the event loop executes the next task.

To schedule a callback from a different thread, the `BaseEventLoop.call_soon_threadsafe()` method should be used. Example:

```python
loop.call_soon_threadsafe(callback, *args)
```

Most asyncio objects are not thread safe. You should only worry if you access objects outside the event loop. For example, to cancel a future, don’t call directly its `Future.cancel()` method, but:

```python
loop.call_soon_threadsafe(fut.cancel)
```

To handle signals and to execute subprocesses, the event loop must be run in the main thread.

To schedule a coroutine object from a different thread, the `run_coroutine_threadsafe()` function should be used. It returns a `concurrent.futures.Future` to access the result:

```python
future = asyncio.run_coroutine_threadsafe(coro_func)  
result = future.result(timeout)  # Wait for the result
```

The `BaseEventLoop.run_in_executor()` method can be used
with a thread pool executor to execute a callback in different thread to not block the thread of the event loop.

**See also:** The *Synchronization primitives* section describes ways to synchronize tasks.

The *Subprocess and threads* section lists asyncio limitations to run subprocesses from different threads.
18.5.9.4. Handle blocking functions correctly

Blocking functions should not be called directly. For example, if a function blocks for 1 second, other tasks are delayed by 1 second which can have an important impact on reactivity.

For networking and subprocesses, the asyncio module provides high-level APIs like protocols.

An executor can be used to run a task in a different thread or even in a different process, to not block the thread of the event loop. See the BaseEventLoop.run_in_executor() method.

See also: The Delayed calls section details how the event loop handles time.
18.5.9.5. Logging

The `asyncio` module logs information with the `logging` module in the logger 'asyncio'. 
18.5.9.6. Detect coroutine objects never scheduled

When a coroutine function is called and its result is not passed to ensure_future() or to the BaseEventLoop.create_task() method, the execution of the coroutine object will never be scheduled which is probably a bug. Enable the debug mode of asyncio to log a warning to detect it.

Example with the bug:

```python
import asyncio

@asyncio.coroutine
def test():
    print("never scheduled")

test()
```

Output in debug mode:

```
Coroutine test() at test.py:3 was never yielded from Coroutine object created at (most recent call last):
    File "test.py", line 7, in <module>
    test()
```

The fix is to call the ensure_future() function or the BaseEventLoop.create_task() method with the coroutine object.

See also: Pending task destroyed.
18.5.9.7. Detect exceptions never consumed

Python usually calls `sys.displayhook()` on unhandled exceptions. If `Future.set_exception()` is called, but the exception is never consumed, `sys.displayhook()` is not called. Instead, a log is emitted when the future is deleted by the garbage collector, with the traceback where the exception was raised.

Example of unhandled exception:

```python
import asyncio

@asyncio.coroutine
def bug():
    raise Exception("not consumed")

loop = asyncio.get_event_loop()
asyncio.ensure_future(bug())
loop.run_forever()
loop.close()
```

Output:

```
Task exception was never retrieved
future: <Task finished coro=<coro() done, defined at Traceback (most recent call last):
  File "asyncio/tasks.py", line 237, in _step
      result = next(coro)
  File "asyncio/coroutines.py", line 141, in coro
      res = func(*args, **kw)
  File "test.py", line 5, in bug
      raise Exception("not consumed")
Exception: not consumed
```
Enable the debug mode of asyncio to get the traceback where the task was created. Output in debug mode:

```
Task exception was never retrieved
future: <Task finished coro=<bug() done, defined at source_traceback: Object created at (most recent call last):
  File "test.py", line 8, in <module>
    asyncio.ensure_future(bug())
Traceback (most recent call last):
  File "asyncio/tasks.py", line 237, in _step
    result = next(coro)
  File "asyncio/coroutines.py", line 79, in __next_
    return next(self.gen)
  File "asyncio/coroutines.py", line 141, in coro
    res = func(*args, **kw)
  File "test.py", line 5, in bug
    raise Exception("not consumed")
Exception: not consumed
```

There are different options to fix this issue. The first option is to chain the coroutine in another coroutine and use classic try/except:

```
@asyncio.coroutine
def handle_exception():
    try:
        yield from bug()
    except Exception:
        print("exception consumed")

loop = asyncio.get_event_loop()
asyncio.ensure_future(handle_exception())
loop.run_forever()
loop.close()
```
Another option is to use the `BaseEventLoop.run_until_complete()` function:

```python
task = asyncio.ensure_future(bug())
try:
    loop.run_until_complete(task)
except Exception:
    print("exception consumed")
```

See also: The `Future.exception()` method.
18.5.9.8. Chain coroutines correctly

When a coroutine function calls other coroutine functions and tasks, they should be chained explicitly with `yield from`. Otherwise, the execution is not guaranteed to be sequential.

Example with different bugs using `asyncio.sleep()` to simulate slow operations:

```python
import asyncio

@asyncio.coroutine
def create():
    yield from asyncio.sleep(3.0)
    print("(1) create file")

@asyncio.coroutine
def write():
    yield from asyncio.sleep(1.0)
    print("(2) write into file")

@asyncio.coroutine
def close():
    print("(3) close file")

@asyncio.coroutine
def test():
    asyncio.ensure_future(create())
    asyncio.ensure_future(write())
    asyncio.ensure_future(close())
    yield from asyncio.sleep(2.0)
    loop.stop()

loop = asyncio.get_event_loop()
asyncio.ensure_future(test())
```
```python
loop.run_forever()
print("Pending tasks at exit: %s" % asyncio.Task.all_tasks)
loop.close()
```

Expected output:

```
(1) create file
(2) write into file
(3) close file
Pending tasks at exit: set()
```

Actual output:

```
(3) close file
(2) write into file
Pending tasks at exit: {<Task pending create() at test.py:7 wait_for=<Future pending cb=[Task._wakeup()]>}
Task was destroyed but it is pending!
task: <Task pending create() done at test.py:5 wait_for=<Future pending cb=[Task._wakeup()]>)
```

The loop stopped before the `create()` finished, `close()` has been called before `write()`, whereas coroutine functions were called in this order: `create()`, `write()`, `close()`.

To fix the example, tasks must be marked with `yield from`:

```python
@asyncio.coroutine
def test():
    yield from asyncio.ensure_future(create())
    yield from asyncio.ensure_future(write())
    yield from asyncio.ensure_future(close())
    yield from asyncio.sleep(2.0)
loop.stop()
```

Or without `asyncio.ensure_future()`:
@asyncio.coroutine
def test():
    yield from create()
    yield from write()
    yield from close()
    yield from asyncio.sleep(2.0)
    loop.stop()
18.5.9.9. Pending task destroyed

If a pending task is destroyed, the execution of its wrapped coroutine did not complete. It is probably a bug and so a warning is logged.

Example of log:

```
Task was destroyed but it is pending!
task: <Task pending coro=<kill_me() done, defined at test.py:5>
wait_for=<Future pending cb=[Task._wakeup()]>>
```

Enable the debug mode of asyncio to get the traceback where the task was created. Example of log in debug mode:

```
Task was destroyed but it is pending!
source_traceback: Object created at (most recent call last):
   File "test.py", line 15, in <module>
     task = asyncio.ensure_future(coro, loop=loop)
task: <Task pending coro=<kill_me() done, defined at test.py:5>
wait_for=<Future pending cb=[Task._wakeup()]> created at test.py:15>
```

See also: Detect coroutine objects never scheduled.
18.5.9.10. Close transports and event loops

When a transport is no more needed, call its close() method to release resources. Event loops must also be closed explicitly.

If a transport or an event loop is not closed explicitly, a ResourceWarning warning will be emitted in its destructor. By default, ResourceWarning warnings are ignored. The Debug mode of asyncio section explains how to display them.
18.6. **asyncore** — Asynchronous socket handler

**Source code:** Lib/asyncore.py

**Note:** This module exists for backwards compatibility only. For new code we recommend using **asyncio**.

This module provides the basic infrastructure for writing asynchronous socket service clients and servers.

There are only two ways to have a program on a single processor do “more than one thing at a time.” Multi-threaded programming is the simplest and most popular way to do it, but there is another very different technique, that lets you have nearly all the advantages of multi-threading, without actually using multiple threads. It’s really only practical if your program is largely I/O bound. If your program is processor bound, then pre-emptive scheduled threads are probably what you really need. Network servers are rarely processor bound, however.

If your operating system supports the `select()` system call in its I/O library (and nearly all do), then you can use it to juggle multiple communication channels at once; doing other work while your I/O is taking place in the “background.” Although this strategy can seem strange and complex, especially at first, it is in many ways easier to understand and control than multi-threaded programming. The **asyncore** module solves many of the difficult problems for you, making the task of building sophisticated high-performance network
servers and clients a snap. For “conversational” applications and protocols the companion asynchat module is invaluable.

The basic idea behind both modules is to create one or more network channels, instances of class asyncore.dispatcher and asynchat.async_chat. Creating the channels adds them to a global map, used by the loop() function if you do not provide it with your own map.

Once the initial channel(s) is(are) created, calling the loop() function activates channel service, which continues until the last channel (including any that have been added to the map during asynchronous service) is closed.

asyncore.loop([timeout[, use_poll[, map[, count]]]])

Enter a polling loop that terminates after count passes or all open channels have been closed. All arguments are optional. The count parameter defaults to None, resulting in the loop terminating only when all channels have been closed. The timeout argument sets the timeout parameter for the appropriate select() or poll() call, measured in seconds; the default is 30 seconds. The use_poll parameter, if true, indicates that poll() should be used in preference to select() (the default is False).

The map parameter is a dictionary whose items are the channels to watch. As channels are closed they are deleted from their map. If map is omitted, a global map is used. Channels (instances of asyncore.dispatcher, asynchat.async_chat and subclasses thereof) can freely be mixed in the map.

class asyncore.dispatcher

The dispatcher class is a thin wrapper around a low-level socket
object. To make it more useful, it has a few methods for event-handling which are called from the asynchronous loop. Otherwise, it can be treated as a normal non-blocking socket object.

The firing of low-level events at certain times or in certain connection states tells the asynchronous loop that certain higher-level events have taken place. For example, if we have asked for a socket to connect to another host, we know that the connection has been made when the socket becomes writable for the first time (at this point you know that you may write to it with the expectation of success). The implied higher-level events are:

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>handle_connect()</td>
<td>Implied by the first read or write event</td>
</tr>
<tr>
<td>handle_close()</td>
<td>Implied by a read event with no data available</td>
</tr>
<tr>
<td>handle_accepted()</td>
<td>Implied by a read event on a listening socket</td>
</tr>
</tbody>
</table>

During asynchronous processing, each mapped channel's `readable()` and `writable()` methods are used to determine whether the channel's socket should be added to the list of channels `select()`ed or `poll()`ed for read and write events.

Thus, the set of channel events is larger than the basic socket events. The full set of methods that can be overridden in your subclass follows:

**handle_read()**

 Called when the asynchronous loop detects that a `read()` call on the channel's socket will succeed.

**handle_write()**
Called when the asynchronous loop detects that a writable socket can be written. Often this method will implement the necessary buffering for performance. For example:

```python
def handle_write(self):
    sent = self.send(self.buffer)
    self.buffer = self.buffer[:sent:]
```

handle_expt()
Called when there is out of band (OOB) data for a socket connection. This will almost never happen, as OOB is tenuously supported and rarely used.

handle_connect()
Called when the active opener’s socket actually makes a connection. Might send a “welcome” banner, or initiate a protocol negotiation with the remote endpoint, for example.

handle_close()
Called when the socket is closed.

handle_error()
Called when an exception is raised and not otherwise handled. The default version prints a condensed traceback.

handle_accept()
Called on listening channels (passive openers) when a connection can be established with a new remote endpoint that has issued a `connect()` call for the local endpoint. Deprecated in version 3.2; use `handle_accepted()` instead.

*Deprecated since version 3.2.*
**handle_accepted**(sock, addr)

Called on listening channels (passive openers) when a connection has been established with a new remote endpoint that has issued a `connect()` call for the local endpoint. `sock` is a *new* socket object usable to send and receive data on the connection, and `addr` is the address bound to the socket on the other end of the connection.

*New in version 3.2.*

**readable()**

Called each time around the asynchronous loop to determine whether a channel's socket should be added to the list on which read events can occur. The default method simply returns `True`, indicating that by default, all channels will be interested in read events.

**writable()**

Called each time around the asynchronous loop to determine whether a channel's socket should be added to the list on which write events can occur. The default method simply returns `True`, indicating that by default, all channels will be interested in write events.

In addition, each channel delegates or extends many of the socket methods. Most of these are nearly identical to their socket partners.

**create_socket**(family=socket.AF_INET,
   type=socket.SOCK_STREAM)

This is identical to the creation of a normal socket, and will use the same options for creation. Refer to the `socket` documentation for information on creating sockets.
Changed in version 3.3: family and type arguments can be omitted.

**connect**(address)
As with the normal socket object, address is a tuple with the first element the host to connect to, and the second the port number.

**send**(data)
Send data to the remote end-point of the socket.

**recv**(buffer_size)
Read at most buffer_size bytes from the socket's remote end-point. An empty bytes object implies that the channel has been closed from the other end.

Note that recv() may raise BlockingIOError, even though select.select() or select.poll() has reported the socket ready for reading.

**listen**(backlog)
Listen for connections made to the socket. The backlog argument specifies the maximum number of queued connections and should be at least 1; the maximum value is system-dependent (usually 5).

**bind**(address)
Bind the socket to address. The socket must not already be bound. (The format of address depends on the address family — refer to the socket documentation for more information.) To mark the socket as re-usable (setting the SO_REUSEADDR option), call the dispatcher object's set_reuse_addr() method.
accept()
Accept a connection. The socket must be bound to an address and listening for connections. The return value can be either None or a pair (conn, address) where conn is a new socket object usable to send and receive data on the connection, and address is the address bound to the socket on the other end of the connection. When None is returned it means the connection didn't take place, in which case the server should just ignore this event and keep listening for further incoming connections.

close()
Close the socket. All future operations on the socket object will fail. The remote end-point will receive no more data (after queued data is flushed). Sockets are automatically closed when they are garbage-collected.

class asyncore.dispatcher_with_send
A dispatcher subclass which adds simple buffered output capability, useful for simple clients. For more sophisticated usage use asyncchat.async_chat.

class asyncore.file_dispatcher
A file_dispatcher takes a file descriptor or file object along with an optional map argument and wraps it for use with the poll() or loop() functions. If provided a file object or anything with a fileno() method, that method will be called and passed to the file_wrapper constructor. Availability: UNIX.

class asyncore.file_wrapper
A file_wrapper takes an integer file descriptor and calls os.dup()
to duplicate the handle so that the original handle may be closed independently of the file_wrapper. This class implements sufficient methods to emulate a socket for use by the file_dispatcher class. Availability: UNIX.
18.6.1. asyncore Example basic HTTP client

Here is a very basic HTTP client that uses the `dispatcher` class to implement its socket handling:

```python
import asyncore

class HTTPClient(asyncore.dispatcher):
    def __init__(self, host, path):
        asyncore.dispatcher.__init__(self)
        self.create_socket()
        self.connect((host, 80))
        self.buffer = bytes('GET %s HTTP/1.0\r\nHost: %s
' % (path, host), 'ascii')

    def handle_connect(self):
        pass

    def handle_close(self):
        self.close()

    def handle_read(self):
        print(self.recv(8192))

    def writable(self):
        return (len(self.buffer) > 0)

    def handle_write(self):
        sent = self.send(self.buffer)
        self.buffer = self.buffer[:sent]

client = HTTPClient('www.python.org', '/')
```
asyncore.loop()
18.6.2. asyncore Example basic echo server

Here is a basic echo server that uses the `dispatcher` class to accept connections and dispatches the incoming connections to a handler:

```python
import asyncore

class EchoHandler(asyncore.dispatcher_with_send):
    def handle_read(self):
        data = self.recv(8192)
        if data:
            self.send(data)

class EchoServer(asyncore.dispatcher):
    def __init__(self, host, port):
        asyncore.dispatcher.__init__(self)
        self.create_socket()
        self.setReuseAddr()
        self.bind((host, port))
        self.listen(5)

    def handle_accepted(self, sock, addr):
        print('Incoming connection from %s' % repr(addr))
        handler = EchoHandler(sock)

server = EchoServer('localhost', 8080)
asyncore.loop()
```
18.7. **asynchat** — Asynchronous socket command/response handler

**Source code:** Lib/asynchat.py

**Note:** This module exists for backwards compatibility only. For new code we recommend using **asyncio**.

This module builds on the **asyncore** infrastructure, simplifying asynchronous clients and servers and making it easier to handle protocols whose elements are terminated by arbitrary strings, or are of variable length. **asynchat** defines the abstract class **async_chat** that you subclass, providing implementations of the `collect_incoming_data()` and `found_terminator()` methods. It uses the same asynchronous loop as **asyncore**, and the two types of channel, **asyncore.dispatcher** and **asynchat.async_chat**, can freely be mixed in the channel map. Typically an **asyncore.dispatcher** server channel generates new **asynchat.async_chat** channel objects as it receives incoming connection requests.

**class** `asynchat.**async_chat**`

This class is an abstract subclass of **asyncore.dispatcher**. To make practical use of the code you must subclass **async_chat**, providing meaningful `collect_incoming_data()` and `found_terminator()` methods. The **asyncore.dispatcher** methods can be used, although not all make sense in a message/response context.
Like `asyncore.dispatcher`, `async_chat` defines a set of events that are generated by an analysis of socket conditions after a `select()` call. Once the polling loop has been started the `async_chat` object's methods are called by the event-processing framework with no action on the part of the programmer.

Two class attributes can be modified, to improve performance, or possibly even to conserve memory.

**ac_in_buffer_size**

The asynchronous input buffer size (default 4096).

**ac_out_buffer_size**

The asynchronous output buffer size (default 4096).

Unlike `asyncore.dispatcher`, `async_chat` allows you to define a first-in-first-out queue (fifo) of *producers*. A producer need have only one method, `more()`, which should return data to be transmitted on the channel. The producer indicates exhaustion (*i.e.* that it contains no more data) by having its `more()` method return the empty bytes object. At this point the `async_chat` object removes the producer from the fifo and starts using the next producer, if any. When the producer fifo is empty the `handle_write()` method does nothing. You use the channel object's `set_terminator()` method to describe how to recognize the end of, or an important breakpoint in, an incoming transmission from the remote endpoint.

To build a functioning `async_chat` subclass your input methods `collect_incoming_data()` and `found_terminator()` must handle the data that the channel receives asynchronously. The methods are described below.
async_chat.close_when_done()

Pushes a None on to the producer fifo. When this producer is popped off the fifo it causes the channel to be closed.

async_chat.collect_incoming_data(data)

Called with data holding an arbitrary amount of received data. The default method, which must be overridden, raises a NotImplementedError exception.

async_chat.discard_buffers()

In emergencies this method will discard any data held in the input and/or output buffers and the producer fifo.

async_chat.found_terminator()

Called when the incoming data stream matches the termination condition set by set_terminator(). The default method, which must be overridden, raises a NotImplementedError exception. The buffered input data should be available via an instance attribute.

async_chat.get_terminator()

Returns the current terminator for the channel.

async_chat.push(data)

Pushes data on to the channel's fifo to ensure its transmission. This is all you need to do to have the channel write the data out to the network, although it is possible to use your own producers in more complex schemes to implement encryption and chunking, for example.

async_chat.push_with_producer(producer)

Takes a producer object and adds it to the producer fifo associated
with the channel. When all currently-pushed producers have been exhausted the channel will consume this producer's data by calling its `more()` method and send the data to the remote endpoint.

async_chat.set_terminator(term)

Sets the terminating condition to be recognized on the channel. `term` may be any of three types of value, corresponding to three different ways to handle incoming protocol data.

<table>
<thead>
<tr>
<th>term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td>Will call <code>found_terminator()</code> when the string is found in the input stream</td>
</tr>
<tr>
<td>integer</td>
<td>Will call <code>found_terminator()</code> when the indicated number of characters have been received</td>
</tr>
<tr>
<td>None</td>
<td>The channel continues to collect data forever</td>
</tr>
</tbody>
</table>

Note that any data following the terminator will be available for reading by the channel after `found_terminator()` is called.
18.7.1. asynchat Example

The following partial example shows how HTTP requests can be read with `async_chat`. A web server might create an `http_request_handler` object for each incoming client connection. Notice that initially the channel terminator is set to match the blank line at the end of the HTTP headers, and a flag indicates that the headers are being read.

Once the headers have been read, if the request is of type POST (indicating that further data are present in the input stream) then the Content-Length: header is used to set a numeric terminator to read the right amount of data from the channel.

The `handle_request()` method is called once all relevant input has been marshalled, after setting the channel terminator to None to ensure that any extraneous data sent by the web client are ignored.

```python
import asyncchat

class http_request_handler(asyncchat.async_chat):
    def __init__(self, sock, addr, sessions, log):
        asyncchat.async_chat.__init__(self, sock=sock)
        self.addr = addr
        self.sessions = sessions
        self.ibuffer = []
        self.obuffer = b"
        self.set_terminator(b"\n\n\n")
        self.reading_headers = True
        self.handling = False
        self.cgi_data = None
        self.log = log
```
```python
def collect_incoming_data(self, data):
    """Buffer the data""
    self.ibuffer.append(data)

def found_terminator(self):
    if self.reading_headers:
        self.reading_headers = False
        self.parse_headers(b"".join(self.ibuffer)
        self.ibuffer = []
    if self.op.upper() == b"POST":
        clen = self.headers.getheader("content-length")
        self.set_terminator(int(clen))
    else:
        self.handling = True
        self.set_terminator(None)
        self.handle_request()
    elif not self.handling:
        self.set_terminator(None)  # browsers sometimes over-send
        self.cgi_data = parse(self.headers, b"
        self.handling = True
        self.ibuffer = []
        self.handle_request()
```
18.8. **signal** — Set handlers for asynchronous events

This module provides mechanisms to use signal handlers in Python.
18.8.1. General rules

The `signal.signal()` function allows to define custom handlers to be executed when a signal is received. A small number of default handlers are installed: SIGPIPE is ignored (so write errors on pipes and sockets can be reported as ordinary Python exceptions) and SIGINT is translated into a `KeyboardInterrupt` exception.

A handler for a particular signal, once set, remains installed until it is explicitly reset (Python emulates the BSD style interface regardless of the underlying implementation), with the exception of the handler for SIGCHLD, which follows the underlying implementation.

There is no way to “block” signals temporarily from critical sections (since this is not supported by all Unix flavors).

18.8.1.1. Execution of Python signal handlers

A Python signal handler does not get executed inside the low-level (C) signal handler. Instead, the low-level signal handler sets a flag which tells the virtual machine to execute the corresponding Python signal handler at a later point (for example at the next bytecode instruction). This has consequences:

- It makes little sense to catch synchronous errors like SIGFPE or SIGSEGV that are caused by an invalid operation in C code. Python will return from the signal handler to the C code, which is likely to raise the same signal again, causing Python to apparently hang. From Python 3.3 onwards, you can use the `faulthandler` module to report on synchronous errors.
- A long-running calculation implemented purely in C (such as regular expression matching on a large body of text) may run
uninterrupted for an arbitrary amount of time, regardless of any signals received. The Python signal handlers will be called when the calculation finishes.

18.8.1.2. Signals and threads

Python signal handlers are always executed in the main Python thread, even if the signal was received in another thread. This means that signals can't be used as a means of inter-thread communication. You can use the synchronization primitives from the `threading` module instead.

Besides, only the main thread is allowed to set a new signal handler.
18.8.2. Module contents

*Changed in version 3.5:* signal (SIG*), handler (SIG_DFL, SIG_IGN) and sigmask (SIG_BLOCK, SIG_UNBLOCK, SIG_SETMASK) related constants listed below were turned into enums. `getsignal()`, `pthread_sigmask()`, `sigpending()` and `sigwait()` functions return human-readable enums.

The variables defined in the `signal` module are:

**signal.SIG_DFL**

This is one of two standard signal handling options; it will simply perform the default function for the signal. For example, on most systems the default action for SIGQUIT is to dump core and exit, while the default action for SIGCHLD is to simply ignore it.

**signal.SIG_IGN**

This is another standard signal handler, which will simply ignore the given signal.

**SIG* **

All the signal numbers are defined symbolically. For example, the hangup signal is defined as `signal.SIGHUP`; the variable names are identical to the names used in C programs, as found in `<signal.h>`. The Unix man page for `signal()` lists the existing signals (on some systems this is `signal(2)`, on others the list is in `signal(7)`). Note that not all systems define the same set of signal names; only those names defined by the system are defined by this module.

**signal.CTRL_C_EVENT**
The signal corresponding to the Ctrl+C keystroke event. This signal can only be used with `os.kill()`.

Availability: Windows.

*New in version 3.2.*

**signal.CTRL_BREAK_EVENT**

The signal corresponding to the Ctrl+Break keystroke event. This signal can only be used with `os.kill()`.

Availability: Windows.

*New in version 3.2.*

**signal.NSIG**

One more than the number of the highest signal number.

**signal.ITIMER_REAL**

Decrements interval timer in real time, and delivers SIGALRM upon expiration.

**signal.ITIMER_VIRTUAL**

Decrements interval timer only when the process is executing, and delivers SIGVTALRM upon expiration.

**signal.ITIMER_PROF**

Decrements interval timer both when the process executes and when the system is executing on behalf of the process. Coupled with ITIMER_VIRTUAL, this timer is usually used to profile the time spent by the application in user and kernel space. SIGPROF is delivered upon expiration.

**signal.SIG_BLOCK**
A possible value for the *how* parameter to `pthread_sigmask()` indicating that signals are to be blocked.

*New in version 3.3.*

`signal.SIG_UNBLOCK`

A possible value for the *how* parameter to `pthread_sigmask()` indicating that signals are to be unblocked.

*New in version 3.3.*

`signal.SIG_SETMASK`

A possible value for the *how* parameter to `pthread_sigmask()` indicating that the signal mask is to be replaced.

*New in version 3.3.*

The `signal` module defines one exception:

*exception* `signal.TimerError`

Raised to signal an error from the underlying `setitimer()` or `getitimer()` implementation. Expect this error if an invalid interval timer or a negative time is passed to `setitimer()`. This error is a subtype of `OSError`.

*New in version 3.3:* This error used to be a subtype of `IOError`, which is now an alias of `OSError`.

The `signal` module defines the following functions:

`signal.alarm(time)`

If `time` is non-zero, this function requests that a SIGALRM signal be sent to the process in `time` seconds. Any previously scheduled
alarm is canceled (only one alarm can be scheduled at any time). The returned value is then the number of seconds before any previously set alarm was to have been delivered. If time is zero, no alarm is scheduled, and any scheduled alarm is canceled. If the return value is zero, no alarm is currently scheduled. (See the Unix man page *alarm(2)*.) Availability: Unix.

**`signal.getsignal(signalnum)`**

Return the current signal handler for the signal `signalnum`. The returned value may be a callable Python object, or one of the special values `signal.SIG_IGN`, `signal.SIG_DFL` or `None`. Here, `signal.SIG_IGN` means that the signal was previously ignored, `signal.SIG_DFL` means that the default way of handling the signal was previously in use, and `None` means that the previous signal handler was not installed from Python.

**`signal.pause()`**

Cause the process to sleep until a signal is received; the appropriate handler will then be called. Returns nothing. Not on Windows. (See the Unix man page *signal(2)*.)

See also `sigwait()`, `sigwaitinfo()`, `sigtimedwait()` and `sigpending()`.

**`signal.pthread_kill(thread_id, signalnum)`**

Send the signal `signalnum` to the thread `thread_id`, another thread in the same process as the caller. The target thread can be executing any code (Python or not). However, if the target thread is executing the Python interpreter, the Python signal handlers will be *executed by the main thread*. Therefore, the only point of sending a signal to a particular Python thread would be to force a running system call to fail with `InterruptedError`. 
Use `threading.get_ident()` or the `ident` attribute of `threading.Thread` objects to get a suitable value for `thread_id`.

If `signalnum` is 0, then no signal is sent, but error checking is still performed; this can be used to check if the target thread is still running.

Availability: Unix (see the man page `pthread_kill(3)` for further information).

See also `os.kill()`.

`New in version 3.3.`

`signal.pthread_sigmask( how, mask )`

Fetch and/or change the signal mask of the calling thread. The signal mask is the set of signals whose delivery is currently blocked for the caller. Return the old signal mask as a set of signals.

The behavior of the call is dependent on the value of `how`, as follows.

- **SIG_BLOCK**: The set of blocked signals is the union of the current set and the `mask` argument.
- **SIG_UNBLOCK**: The signals in `mask` are removed from the current set of blocked signals. It is permissible to attempt to unblock a signal which is not blocked.
- **SIG_SETMASK**: The set of blocked signals is set to the `mask` argument.

`mask` is a set of signal numbers (e.g. `{signal.SIGINT, signal.SIGTERM}`). Use `range(1, signal.NSIG)` for a full mask including all signals.
For example, `signal.pthread_sigmask(signal.SIG_BLOCK, [])` reads the signal mask of the calling thread.

Availability: Unix. See the man page `sigprocmask(3)` and `pthread_sigmask(3)` for further information.

See also `pause()`, `sigpending()` and `sigwait()`.

*New in version 3.3.*

`signal.setitimer(which, seconds[, interval])`  
Sets given interval timer (one of `signal.ITIMER_REAL`, `signal.ITIMER_VIRTUAL` or `signal.ITIMER_PROF`) specified by `which` to fire after `seconds` (float is accepted, different from `alarm()`) and after that every `interval` seconds. The interval timer specified by `which` can be cleared by setting `seconds` to zero.

When an interval timer fires, a signal is sent to the process. The signal sent is dependent on the timer being used; `signal.ITIMER_REAL` will deliver SIGALRM, `signal.ITIMER_VIRTUAL` sends SIGVTALRM, and `signal.ITIMER_PROF` will deliver SIGPROF.

The old values are returned as a tuple: (delay, interval).

Attempting to pass an invalid interval timer will cause an `ItimerError`. Availability: Unix.

`signal.getitimer(which)`  
Returns current value of a given interval timer specified by `which`. Availability: Unix.
**signal.set_wakeup_fd(fd)**

Set the wakeup file descriptor to *fd*. When a signal is received, the signal number is written as a single byte into the fd. This can be used by a library to wakeup a poll or select call, allowing the signal to be fully processed.

The old wakeup fd is returned. *fd* must be non-blocking. It is up to the library to remove any bytes before calling poll or select again.

Use for example `struct.unpack('%uB' % len(data), data)` to decode the signal numbers list.

When threads are enabled, this function can only be called from the main thread; attempting to call it from other threads will cause a `ValueError` exception to be raised.

*Changed in version 3.5:* On Windows, the function now also supports socket handles.

**signal.siginterrupt(signalnum, flag)**

Change system call restart behaviour: if *flag* is `False`, system calls will be restarted when interrupted by signal *signalnum*, otherwise system calls will be interrupted. Returns nothing. Availability: Unix (see the man page `siginterrupt(3)` for further information).

Note that installing a signal handler with `signal()` will reset the restart behaviour to interruptible by implicitly calling `siginterrupt()` with a true *flag* value for the given signal.

**signal.signal(signalnum, handler)**

Set the handler for signal *signalnum* to the function *handler*. *handler* can be a callable Python object taking two arguments (see below), or one of the special values `signal.SIG_IGN` or
**signal.SIG_DFL**. The previous signal handler will be returned (see the description of `getsignal()` above). (See the Unix man page `signal(2)`.)

When threads are enabled, this function can only be called from the main thread; attempting to call it from other threads will cause a `ValueError` exception to be raised.

The **handler** is called with two arguments: the signal number and the current stack frame (None or a frame object; for a description of frame objects, see the description in the type hierarchy or see the attribute descriptions in the `inspect` module).

On Windows, `signal()` can only be called with SIGABRT, SIGFPE, SIGILL, SIGINT, SIGSEGV, or SIGTERM. A `ValueError` will be raised in any other case.

**signal.sigpending()**

Examine the set of signals that are pending for delivery to the calling thread (i.e., the signals which have been raised while blocked). Return the set of the pending signals.

Availability: Unix (see the man page `sigpending(2)` for further information).

See also `pause()`, `pthread_sigmask()` and `sigwait()`.

*New in version 3.3.*

**signal.sigwait(sigset)**

Suspend execution of the calling thread until the delivery of one of the signals specified in the signal set `sigset`. The function accepts the signal (removes it from the pending list of signals), and returns
the signal number.

Availability: Unix (see the man page `sigwait(3)` for further information).

See also `pause()`, `pthread_sigmask()`, `sigpending()`, `sigwaitinfo()` and `sigtimedwait()`.

*New in version 3.3.*

**signal.** `sigwaitinfo(sigset)`

Suspend execution of the calling thread until the delivery of one of the signals specified in the signal set `sigset`. The function accepts the signal and removes it from the pending list of signals. If one of the signals in `sigset` is already pending for the calling thread, the function will return immediately with information about that signal. The signal handler is not called for the delivered signal. The function raises an `InterruptedError` if it is interrupted by a signal that is not in `sigset`.

The return value is an object representing the data contained in the `siginfo_t` structure, namely: `si_signo`, `si_code`, `si_errno`, `si_pid`, `si_uid`, `si_status`, `si_band`.

Availability: Unix (see the man page `sigwaitinfo(2)` for further information).

See also `pause()`, `sigwait()` and `sigtimedwait()`.

*New in version 3.3.*

*Changed in version 3.5:* The function is now retried if interrupted by a signal not in `sigset` and the signal handler does not raise an exception (see [PEP 475](https://www.python.org/dev/peps/pep-0475) for the rationale).
signal.\texttt{sigtimedwait}(\textit{sigset, timeout})

Like \texttt{sigwaitinfo()}, but takes an additional \textit{timeout} argument specifying a timeout. If \textit{timeout} is specified as 0, a poll is performed. Returns \texttt{None} if a timeout occurs.

Availability: Unix (see the man page \texttt{sigtimedwait(2)} for further information).

See also \texttt{pause()}, \texttt{sigwait()} and \texttt{sigwaitinfo()}.

\textit{New in version 3.3.}

\textit{Changed in version 3.5:} The function is now retried with the recomputed \textit{timeout} if interrupted by a signal not in \textit{sigset} and the signal handler does not raise an exception (see \texttt{PEP 475} for the rationale).
18.8.3. Example

Here is a minimal example program. It uses the `alarm()` function to limit the time spent waiting to open a file; this is useful if the file is for a serial device that may not be turned on, which would normally cause the `os.open()` to hang indefinitely. The solution is to set a 5-second alarm before opening the file; if the operation takes too long, the alarm signal will be sent, and the handler raises an exception.

```python
import signal, os

def handler(signum, frame):
    print('Signal handler called with signal', signum)
    raise OSError("Couldn't open device!")

# Set the signal handler and a 5-second alarm
signal.signal(signal.SIGALRM, handler)
signal.alarm(5)

# This open() may hang indefinitely
fd = os.open('/dev/ttyS0', os.O_RDWR)

signal.alarm(0)  # Disable the alarm
```

18.9. mmap — Memory-mapped file support

Memory-mapped file objects behave like both bytearray and like file objects. You can use mmap objects in most places where bytearray are expected; for example, you can use the re module to search through a memory-mapped file. You can also change a single byte by doing obj[index] = 97, or change a subsequence by assigning to a slice: obj[i1:i2] = b'...'. You can also read and write data starting at the current file position, and seek() through the file to different positions.

A memory-mapped file is created by the mmap constructor, which is different on Unix and on Windows. In either case you must provide a file descriptor for a file opened for update. If you wish to map an existing Python file object, use its fileno() method to obtain the correct value for the fileno parameter. Otherwise, you can open the file using the os.open() function, which returns a file descriptor directly (the file still needs to be closed when done).

**Note:** If you want to create a memory-mapping for a writable, buffered file, you should flush() the file first. This is necessary to ensure that local modifications to the buffers are actually available to the mapping.

For both the Unix and Windows versions of the constructor, access may be specified as an optional keyword parameter. access accepts one of three values: ACCESS_READ, ACCESS_WRITE, or ACCESS_COPY to specify read-only, write-through or copy-on-write
memory respectively. access can be used on both Unix and Windows. If access is not specified, Windows mmap returns a write-through mapping. The initial memory values for all three access types are taken from the specified file. Assignment to an ACCESS_READ memory map raises a TypeError exception. Assignment to an ACCESS_WRITE memory map affects both memory and the underlying file. Assignment to an ACCESS_COPY memory map affects memory but does not update the underlying file.

To map anonymous memory, -1 should be passed as the fileno along with the length.

```python
class mmap.mmap(fileno, length, tagname=None, access=ACCESS_DEFAULT[, offset])
```

(Windows version) Maps length bytes from the file specified by the file handle fileno, and creates a mmap object. If length is larger than the current size of the file, the file is extended to contain length bytes. If length is 0, the maximum length of the map is the current size of the file, except that if the file is empty Windows raises an exception (you cannot create an empty mapping on Windows).

tagname, if specified and not None, is a string giving a tag name for the mapping. Windows allows you to have many different mappings against the same file. If you specify the name of an existing tag, that tag is opened, otherwise a new tag of this name is created. If this parameter is omitted or None, the mapping is created without a name. Avoiding the use of the tag parameter will assist in keeping your code portable between Unix and Windows.

offset may be specified as a non-negative integer offset. mmap references will be relative to the offset from the beginning of the
file. offset defaults to 0. offset must be a multiple of the ALLOCATIONGRANULARITY.

class mmap

mmap(fileno, length, flags=MAP_SHARED,
prot=PROT_WRITE|PROT_READ, access=ACCESS_DEFAULT[, offset])

(UNIX version) Maps length bytes from the file specified by the file descriptor fileno, and returns a mmap object. If length is 0, the maximum length of the map will be the current size of the file when mmap is called.

flags specifies the nature of the mapping. MAP_PRIVATE creates a private copy-on-write mapping, so changes to the contents of the mmap object will be private to this process, and MAP_SHARED creates a mapping that’s shared with all other processes mapping the same areas of the file. The default value is MAP_SHARED.

prot, if specified, gives the desired memory protection; the two most useful values are PROT_READ and PROT_WRITE, to specify that the pages may be read or written. prot defaults to PROT_READ | PROT_WRITE.

access may be specified in lieu of flags and prot as an optional keyword parameter. It is an error to specify both flags, prot and access. See the description of access above for information on how to use this parameter.

offset may be specified as a non-negative integer offset. mmap references will be relative to the offset from the beginning of the file. offset defaults to 0. offset must be a multiple of the PAGESIZE or ALLOCATIONGRANULARITY.
To ensure validity of the created memory mapping the file specified by the descriptor `fileno` is internally automatically synchronized with physical backing store on Mac OS X and OpenVMS.

This example shows a simple way of using `mmap`:

```
import mmap

# write a simple example file
with open("hello.txt", "wb") as f:
    f.write(b"Hello Python!
"
)

with open("hello.txt", "r+b") as f:
    # memory-map the file, size 0 means whole file
    mm = mmap.mmap(f.fileno(), 0)
    # read content via standard file methods
    print(mm.readline())  # prints b"Hello Python"
    # read content via slice notation
    print(mm[:5])  # prints b"Hello"
    # update content using slice notation;
    # note that new content must have same size
    mm[6:] = b" world!"
    # ... and read again using standard file methods
    mm.seek(0)
    print(mm.readline())  # prints b"Hello world"
    # close the map
    mm.close()
```

`mmap` can also be used as a context manager in a `with` statement:

```
import mmap

with mmap.mmap(-1, 13) as mm:
    mm.write("Hello world!")
```
New in version 3.2: Context manager support.

The next example demonstrates how to create an anonymous map and exchange data between the parent and child processes:

```python
import mmap
import os

mm = mmap.mmap(-1, 13)
mm.write(b"Hello world!"

pid = os.fork()

if pid == 0:  # In a child process
    mm.seek(0)
    print(mm.readline())
    mm.close()
```

Memory-mapped file objects support the following methods:

**close()**

Closes the mmap. Subsequent calls to other methods of the object will result in a ValueError exception being raised. This will not close the open file.

**closed**

True if the file is closed.

New in version 3.2.

**find(sub[, start[, end]])**

Returns the lowest index in the object where the subsequence `sub` is found, such that `sub` is contained in the range `start`,
Optional arguments \textit{start} and \textit{end} are interpreted as in slice notation. Returns -1 on failure.

\textbf{flush([offset[, size]])}

Flushes changes made to the in-memory copy of a file back to disk. Without use of this call there is no guarantee that changes are written back before the object is destroyed. If \textit{offset} and \textit{size} are specified, only changes to the given range of bytes will be flushed to disk; otherwise, the whole extent of the mapping is flushed.

\textbf{(Windows version)} A nonzero value returned indicates success; zero indicates failure.

\textbf{(Unix version)} A zero value is returned to indicate success. An exception is raised when the call failed.

\textbf{move(dest, src, count)}

Copy the \textit{count} bytes starting at offset \textit{src} to the destination index \textit{dest}. If the mmap was created with \texttt{ACCESS\_READ}, then calls to \texttt{move} will raise a \texttt{TypeError} exception.

\textbf{read([n])}

Return a \texttt{bytes} containing up to \textit{n} bytes starting from the current file position. If the argument is omitted, \texttt{None} or negative, return all bytes from the current file position to the end of the mapping. The file position is updated to point after the bytes that were returned.

\textit{Changed in version 3.3:} Argument can be omitted or \texttt{None}.

\textbf{read\_byte()}

Returns a byte at the current file position as an integer, and advances the file position by 1.

**readline()**
Returns a single line, starting at the current file position and up to the next newline.

**resize(newsize)**
Resizes the map and the underlying file, if any. If the mmap was created with ACCESS_READ or ACCESS_COPY, resizing the map will raise a `TypeError` exception.

**rfind(sub[start:end])**
Returns the highest index in the object where the subsequence `sub` is found, such that `sub` is contained in the range `[start, end]`. Optional arguments `start` and `end` are interpreted as in slice notation. Returns -1 on failure.

**seek(pos[whence])**
Set the file's current position. `whence` argument is optional and defaults to `os.SEEK_SET` or 0 (absolute file positioning); other values are `os.SEEK_CUR` or 1 (seek relative to the current position) and `os.SEEK_END` or 2 (seek relative to the file's end).

**size()**
Return the length of the file, which can be larger than the size of the memory-mapped area.

**tell()**
Returns the current position of the file pointer.
**write**(*bytes*)

Write the bytes in *bytes* into memory at the current position of the file pointer; the file position is updated to point after the bytes that were written. If the mmap was created with ACCESS_READ, then writing to it will raise a **TypeError** exception.

**write_byte**(*byte*)

Write the integer *byte* into memory at the current position of the file pointer; the file position is advanced by 1. If the mmap was created with ACCESS_READ, then writing to it will raise a **TypeError** exception.
19. Internet Data Handling

This chapter describes modules which support handling data formats commonly used on the Internet.

- 19.1. email — An email and MIME handling package
  - 19.1.1. email.message: Representing an email message
  - 19.1.2. email.parser: Parsing email messages
    - 19.1.2.1. FeedParser API
    - 19.1.2.2. Parser class API
    - 19.1.2.3. Additional notes
  - 19.1.3. email.generator: Generating MIME documents
  - 19.1.4. email.policy: Policy Objects
  - 19.1.5. email.headerregistry: Custom Header Objects
  - 19.1.6. email.contentmanager: Managing MIME Content
    - 19.1.6.1. Content Manager Instances
  - 19.1.7. email.mime: Creating email and MIME objects from scratch
  - 19.1.8. email.header: Internationalized headers
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  - 19.1.10. email.encoders: Encoders
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- 19.2. json — JSON encoder and decoder
  - 19.2.1. Basic Usage
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- 19.3. mailcap — Mailcap file handling
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- 19.5. mimetypes — Map filenames to MIME types
  - 19.5.1. MimeTypes Objects
- 19.6. base64 — Base16, Base32, Base64, Base85 Data Encodings
- 19.7. binhex — Encode and decode binhex4 files
  - 19.7.1. Notes
- 19.8. binascii — Convert between binary and ASCII
- 19.9. quopri — Encode and decode MIME quoted-printable data
19.10. uu — Encode and decode uuencode files

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Last updated on Dec 06, 2015. Found a bug?
Created using Sphinx 1.3.1.
19.1. **email** — An email and MIME handling package

The **email** package is a library for managing email messages, including MIME and other [RFC 2822]-based message documents. It is specifically *not* designed to do any sending of email messages to SMTP ([RFC 2821]), NNTP, or other servers; those are functions of modules such as **smtplib** and **nntplib**. The **email** package attempts to be as RFC-compliant as possible, supporting in addition to [RFC 2822], such MIME-related RFCs as [RFC 2045], [RFC 2046], [RFC 2047], and [RFC 2231].

The primary distinguishing feature of the **email** package is that it splits the parsing and generating of email messages from the internal **object model** representation of email. Applications using the **email** package deal primarily with objects; you can add sub-objects to messages, remove sub-objects from messages, completely re-arrange the contents, etc. There is a separate parser and a separate generator which handles the transformation from flat text to the object model, and then back to flat text again. There are also handy subclasses for some common MIME object types, and a few miscellaneous utilities that help with such common tasks as extracting and parsing message field values, creating RFC-compliant dates, etc.

The following sections describe the functionality of the **email** package. The ordering follows a progression that should be common in applications: an email message is read as flat text from a file or other source, the text is parsed to produce the object structure of the email message, this structure is manipulated, and finally, the object tree is rendered back into flat text.
It is perfectly feasible to create the object structure out of whole cloth — i.e. completely from scratch. From there, a similar progression can be taken as above.

Also included are detailed specifications of all the classes and modules that the email package provides, the exception classes you might encounter while using the email package, some auxiliary utilities, and a few examples. For users of the older mimelib package, or previous versions of the email package, a section on differences and porting is provided.

Contents of the email package documentation:

- 19.1.1. email.message: Representing an email message
- 19.1.2. email.parser: Parsing email messages
  - 19.1.2.1. FeedParser API
  - 19.1.2.2. Parser class API
  - 19.1.2.3. Additional notes
- 19.1.3. email.generator: Generating MIME documents
- 19.1.4. email.policy: Policy Objects
- 19.1.5. email.headerregistry: Custom Header Objects
- 19.1.6. email.contentmanager: Managing MIME Content
  - 19.1.6.1. Content Manager Instances
- 19.1.7. email.mime: Creating email and MIME objects from scratch
- 19.1.8. email.header: Internationalized headers
- 19.1.9. email.charset: Representing character sets
- 19.1.10. email.encoders: Encoders
- 19.1.11. email.errors: Exception and Defect classes
- 19.1.12. email.utils: Miscellaneous utilities
- 19.1.13. email.iterators: Iterators
- 19.1.14. email: Examples
  - 19.1.14.1. Examples using the Provisional API
See also:

**Module** `smtplib`
   SMTP protocol client

**Module** `nntplib`
   NNTP protocol client
19.1.15. Package History

This table describes the release history of the email package, corresponding to the version of Python that the package was released with. For purposes of this document, when you see a note about change or added versions, these refer to the Python version the change was made in, not the email package version. This table also describes the Python compatibility of each version of the package.

<table>
<thead>
<tr>
<th>email version</th>
<th>distributed with</th>
<th>compatible with</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.x</td>
<td>Python 2.2.0 to Python 2.2.1</td>
<td>no longer supported</td>
</tr>
<tr>
<td>2.5</td>
<td>Python 2.2.2+ and Python 2.3</td>
<td>Python 2.1 to 2.5</td>
</tr>
<tr>
<td>3.0</td>
<td>Python 2.4 and Python 2.5</td>
<td>Python 2.3 to 2.6</td>
</tr>
<tr>
<td>4.0</td>
<td>Python 2.5 to Python 2.7</td>
<td>Python 2.3 to 2.7</td>
</tr>
<tr>
<td>5.0</td>
<td>Python 3.0 and Python 3.1</td>
<td>Python 3.0 to 3.2</td>
</tr>
<tr>
<td>5.1</td>
<td>Python 3.2</td>
<td>Python 3.2</td>
</tr>
</tbody>
</table>

After Version 5.1 (Python 3.2), the email package no longer has a version that is separate from the Python version. (See the What’s New in Python documents for the respective Python versions for details on changes.)

Here are the major differences between email version 5.1 and version 5.0:

- It is once again possible to parse messages containing non-ASCII bytes, and to reproduce such messages if the data containing the non-ASCII bytes is not modified.
• New functions `message_from_bytes()` and `message_from_binary_file()`, and new classes `BytesFeedParser` and `BytesParser` allow binary message data to be parsed into model objects.

• Given bytes input to the model, `get_payload()` will by default decode a message body that has a `Content-Transfer-Encoding` of 8bit using the charset specified in the MIME headers and return the resulting string.

• Given bytes input to the model, `Generator` will convert message bodies that have a `Content-Transfer-Encoding` of 8bit to instead have a 7bit `Content-Transfer-Encoding`.

• New class `BytesGenerator` produces bytes as output, preserving any unchanged non-ASCII data that was present in the input used to build the model, including message bodies with a `Content-Transfer-Encoding` of 8bit.

Here are the major differences between `email` version 5.0 and version 4:

• All operations are on unicode strings. Text inputs must be strings, text outputs are strings. Outputs are limited to the ASCII character set and so can be encoded to ASCII for transmission. Inputs are also limited to ASCII; this is an acknowledged limitation of email 5.0 and means it can only be used to parse email that is 7bit clean.

Here are the major differences between `email` version 4 and version 3:

• All modules have been renamed according to PEP 8 standards. For example, the version 3 module `email.Message` was renamed to `email.message` in version 4.

• A new subpackage `email.mime` was added and all the version 3
email.MIME* modules were renamed and situated into the *email.mime* subpackage. For example, the version 3 module *email.MIMEText* was renamed to *email.mime.text*.

Note that the version 3 names will continue to work until Python 2.6.

- The *email.mime.application* module was added, which contains the MIMEApplication class.

- Methods that were deprecated in version 3 have been removed. These include Generator.__call__(), Message.get_type(), Message.get_main_type(), Message.get_subtype().

- Fixes have been added for RFC 2231 support which can change some of the return types for Message.get_param and friends. Under some circumstances, values which used to return a 3-tuple now return simple strings (specifically, if all extended parameter segments were unencoded, there is no language and charset designation expected, so the return type is now a simple string). Also, %-decoding used to be done for both encoded and unencoded segments; this decoding is now done only for encoded segments.

Here are the major differences between email version 3 and version 2:

- The FeedParser class was introduced, and the Parser class was implemented in terms of the FeedParser. All parsing therefore is non-strict, and parsing will make a best effort never to raise an exception. Problems found while parsing messages are stored in the message’s defect attribute.
All aspects of the API which raised DeprecationWarnings in version 2 have been removed. These include the `_encoder` argument to the MIMEText constructor, the Message.add_payload() method, the Utils.dump_address_pair() function, and the functions Utils.decode() and Utils.encode().

New DeprecationWarnings have been added to: Generator.__call__(), Message.get_type(), Message.get_main_type(), Message.get_subtype(), and the `strict` argument to the Parser class. These are expected to be removed in future versions.

Support for Pythons earlier than 2.3 has been removed.

Here are the differences between email version 2 and version 1:

- The email.Header and email.Charset modules have been added.

- The pickle format for Message instances has changed. Since this was never (and still isn't) formally defined, this isn't considered a backward incompatibility. However if your application pickles and unpickles Message instances, be aware that in email version 2, Message instances now have private variables `_charset` and `_default_type`.

- Several methods in the Message class have been deprecated, or their signatures changed. Also, many new methods have been added. See the documentation for the Message class for details. The changes should be completely backward compatible.

- The object structure has changed in the face of message/rfc822 content types. In email version 1, such a type would be represented by a scalar payload, i.e. the container message's
is_multipart() returned false, get_payload() was not a list object, but a single Message instance.

This structure was inconsistent with the rest of the package, so the object representation for message/rfc822 content types was changed. In email version 2, the container does return True from is_multipart(), and get_payload() returns a list containing a single Message item.

Note that this is one place that backward compatibility could not be completely maintained. However, if you’re already testing the return type of get_payload(), you should be fine. You just need to make sure your code doesn’t do a set_payload() with a Message instance on a container with a content type of message/rfc822.

- The Parser constructor’s strict argument was added, and its parse() and parsestr() methods grew a headersonly argument. The strict flag was also added to functions email.message_from_file() and email.message_from_string().

- Generator.__call__() is deprecated; use Generator.flatten instead. The Generator class has also grown the clone() method.

- The DecodedGenerator class in the email.generator module was added.

- The intermediate base classes MIMENonMultipart and MIMEMultipart have been added, and interposed in the class hierarchy for most of the other MIME-related derived classes.
- The `_encoder` argument to the `MIMEText` constructor has been deprecated. Encoding now happens implicitly based on the `_charset` argument.

- The following functions in the `email.Utils` module have been deprecated: `dump_address_pairs()`, `decode()`, and `encode()`. The following functions have been added to the module: `make_msgid()`, `decode_rfc2231()`, `encode_rfc2231()`, and `decode_params()`.

- The non-public function `email.Iterators._structure()` was added.
19.1.16. Differences from mimelib

The email package was originally prototyped as a separate library called mimelib. Changes have been made so that method names are more consistent, and some methods or modules have either been added or removed. The semantics of some of the methods have also changed. For the most part, any functionality available in mimelib is still available in the email package, albeit often in a different way. Backward compatibility between the mimelib package and the email package was not a priority.

Here is a brief description of the differences between the mimelib and the email packages, along with hints on how to port your applications.

Of course, the most visible difference between the two packages is that the package name has been changed to email. In addition, the top-level package has the following differences:

- messageFromString() has been renamed to message_from_string().
- messageFromFile() has been renamed to message_from_file().

The Message class has the following differences:

- The method asString() was renamed to as_string().
- The method ismultipart() was renamed to is_multipart().
- The get_payload() method has grown a decode optional argument.
- The method getall() was renamed to get_all().
The method `addheader()` was renamed to `add_header()`.
- The method `gettype()` was renamed to `get_type()`.
- The method `getmaintype()` was renamed to `get_main_type()`.
- The method `getsubtype()` was renamed to `get_subtype()`.
- The method `getparams()` was renamed to `get_params()`. Also, whereas `getparams()` returned a list of strings, `get_params()` returns a list of 2-tuples, effectively the key/value pairs of the parameters, split on the '=' sign.
- The method `getparam()` was renamed to `get_param()`.
- The method `getcharsets()` was renamed to `get_charsets()`.
- The method `getfilename()` was renamed to `get_filename()`.
- The method `getboundary()` was renamed to `get_boundary()`.
- The method `setboundary()` was renamed to `set_boundary()`.
- The method `getdecodedpayload()` was removed. To get similar functionality, pass the value 1 to the `decode` flag of the `get_payload()` method.
- The method `getpayloadastext()` was removed. Similar functionality is supported by the `DecodedGenerator` class in the `email.generator` module.
- The method `getbodyastext()` was removed. You can get similar functionality by creating an iterator with `typed_subpart_iterator()` in the `email.iterators` module.

The `Parser` class has no differences in its public interface. It does have some additional smarts to recognize `message/delivery-status` type messages, which it represents as a `Message` instance containing
separate Message subparts for each header block in the delivery status notification [1].

The Generator class has no differences in its public interface. There is a new class in the email generator module though, called DecodedGenerator which provides most of the functionality previously available in the Message.getpayloadastext() method.

The following modules and classes have been changed:

- The MIMEBase class constructor arguments _major and _minor have changed to _maintype and _subtype respectively.

- The Image class/module has been renamed to MIMEImage. The _minor argument has been renamed to _subtype.

- The Text class/module has been renamed to MIMEText. The _minor argument has been renamed to _subtype.

- The MessageRFC822 class/module has been renamed to MIMEMessage. Note that an earlier version of mimelib called this class/module RFC822, but that clashed with the Python standard library module rfc822 on some case-insensitive file systems.

   Also, the MIMEMessage class now represents any kind of MIME message with main type message. It takes an optional argument _subtype which is used to set the MIME subtype. _subtype defaults to rfc822.

mimelib provided some utility functions in its address and date modules. All of these functions have been moved to the email.utils module.
The MsgReader class/module has been removed. Its functionality is most closely supported in the `body_line_iterator()` function in the `email.iterators` module.

Footnotes

[1] Delivery Status Notifications (DSN) are defined in RFC 1894.
19.1.1. **email.message**: Representing an email message

The central class in the `email` package is the `Message` class, imported from the `email.message` module. It is the base class for the `email` object model. `Message` provides the core functionality for setting and querying header fields, and for accessing message bodies.

Conceptually, a `Message` object consists of *headers* and *payloads*. Headers are **RFC 2822** style field names and values where the field name and value are separated by a colon. The colon is not part of either the field name or the field value.

Headers are stored and returned in case-preserving form but are matched case-insensitively. There may also be a single envelope header, also known as the `Unix-From` header or the `From_` header. The payload is either a string in the case of simple message objects or a list of `Message` objects for MIME container documents (e.g. `multipart/*` and `message/rfc822').

`Message` objects provide a mapping style interface for accessing the message headers, and an explicit interface for accessing both the headers and the payload. It provides convenience methods for generating a flat text representation of the message object tree, for accessing commonly used header parameters, and for recursively walking over the object tree.

Here are the methods of the `Message` class:

```python
class email.message.Message(policy=compat32)
```
If *policy* is specified (it must be an instance of a *policy* class) use the rules it specifies to update and serialize the representation of the message. If *policy* is not set, use the *compat32* policy, which maintains backward compatibility with the Python 3.2 version of the email package. For more information see the *policy* documentation.

*Changed in version 3.3:* The *policy* keyword argument was added.

**as_string**(*unixfrom=False, maxheaderlen=0, policy=None*)

Return the entire message flattened as a string. When optional *unixfrom* is true, the envelope header is included in the returned string. *unixfrom* defaults to False. For backward compatibility reasons, *maxheaderlen* defaults to 0, so if you want a different value you must override it explicitly (the value specified for *max_line_length* in the policy will be ignored by this method).

The *policy* argument may be used to override the default policy obtained from the message instance. This can be used to control some of the formatting produced by the method, since the specified *policy* will be passed to the Generator.

Flattening the message may trigger changes to the *Message* if defaults need to be filled in to complete the transformation to a string (for example, MIME boundaries may be generated or modified).

Note that this method is provided as a convenience and may not always format the message the way you want. For example, by default it does not do the mangling of lines that begin with From that is required by the unix mbox format. For more flexibility, instantiate a *Generator* instance and use its *flatten()* method directly. For example:
```python
from io import StringIO
from email.generator import Generator
fp = StringIO()
g = Generator(fp, mangle_from_=True, maxheaderlen)
g.flatten(msg)
text = fp.getvalue()
```

If the message object contains binary data that is not encoded according to RFC standards, the non-compliant data will be replaced by unicode “unknown character” code points. (See also `as_bytes()` and `BytesGenerator`.)

*Changed in version 3.4:* the `policy` keyword argument was added.

```python
__str__()
```
Equivalent to `as_string()`. Allows `str(msg)` to produce a string containing the formatted message.

```python
as_bytes(unixfrom=False, policy=None)
```
Return the entire message flattened as a bytes object. When optional `unixfrom` is true, the envelope header is included in the returned string. `unixfrom` defaults to False. The `policy` argument may be used to override the default policy obtained from the message instance. This can be used to control some of the formatting produced by the method, since the specified `policy` will be passed to the `BytesGenerator`.

Flattening the message may trigger changes to the `Message` if defaults need to be filled in to complete the transformation to a string (for example, MIME boundaries may be generated or modified).
Note that this method is provided as a convenience and may not always format the message the way you want. For example, by default it does not do the mangling of lines that begin with From that is required by the unix mbox format. For more flexibility, instantiate a **BytesGenerator** instance and use its **flatten()** method directly. For example:

```python
from io import BytesIO
from email.generator import BytesGenerator
fp = BytesIO()
g = BytesGenerator(fp, mangle_from_=True, maxheaderlen)
g.flatten(msg)
text = fp.getvalue()
```

*New in version 3.4.*

**__bytes__()**

Equivalent to **as_bytes()**. Allows `bytes(msg)` to produce a `bytes` object containing the formatted message.

*New in version 3.4.*

**is_multipart()**

Return True if the message's payload is a list of sub-**Message** objects, otherwise return False. When **is_multipart()** returns False, the payload should be a string object. (Note that **is_multipart()** returning True does not necessarily mean that “msg.get_content_maintype() == 'multipart'” will return the True. For example, **is_multipart** will return True when the **Message** is of type `message/rfc822`.)

**set_unixfrom(unixfrom)**
Set the message’s envelope header to `unixfrom`, which should be a string.

**get_unixfrom()**
Return the message’s envelope header. Defaults to None if the envelope header was never set.

**attach(payload)**
Add the given `payload` to the current payload, which must be None or a list of `Message` objects before the call. After the call, the payload will always be a list of `Message` objects. If you want to set the payload to a scalar object (e.g. a string), use `set_payload()` instead.

**get_payload(i=None, decode=False)**
Return the current payload, which will be a list of `Message` objects when `is_multipart()` is True, or a string when `is_multipart()` is False. If the payload is a list and you mutate the list object, you modify the message's payload in place.

With optional argument `i`, `get_payload()` will return the `i`-th element of the payload, counting from zero, if `is_multipart()` is True. An `IndexError` will be raised if `i` is less than 0 or greater than or equal to the number of items in the payload. If the payload is a string (i.e. `is_multipart()` is False) and `i` is given, a `TypeError` is raised.

Optional `decode` is a flag indicating whether the payload should be decoded or not, according to the `Content-Transfer-Encoding` header. When True and the message is not a multipart, the payload will be decoded if this header’s value is quoted-
printable or base64. If some other encoding is used, or `Content-Transfer-Encoding` header is missing, the payload is returned as-is (undecoded). In all cases the returned value is binary data. If the message is a multipart and the `decode` flag is True, then None is returned. If the payload is base64 and it was not perfectly formed (missing padding, characters outside the base64 alphabet), then an appropriate defect will be added to the message’s defect property (InvalidBase64PaddingDefect or InvalidBase64CharactersDefect, respectively).

When `decode` is False (the default) the body is returned as a string without decoding the `Content-Transfer-Encoding`. However, for a `Content-Transfer-Encoding` of 8bit, an attempt is made to decode the original bytes using the charset specified by the `Content-Type` header, using the replace error handler. If no charset is specified, or if the charset given is not recognized by the email package, the body is decoded using the default ASCII charset.

**set_payload**(*payload*, *charset=None*)

Set the entire message object's payload to *payload*. It is the client's responsibility to ensure the payload invariants. Optional *charset* sets the message's default character set; see `set_charset()` for details.

**set_charset**(*charset*)

Set the character set of the payload to *charset*, which can either be a Charset instance (see `email.charset`), a string naming a character set, or None. If it is a string, it will be converted to a Charset instance. If *charset* is None, the
charset parameter will be removed from the Content-Type header (the message will not be otherwise modified). Anything else will generate a TypeError.

If there is no existing MIME-Version header one will be added. If there is no existing Content-Type header, one will be added with a value of text/plain. Whether the Content-Type header already exists or not, its charset parameter will be set to charset.output_charset. If charset.input_charset and charset.output_charset differ, the payload will be re-encoded to the output_charset. If there is no existing Content-Transfer-Encoding header, then the payload will be transfer-encoded, if needed, using the specified Charset, and a header with the appropriate value will be added. If a Content-Transfer-Encoding header already exists, the payload is assumed to already be correctly encoded using that Content-Transfer-Encoding and is not modified.

get_charset()

Return the Charset instance associated with the message's payload.

The following methods implement a mapping-like interface for accessing the message’s RFC 2822 headers. Note that there are some semantic differences between these methods and a normal mapping (i.e. dictionary) interface. For example, in a dictionary there are no duplicate keys, but here there may be duplicate message headers. Also, in dictionaries there is no guaranteed order to the keys returned by keys(), but in a Message object, headers are always returned in the order they appeared in the original message, or were added to the message later. Any header deleted and then re-added are always appended to the end of the
header list.

These semantic differences are intentional and are biased toward maximal convenience.

Note that in all cases, any envelope header present in the message is not included in the mapping interface.

In a model generated from bytes, any header values that (in contravention of the RFCs) contain non-ASCII bytes will, when retrieved through this interface, be represented as Header objects with a charset of unknown-8bit.

__len__()  
Return the total number of headers, including duplicates.

__contains__(name)  
Return true if the message object has a field named name. Matching is done case-insensitively and name should not include the trailing colon. Used for the in operator, e.g.:

```python
if 'message-id' in myMessage:
    print('Message-ID:', myMessage['message-id'])
```

__getitem__(name)  
Return the value of the named header field. name should not include the colon field separator. If the header is missing, None is returned; a KeyError is never raised.

Note that if the named field appears more than once in the message’s headers, exactly which of those field values will be returned is undefined. Use the get_all() method to get the
values of all the extant named headers.

__setitem__(name, val)
Add a header to the message with field name name and value val. The field is appended to the end of the message’s existing fields.

Note that this does not overwrite or delete any existing header with the same name. If you want to ensure that the new header is the only one present in the message with field name name, delete the field first, e.g.:

```python
del msg['subject']
msg['subject'] = 'Python roolz!'
```

__delitem__(name)
Delete all occurrences of the field with name name from the message’s headers. No exception is raised if the named field isn’t present in the headers.

keys()
Return a list of all the message’s header field names.

values()
Return a list of all the message’s field values.

items()
Return a list of 2-tuples containing all the message’s field headers and values.

get(name, failobj=None)
Return the value of the named header field. This is identical to __getitem__() except that optional failobj is returned if the
named header is missing (defaults to None).

Here are some additional useful methods:

**get_all(name, failobj=None)**

Return a list of all the values for the field named name. If there are no such named headers in the message, failobj is returned (defaults to None).

**add_header(_name, _value, **_params)**

Extended header setting. This method is similar to __setitem__() except that additional header parameters can be provided as keyword arguments. _name is the header field to add and _value is the primary value for the header.

For each item in the keyword argument dictionary _params, the key is taken as the parameter name, with underscores converted to dashes (since dashes are illegal in Python identifiers). Normally, the parameter will be added as key="value" unless the value is None, in which case only the key will be added. If the value contains non-ASCII characters, it can be specified as a three tuple in the format (CHARSET, LANGUAGE, VALUE), where CHARSET is a string naming the charset to be used to encode the value, LANGUAGE can usually be set to None or the empty string (see RFC 2231 for other possibilities), and VALUE is the string value containing non-ASCII code points. If a three tuple is not passed and the value contains non-ASCII characters, it is automatically encoded in RFC 2231 format using a CHARSET of utf-8 and a LANGUAGE of None.

Here's an example:
This will add a header that looks like

```
Content-Disposition: attachment; filename="bud.
```

An example with non-ASCII characters:

```
msg.add_header('Content-Disposition', 'attachment',
filename=('iso-8859-1', '', 'Fuß
```

Which produces

```
Content-Disposition: attachment; filename*="iso-
```

**replace_header**(_name, _value)

Replace a header. Replace the first header found in the message that matches _name, retaining header order and field name case. If no matching header was found, a **KeyError** is raised.

**get_content_type**()

Return the message’s content type. The returned string is coerced to lower case of the form `maintype/subtype`. If there was no `Content-Type` header in the message the default type as given by `get_default_type()` will be returned. Since according to **RFC 2045**, messages always have a default type, `get_content_type()` will always return a value.

**RFC 2045** defines a message’s default type to be `text/plain`
unless it appears inside a multipart/digest container, in which case it would be message/rfc822. If the Content-Type header has an invalid type specification, RFC 2045 mandates that the default type be text/plain.

get_content_maintype()
Return the message’s main content type. This is the maintype part of the string returned by get_content_type().

get_content_subtype()
Return the message’s sub-content type. This is the subtype part of the string returned by get_content_type().

get_default_type()
Return the default content type. Most messages have a default content type of text/plain, except for messages that are subparts of multipart/digest containers. Such subparts have a default content type of message/rfc822.

set_default_type(ctype)
Set the default content type. ctype should either be text/plain or message/rfc822, although this is not enforced. The default content type is not stored in the Content-Type header.

get_params(failobj=None, header='content-type', unquote=True)
Return the message’s Content-Type parameters, as a list. The elements of the returned list are 2-tuples of key/value pairs, as split on the ‘=’ sign. The left hand side of the ‘=’ is the key, while the right hand side is the value. If there is no ‘=’ sign in the parameter the value is the empty string, otherwise the value is as described in get_param() and is unquoted if optional
unquote is True (the default).

Optional failobj is the object to return if there is no Content-Type header. Optional header is the header to search instead of Content-Type.

get_param(param, failobj=None, header='content-type', unquote=True)

Return the value of the Content-Type header's parameter param as a string. If the message has no Content-Type header or if there is no such parameter, then failobj is returned (defaults to None).

Optional header if given, specifies the message header to use instead of Content-Type.

Parameter keys are always compared case insensitively. The return value can either be a string, or a 3-tuple if the parameter was RFC 2231 encoded. When it's a 3-tuple, the elements of the value are of the form (CHARSET, LANGUAGE, VALUE). Note that both CHARSET and LANGUAGE can be None, in which case you should consider VALUE to be encoded in the us-ascii charset. You can usually ignore LANGUAGE.

If your application doesn’t care whether the parameter was encoded as in RFC 2231, you can collapse the parameter value by calling email.utils.collapse_rfc2231_value(), passing in the return value from get_param(). This will return a suitably decoded Unicode string when the value is a tuple, or the original string unquoted if it isn’t. For example:

```
rawparam = msg.get_param('foo')
param = email.utils.collapse_rfc2231_value(rawparam)
```
In any case, the parameter value (either the returned string, or the VALUE item in the 3-tuple) is always unquoted, unless unquote is set to False.

```python
set_param(param, value, header='Content-Type', requote=True, charset=None, language='', replace=False)
```

Set a parameter in the `Content-Type` header. If the parameter already exists in the header, its value will be replaced with `value`. If the `Content-Type` header as not yet been defined for this message, it will be set to `text/plain` and the new parameter value will be appended as per RFC 2045.

Optional `header` specifies an alternative header to `Content-Type`, and all parameters will be quoted as necessary unless optional `requote` is False (the default is True).

If optional `charset` is specified, the parameter will be encoded according to RFC 2231. Optional `language` specifies the RFC 2231 language, defaulting to the empty string. Both `charset` and `language` should be strings.

If `replace` is False (the default) the header is moved to the end of the list of headers. If `replace` is True, the header will be updated in place.

*Changed in version 3.4:* replace keyword was added.

```python
del_param(param, header='content-type', requote=True)
```

Remove the given parameter completely from the `Content-Type` header. The header will be re-written in place without the parameter or its value. All values will be quoted as necessary.
unless `requote` is False (the default is True). Optional `header` specifies an alternative to `Content-Type`.

**set_type**(type, header='Content-Type', requote=True)

Set the main type and subtype for the `Content-Type` header. `type` must be a string in the form `maintype/subtype`, otherwise a `ValueError` is raised.

This method replaces the `Content-Type` header, keeping all the parameters in place. If `requote` is False, this leaves the existing header’s quoting as is, otherwise the parameters will be quoted (the default).

An alternative header can be specified in the `header` argument. When the `Content-Type` header is set a `MIME-Version` header is also added.

**get_filename**(failobj=None)

Return the value of the filename parameter of the `Content-Disposition` header of the message. If the header does not have a filename parameter, this method falls back to looking for the name parameter on the `Content-Type` header. If neither is found, or the header is missing, then `failobj` is returned. The returned string will always be unquoted as per `email.utils.unquote()`.

**get_boundary**(failobj=None)

Return the value of the boundary parameter of the `Content-Type` header of the message, or `failobj` if either the header is missing, or has no boundary parameter. The returned string will always be unquoted as per `email.utils.unquote()`.
**set_boundary**(boundary)

Set the boundary parameter of the *Content-Type* header to *boundary*. *set_boundary()* will always quote *boundary* if necessary. A *HeaderParseError* is raised if the message object has no *Content-Type* header.

Note that using this method is subtly different than deleting the old *Content-Type* header and adding a new one with the new boundary via *add_header()*, because *set_boundary()* preserves the order of the *Content-Type* header in the list of headers. However, it does *not* preserve any continuation lines which may have been present in the original *Content-Type* header.

**get_content_charset**(failobj=None)

Return the charset parameter of the *Content-Type* header, coerced to lower case. If there is no *Content-Type* header, or if that header has no charset parameter, *failobj* is returned.

Note that this method differs from *get_charset()* which returns the *Charset* instance for the default encoding of the message body.

**get_charsets**(failobj=None)

Return a list containing the character set names in the message. If the message is a *multipart*, then the list will contain one element for each subpart in the payload, otherwise, it will be a list of length 1.

Each item in the list will be a string which is the value of the charset parameter in the *Content-Type* header for the represented subpart. However, if the subpart has no *Content-
Type header, no charset parameter, or is not of the text main MIME type, then that item in the returned list will be failobj.

**get_content_disposition()**
Return the lowercased value (without parameters) of the message’s Content-Disposition header if it has one, or None. The possible values for this method are inline, attachment or None if the message follows RFC 2183.

*New in version 3.5.*

**walk()**
The walk() method is an all-purpose generator which can be used to iterate over all the parts and subparts of a message object tree, in depth-first traversal order. You will typically use walk() as the iterator in a for loop; each iteration returns the next subpart.

Here’s an example that prints the MIME type of every part of a multipart message structure:

```python
>>> for part in msg.walk():
...     print(part.get_content_type())
multipart/report
text/plaint
message/delivery-status
text/plain
text/plain
message/rfc822
text/plain
```

walk iterates over the subparts of any part where is_multipart() returns True, even though
msg.get_content_maintype() == 'multipart' may return False. We can see this in our example by making use of the _structure debug helper function:

```python
>>> for part in msg.walk():
...     print(part.get_content_maintype() == 'multipart')
...     part.is_multipart()
True True
False False
False True
False False
False False
False True
False False
>>> _structure(msg)
multipart/report
  text/plain
message/delivery-status
  text/plain
  text/plain
message/rfc822
  text/plain
```

Here the message parts are not multipartes, but they do contain subparts. is_multipart() returns True and walk descends into the subparts.

**Message** objects can also optionally contain two instance attributes, which can be used when generating the plain text of a MIME message.

**preamble**

The format of a MIME document allows for some text between the blank line following the headers, and the first multipart
boundary string. Normally, this text is never visible in a MIME-aware mail reader because it falls outside the standard MIME armor. However, when viewing the raw text of the message, or when viewing the message in a non-MIME aware reader, this text can become visible.

The *preamble* attribute contains this leading extra-armor text for MIME documents. When the *Parser* discovers some text after the headers but before the first boundary string, it assigns this text to the message's *preamble* attribute. When the *Generator* is writing out the plain text representation of a MIME message, and it finds the message has a *preamble* attribute, it will write this text in the area between the headers and the first boundary. See `email.parser` and `email.generator` for details.

Note that if the message object has no preamble, the *preamble* attribute will be None.

**epilogue**

The *epilogue* attribute acts the same way as the *preamble* attribute, except that it contains text that appears between the last boundary and the end of the message.

You do not need to set the epilogue to the empty string in order for the *Generator* to print a newline at the end of the file.

**defects**

The *defects* attribute contains a list of all the problems found when parsing this message. See `email.errors` for a detailed description of the possible parsing defects.
19.1.2. **email.parser**: Parsing email messages

Message object structures can be created in one of two ways: they can be created from whole cloth by instantiating `Message` objects and stringing them together via `attach()` and `set_payload()` calls, or they can be created by parsing a flat text representation of the email message.

The `email` package provides a standard parser that understands most email document structures, including MIME documents. You can pass the parser a string or a file object, and the parser will return to you the root `Message` instance of the object structure. For simple, non-MIME messages the payload of this root object will likely be a string containing the text of the message. For MIME messages, the root object will return `True` from its `is_multipart()` method, and the subparts can be accessed via the `get_payload()` and `walk()` methods.

There are actually two parser interfaces available for use, the classic `Parser` API and the incremental `FeedParser` API. The classic `Parser` API is fine if you have the entire text of the message in memory as a string, or if the entire message lives in a file on the file system. `FeedParser` is more appropriate for when you're reading the message from a stream which might block waiting for more input (e.g. reading an email message from a socket). The `FeedParser` can consume and parse the message incrementally, and only returns the root object when you close the parser [1].

Note that the parser can be extended in limited ways, and of course
you can implement your own parser completely from scratch. There is no magical connection between the `email` package's bundled parser and the `Message` class, so your custom parser can create message object trees any way it finds necessary.
19.1.2.1. FeedParser API

The **FeedParser**, imported from the `email.feedparser` module, provides an API that is conducive to incremental parsing of email messages, such as would be necessary when reading the text of an email message from a source that can block (e.g. a socket). The **FeedParser** can of course be used to parse an email message fully contained in a string or a file, but the classic **Parser** API may be more convenient for such use cases. The semantics and results of the two parser APIs are identical.

The **FeedParser**'s API is simple; you create an instance, feed it a bunch of text until there's no more to feed it, then close the parser to retrieve the root message object. The **FeedParser** is extremely accurate when parsing standards-compliant messages, and it does a very good job of parsing non-compliant messages, providing information about how a message was deemed broken. It will populate a message object's `defects` attribute with a list of any problems it found in a message. See the `email.errors` module for the list of defects that it can find.

Here is the API for the **FeedParser**:

```python
class email.parser.FeedParser(_factory=email.message.Message, *, policy=policy.compat32)

Create a **FeedParser** instance. Optional `_factory` is a no-argument callable that will be called whenever a new message object is needed. It defaults to the `email.message.Message` class.
If `policy` is specified (it must be an instance of a `policy` class) use the rules it specifies to update the representation of the message. If `policy` is not set, use the `compat32` policy, which maintains backward compatibility with the Python 3.2 version of the email package. For more information see the `policy` documentation.

`Changed in version 3.3: Added the policy keyword.`

`feed(data)`

Feed the `FeedParser` some more data. `data` should be a string containing one or more lines. The lines can be partial and the `FeedParser` will stitch such partial lines together properly. The lines in the string can have any of the common three line endings, carriage return, newline, or carriage return and newline (they can even be mixed).

`close()`

Closing a `FeedParser` completes the parsing of all previously fed data, and returns the root message object. It is undefined what happens if you feed more data to a closed `FeedParser`.

`class` email.parser.BytesFeedParser(_factory=email.message.Message

Works exactly like `FeedParser` except that the input to the `feed()` method must be bytes and not string.

`New in version 3.2.`
19.1.2.2. Parser class API

The `Parser` class, imported from the `email.parser` module, provides an API that can be used to parse a message when the complete contents of the message are available in a string or file. The `email.parser` module also provides header-only parsers, called `HeaderParser` and `BytesHeaderParser`, which can be used if you're only interested in the headers of the message. `HeaderParser` and `BytesHeaderParser` can be much faster in these situations, since they do not attempt to parse the message body, instead setting the payload to the raw body as a string. They have the same API as the `Parser` and `BytesParser` classes.

*New in version 3.3:* The `BytesHeaderParser` class.

```python
class email.parser.Parser(_class=email.message.Message, *, policy=policy.compat32)
```

The constructor for the `Parser` class takes an optional argument `_class`. This must be a callable factory (such as a function or a class), and it is used whenever a sub-message object needs to be created. It defaults to `Message` (see `email.message`). The factory will be called without arguments.

If `policy` is specified (it must be an instance of a `policy` class) use the rules it specifies to update the representation of the message. If `policy` is not set, use the `compat32` policy, which maintains backward compatibility with the Python 3.2 version of the email package. For more information see the `policy` documentation.

*Changed in version 3.3:* Removed the `strict` argument that was deprecated in 2.4. Added the `policy` keyword.
The other public `Parser` methods are:

**parse**(fp, headersonly=False)

Read all the data from the file-like object `fp`, parse the resulting text, and return the root message object. `fp` must support both the `readline()` and the `read()` methods on file-like objects.

The text contained in `fp` must be formatted as a block of RFC 2822 style headers and header continuation lines, optionally preceded by an envelope header. The header block is terminated either by the end of the data or by a blank line. Following the header block is the body of the message (which may contain MIME-encoded subparts).

Optional `headersonly` is a flag specifying whether to stop parsing after reading the headers or not. The default is `False`, meaning it parses the entire contents of the file.

**parsestr**(text, headersonly=False)

Similar to the `parse()` method, except it takes a string object instead of a file-like object. Calling this method on a string is exactly equivalent to wrapping `text` in a `StringIO` instance first and calling `parse()`.

Optional `headersonly` is as with the `parse()` method.

```python
class email.parser.BytesParser(_class=email.message.Message, *, policy=policy.compat32)
```

This class is exactly parallel to `Parser`, but handles bytes input. The `_class` and `strict` arguments are interpreted in the same way as for the `Parser` constructor.
If *policy* is specified (it must be an instance of a *policy* class) use the rules it specifies to update the representation of the message. If *policy* is not set, use the *compat32* policy, which maintains backward compatibility with the Python 3.2 version of the email package. For more information see the *policy* documentation.

*Changed in version 3.3:* Removed the *strict* argument. Added the *policy* keyword.

**parse**(*fp, headersonly=False*)

Read all the data from the binary file-like object *fp*, parse the resulting bytes, and return the message object. *fp* must support both the *readline()* and the *read()* methods on file-like objects.

The bytes contained in *fp* must be formatted as a block of **RFC 2822** style headers and header continuation lines, optionally preceded by an envelope header. The header block is terminated either by the end of the data or by a blank line. Following the header block is the body of the message (which may contain MIME-encoded subparts, including subparts with a *Content-Transfer-Encoding* of 8bit.

Optional *headersonly* is a flag specifying whether to stop parsing after reading the headers or not. The default is *False*, meaning it parses the entire contents of the file.

**parsebytes**(*bytes, headersonly=False*)

Similar to the *parse()* method, except it takes a byte string object instead of a file-like object. Calling this method on a byte string is exactly equivalent to wrapping *text* in a **BytesIO** instance first and calling *parse()*.
Optional *headersonly* is as with the *parse()* method.

*New in version 3.2.*

Since creating a message object structure from a string or a file object is such a common task, four functions are provided as a convenience. They are available in the top-level *email* package namespace.

**email.message_from_string(s,  
_class=email.message.Message, *, policy=policy.compat32)**

Return a message object structure from a string. This is exactly equivalent to *Parser().parsestr(s)*. *_class* and *policy* are interpreted as with the *Parser* class constructor.

*Changed in version 3.3:* Removed the *strict* argument. Added the *policy* keyword.

**email.message_from_bytes(s,  
_class=email.message.Message, *, policy=policy.compat32)**

Return a message object structure from a byte string. This is exactly equivalent to *BytesParser().parsebytes(s)*. Optional *_class* and *strict* are interpreted as with the *Parser* class constructor.

*New in version 3.2.*

*Changed in version 3.3:* Removed the *strict* argument. Added the *policy* keyword.

**email.message_from_file(fp,  
_class=email.message.Message, *, policy=policy.compat32)**

Return a message object structure tree from an open *file object*. This is exactly equivalent to *Parser().parse(fp)*. *_class* and
policy are interpreted as with the Parser class constructor.

Changed in version Removed: the strict argument. Added the policy keyword.

email.message_from_binary_file(fp, _class=email.message.Message, *, policy=policy.compat32)

Return a message object structure tree from an open binary file object. This is exactly equivalent to BytesParser().parse(fp). _class and policy are interpreted as with the Parser class constructor.

New in version 3.2.

Changed in version 3.3: Removed the strict argument. Added the policy keyword.

Here’s an example of how you might use this at an interactive Python prompt:

```python
>>> import email
>>> msg = email.message_from_string(myString)
```
19.1.2.3. Additional notes

Here are some notes on the parsing semantics:

- Most non-
  multipart type messages are parsed as a single message object with a string payload. These objects will return False for is_multipart(). Their get_payload() method will return a string object.
- All multipart type messages will be parsed as a container message object with a list of sub-message objects for their payload. The outer container message will return True for is_multipart() and their get_payload() method will return the list of Message subparts.
- Most messages with a content type of message/* (e.g. message/delivery-status and message/rfc822) will also be parsed as container object containing a list payload of length 1. Their is_multipart() method will return True. The single element in the list payload will be a sub-message object.
- Some non-standards compliant messages may not be internally consistent about their multipart-edness. Such messages may have a Content-Type header of type multipart, but their is_multipart() method may return False. If such messages were parsed with the FeedParser, they will have an instance of the MultipartInvariantViolationDefect class in their defects attribute list. See email.errors for details.

Footnotes

[1] As of email package version 3.0, introduced in Python 2.4, the classic Parser was re-implemented in terms of the FeedParser, so the semantics and results are identical between the two parsers.
19.1. email — An email and MIME handling package
19.1.3. email.generator: Generating MIME documents

One of the most common tasks is to generate the flat text of the email message represented by a message object structure. You will need to do this if you want to send your message via the `smtplib` module or the `nntplib` module, or print the message on the console. Taking a message object structure and producing a flat text document is the job of the `Generator` class.

Again, as with the `email.parser` module, you aren't limited to the functionality of the bundled generator; you could write one from scratch yourself. However the bundled generator knows how to generate most email in a standards-compliant way, should handle MIME and non-MIME email messages just fine, and is designed so that the transformation from flat text, to a message structure via the `Parser` class, and back to flat text, is idempotent (the input is identical to the output) [1]. On the other hand, using the Generator on a `Message` constructed by program may result in changes to the `Message` object as defaults are filled in.

`bytes` output can be generated using the `BytesGenerator` class. If the message object structure contains non-ASCII bytes, this generator’s `flatten()` method will emit the original bytes. Parsing a binary message and then flattening it with `BytesGenerator` should be idempotent for standards compliant messages.

Here are the public methods of the `Generator` class, imported from the `email.generator` module:
class email.generator.Generator(outfp, mangle_from_=True, maxheaderlen=78, *, policy=None)

The constructor for the Generator class takes a file-like object called outfp for an argument. outfp must support the write() method and be usable as the output file for the print() function.

Optional mangle_from_ is a flag that, when True, puts a > character in front of any line in the body that starts exactly as From, i.e. From followed by a space at the beginning of the line. This is the only guaranteed portable way to avoid having such lines be mistaken for a Unix mailbox format envelope header separator (see WHY THE CONTENT-LENGTH FORMAT IS BAD for details). mangle_from_ defaults to True, but you might want to set this to False if you are not writing Unix mailbox format files.

Optional maxheaderlen specifies the longest length for a non-continued header. When a header line is longer than maxheaderlen (in characters, with tabs expanded to 8 spaces), the header will be split as defined in the Header class. Set to zero to disable header wrapping. The default is 78, as recommended (but not required) by RFC 2822.

The policy keyword specifies a policy object that controls a number of aspects of the generator’s operation. If no policy is specified, then the policy attached to the message object passed to flatten is used.

Changed in version 3.3: Added the policy keyword.

The other public Generator methods are:

flatten(msg, unixfrom=False, linesep=None)
Print the textual representation of the message object structure rooted at \textit{msg} to the output file specified when the \texttt{Generator} instance was created. Subparts are visited depth-first and the resulting text will be properly MIME encoded.

Optional \textit{unixfrom} is a flag that forces the printing of the envelope header delimiter before the first \texttt{RFC 2822} header of the root message object. If the root object has no envelope header, a standard one is crafted. By default, this is set to \texttt{False} to inhibit the printing of the envelope delimiter.

Note that for subparts, no envelope header is ever printed.

Optional \textit{linesep} specifies the line separator character used to terminate lines in the output. If specified it overrides the value specified by the \textit{msg}'s or \texttt{Generator}'s policy.

Because strings cannot represent non-ASCII bytes, if the policy that applies when flatten is run has \texttt{cte_type} set to 8bit, \texttt{Generator} will operate as if it were set to 7bit. This means that messages parsed with a Bytes parser that have a \texttt{Content-Transfer-Encoding} of 8bit will be converted to a use a 7bit Content-Transfer-Encoding. Non-ASCII bytes in the headers will be \texttt{RFC 2047} encoded with a charset of unknown-8bit.

\textit{Changed in version 3.2: Added support for re-encoding 8bit message bodies, and the \textit{linesep} argument.}

\textit{clone}(\textit{fp})

Return an independent clone of this \texttt{Generator} instance with the exact same options.

\textit{write}(\textit{s})
Write the string \textit{s} to the underlying file object, i.e. \texttt{outfp} passed to \texttt{Generator}'s constructor. This provides just enough file-like API for \texttt{Generator} instances to be used in the \texttt{print()} function.

As a convenience, see the \texttt{Message} methods \texttt{as\_string()} and \texttt{str(aMessage)}, a.k.a. \texttt{\_\_str\_()}, which simplify the generation of a formatted string representation of a message object. For more detail, see \texttt{email.message}.

\texttt{class email\.generator\.BytesGenerator(outfp, mangle\_from\_=True, maxheaderlen=78, \*, policy=None)}

The constructor for the \texttt{BytesGenerator} class takes a binary file-like object called \texttt{outfp} for an argument. \texttt{outfp} must support a \texttt{write()} method that accepts binary data.

Optional \texttt{mangle\_from\_} is a flag that, when True, puts a > character in front of any line in the body that starts exactly as From, i.e. From followed by a space at the beginning of the line. This is the only guaranteed portable way to avoid having such lines be mistaken for a Unix mailbox format envelope header separator (see \texttt{WHY THE CONTENT-LENGTH FORMAT IS BAD} for details). \texttt{mangle\_from\_} defaults to True, but you might want to set this to False if you are not writing Unix mailbox format files.

Optional \texttt{maxheaderlen} specifies the longest length for a non-continued header. When a header line is longer than \texttt{maxheaderlen} (in characters, with tabs expanded to 8 spaces), the header will be split as defined in the \texttt{Header} class. Set to zero to disable header wrapping. The default is 78, as recommended (but not required) by \texttt{RFC 2822}. 

The `policy` keyword specifies a `policy` object that controls a number of aspects of the generator’s operation. If no `policy` is specified, then the `policy` attached to the message object passed to `flatten` is used.

*Changed in version 3.3:* Added the `policy` keyword.

The other public `BytesGenerator` methods are:

```python
flatten(msg, unixfrom=False, linesep=None)
```

Print the textual representation of the message object structure rooted at `msg` to the output file specified when the `BytesGenerator` instance was created. Subparts are visited depth-first and the resulting text will be properly MIME encoded. If the `policy` option `cte_type` is 8bit (the default), then any bytes with the high bit set in the original parsed message that have not been modified will be copied faithfully to the output. If `cte_type` is 7bit, the bytes will be converted as needed using an ASCII-compatible Content-Transfer-Encoding. In particular, RFC-invalid non-ASCII bytes in headers will be encoded using the MIME unknown-8bit character set, thus rendering them RFC-compliant.

Messages parsed with a Bytes parser that have a `Content-Transfer-Encoding` of 8bit will be reconstructed as 8bit if they have not been modified.

Optional `unixfrom` is a flag that forces the printing of the envelope header delimiter before the first RFC 2822 header of the root message object. If the root object has no envelope header, a standard one is crafted. By default, this is set to `False` to inhibit the printing of the envelope delimiter.
Note that for subparts, no envelope header is ever printed.

Optional \textit{linesep} specifies the line separator character used to terminate lines in the output. If specified it overrides the value specified by the Generator or \texttt{msg}'s policy.

\textbf{clone}(\texttt{fp})

Return an independent clone of this \texttt{BytesGenerator} instance with the exact same options.

\textbf{write}(\texttt{s})

Write the string \texttt{s} to the underlying file object. \texttt{s} is encoded using the ASCII codec and written to the \texttt{write} method of the \texttt{outfp} passed to the \texttt{BytesGenerator}'s constructor. This provides just enough file-like API for \texttt{BytesGenerator} instances to be used in the \texttt{print()} function.

\textit{New in version 3.2.}

The \texttt{email.generator} module also provides a derived class, called \texttt{DecodedGenerator} which is like the \texttt{Generator} base class, except that non-text parts are substituted with a format string representing the part.

\texttt{class email.generator.\textbf{DecodedGenerator}(outfp, mangle_from_=True, maxheaderlen=78, fmt=None)}

This class, derived from \texttt{Generator} walks through all the subparts of a message. If the subpart is of main type \texttt{text}, then it prints the decoded payload of the subpart. Optional \texttt{mangle_from_} and \texttt{maxheaderlen} are as with the \texttt{Generator} base class.

If the subpart is not of main type \texttt{text}, optional \texttt{fmt} is a format string that is used instead of the message payload. \texttt{fmt} is expanded with
the following keywords, \%(keyword)s format:

- **type** – Full MIME type of the non-text part
- **maintype** – Main MIME type of the non-text part
- **subtype** – Sub-MIME type of the non-text part
- **filename** – Filename of the non-text part
- **description** – Description associated with the non-text part
- **encoding** – Content transfer encoding of the non-text part

The default value for *fmt* is None, meaning

```
[Non-text (%(type)s) part of message omitted, file
```

**Footnotes**

This statement assumes that you use the appropriate setting for the `unixfrom` argument, and that you set `maxheaderlen=0` (which will preserve whatever the input line lengths were). It is also not strictly true, since in many cases runs of whitespace in headers are collapsed into single blanks. The latter is a bug that will eventually be fixed.

[1]
19. Internet Data Handling

19.1. `email` — An email and MIME handling package
19.1.4. `email.policy`: Policy Objects

*New in version 3.3.*

The `email` package's prime focus is the handling of email messages as described by the various email and MIME RFCs. However, the general format of email messages (a block of header fields each consisting of a name followed by a colon followed by a value, the whole block followed by a blank line and an arbitrary ‘body’), is a format that has found utility outside of the realm of email. Some of these uses conform fairly closely to the main RFCs, some do not. And even when working with email, there are times when it is desirable to break strict compliance with the RFCs.

Policy objects give the email package the flexibility to handle all these disparate use cases.

A `Policy` object encapsulates a set of attributes and methods that control the behavior of various components of the email package during use. `Policy` instances can be passed to various classes and methods in the email package to alter the default behavior. The settable values and their defaults are described below.

There is a default policy used by all classes in the email package. This policy is named `Compat32`, with a corresponding pre-defined instance named `compat32`. It provides for complete backward compatibility (in some cases, including bug compatibility) with the pre-Python3.3 version of the email package.

The first part of this documentation covers the features of `Policy`, an
abstract base class that defines the features that are common to all policy objects, including compat32. This includes certain hook methods that are called internally by the email package, which a custom policy could override to obtain different behavior.

When a Message object is created, it acquires a policy. By default this will be compat32, but a different policy can be specified. If the Message is created by a parser, a policy passed to the parser will be the policy used by the Message it creates. If the Message is created by the program, then the policy can be specified when it is created. When a Message is passed to a generator, the generator uses the policy from the Message by default, but you can also pass a specific policy to the generator that will override the one stored on the Message object.

Policy instances are immutable, but they can be cloned, accepting the same keyword arguments as the class constructor and returning a new Policy instance that is a copy of the original but with the specified attributes values changed.

As an example, the following code could be used to read an email message from a file on disk and pass it to the system sendmail program on a Unix system:

```python
>>> from email import message_from_binary_file
>>> from email.generator import BytesGenerator
>>> from email import policy
>>> from subprocess import Popen, PIPE
>>> with open('mymsg.txt', 'rb') as f:
...     msg = message_from_binary_file(f, policy=policy)
>>> p = Popen(['sendmail', msg['To'][0].addresses[0]],
>>> g = BytesGenerator(p.stdin, policy=msg.policy.clone)
>>> g.flatten(msg)
```
Here we are telling `BytesGenerator` to use the RFC correct line separator characters when creating the binary string to feed into sendmail's stdin, where the default policy would use \n line separators.

Some email package methods accept a `policy` keyword argument, allowing the policy to be overridden for that method. For example, the following code uses the `as_bytes()` method of the `msg` object from the previous example and writes the message to a file using the native line separators for the platform on which it is running:

```python
>>> import os
>>> with open('converted.txt', 'wb') as f:
...     f.write(msg.as_bytes(policy=msg.policy.clone)
```

Policy objects can also be combined using the addition operator, producing a policy object whose settings are a combination of the non-default values of the summed objects:

```python
>>> compat_SMTP = policy.compat32.clone(linesep='\r\n')
>>> compat_strict = policy.compat32.clone(raise_on_defect=True)
>>> compat_strict_SMTP = compat_SMTP + compat_strict
```

This operation is not commutative; that is, the order in which the objects are added matters. To illustrate:

```python
>>> policy100 = policy.compat32.clone(max_line_length=100)
>>> policy80 = policy.compat32.clone(max_line_length=80)
```
class email.policy.Policy(**kw)

This is the abstract base class for all policy classes. It provides default implementations for a couple of trivial methods, as well as the implementation of the immutability property, the clone() method, and the constructor semantics.

The constructor of a policy class can be passed various keyword arguments. The arguments that may be specified are any non-method properties on this class, plus any additional non-method properties on the concrete class. A value specified in the constructor will override the default value for the corresponding attribute.

This class defines the following properties, and thus values for the following may be passed in the constructor of any policy class:

**max_line_length**

The maximum length of any line in the serialized output, not counting the end of line character(s). Default is 78, per RFC 5322. A value of 0 or None indicates that no line wrapping should be done at all.

**linesep**

The string to be used to terminate lines in serialized output. The default is \n because that's the internal end-of-line discipline used by Python, though \r\n is required by the RFCs.
**cte_type**

Controls the type of Content Transfer Encodings that may be or are required to be used. The possible values are:

<table>
<thead>
<tr>
<th>7bit</th>
<th>all data must be “7 bit clean” (ASCII-only). This means that where necessary data will be encoded using either quoted-printable or base64 encoding.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8bit</td>
<td>data is not constrained to be 7 bit clean. Data in headers is still required to be ASCII-only and so will be encoded (see ‘binary_fold’ below for an exception), but body parts may use the 8bit CTE.</td>
</tr>
</tbody>
</table>

A cte_type value of 8bit only works with BytesGenerator, not Generator, because strings cannot contain binary data. If a Generator is operating under a policy that specifies cte_type=8bit, it will act as if cte_type is 7bit.

**raise_on_defect**

If True, any defects encountered will be raised as errors. If False (the default), defects will be passed to the register_defect() method.

**mangle_from_**

If True, lines starting with “From “ in the body are escaped by putting a > in front of them. This parameter is used when the message is being serialized by a generator. Default: False.

*New in version 3.5: The mangle_from_ parameter.*

The following Policy method is intended to be called by code using the email library to create policy instances with custom settings:
clone(**kw)

Return a new Policy instance whose attributes have the same values as the current instance, except where those attributes are given new values by the keyword arguments.

The remaining Policy methods are called by the email package code, and are not intended to be called by an application using the email package. A custom policy must implement all of these methods.

handle_defect(obj, defect)

Handle a defect found on obj. When the email package calls this method, defect will always be a subclass of Defect.

The default implementation checks the raise_on_defect flag. If it is True, defect is raised as an exception. If it is False (the default), obj and defect are passed to register_defect().

register_defect(obj, defect)

Register a defect on obj. In the email package, defect will always be a subclass of Defect.

The default implementation calls the append method of the defects attribute of obj. When the email package calls handle_defect, obj will normally have a defects attribute that has an append method. Custom object types used with the email package (for example, custom Message objects) should also provide such an attribute, otherwise defects in parsed messages will raise unexpected errors.

header_max_count(name)
Return the maximum allowed number of headers named *name*.

Called when a header is added to a *Message* object. If the returned value is not 0 or *None*, and there are already a number of headers with the name *name* equal to the value returned, a *ValueError* is raised.

Because the default behavior of *Message.*`__setitem__` is to append the value to the list of headers, it is easy to create duplicate headers without realizing it. This method allows certain headers to be limited in the number of instances of that header that may be added to a *Message* programmatically. (The limit is not observed by the parser, which will faithfully produce as many headers as exist in the message being parsed.)

The default implementation returns None for all header names.

**header_source_parse**(*sourcelines*)

The email package calls this method with a list of strings, each string ending with the line separation characters found in the source being parsed. The first line includes the field header name and separator. All whitespace in the source is preserved. The method should return the (*name*, *value*) tuple that is to be stored in the *Message* to represent the parsed header.

If an implementation wishes to retain compatibility with the existing email package policies, *name* should be the case preserved name (all characters up to the ‘:‘ separator), while *value* should be the unfolded value (all line separator characters removed, but whitespace kept intact), stripped of leading whitespace.
sourcelines may contain surrogateescaped binary data.

There is no default implementation

**header_store_parse**(name, value)

The email package calls this method with the name and value provided by the application program when the application program is modifying a Message programmatically (as opposed to a Message created by a parser). The method should return the (name, value) tuple that is to be stored in the Message to represent the header.

If an implementation wishes to retain compatibility with the existing email package policies, the name and value should be strings or string subclasses that do not change the content of the passed in arguments.

There is no default implementation

**header_fetch_parse**(name, value)

The email package calls this method with the name and value currently stored in the Message when that header is requested by the application program, and whatever the method returns is what is passed back to the application as the value of the header being retrieved. Note that there may be more than one header with the same name stored in the Message; the method is passed the specific name and value of the header destined to be returned to the application.

value may contain surrogateescaped binary data. There should be no surrogateescaped binary data in the value returned by the method.
There is no default implementation

**fold(name, value)**

The email package calls this method with the *name* and *value* currently stored in the Message for a given header. The method should return a string that represents that header “folded” correctly (according to the policy settings) by composing the *name* with the *value* and inserting *linesep* characters at the appropriate places. See RFC 5322 for a discussion of the rules for folding email headers.

*value* may contain surrogateescaped binary data. There should be no surrogateescaped binary data in the string returned by the method.

**fold_binary(name, value)**

The same as **fold()**, except that the returned value should be a bytes object rather than a string.

*value* may contain surrogateescaped binary data. These could be converted back into binary data in the returned bytes object.

**class email.policy.Compat32(**kw**)**

This concrete *Policy* is the backward compatibility policy. It replicates the behavior of the email package in Python 3.2. The *policy* module also defines an instance of this class, *compat32*, that is used as the default policy. Thus the default behavior of the email package is to maintain compatibility with Python 3.2.

The following attributes have values that are different from the *Policy* default:

**mangle_from_**
The default is True.

The class provides the following concrete implementations of the abstract methods of Policy:

**header_source_parse**(*sourcelines*)

The name is parsed as everything up to the `':` and returned unmodified. The value is determined by stripping leading whitespace off the remainder of the first line, joining all subsequent lines together, and stripping any trailing carriage return or linefeed characters.

**header_store_parse**(*name, value*)

The name and value are returned unmodified.

**header_fetch_parse**(*name, value*)

If the value contains binary data, it is converted into a Header object using the unknown-8bit charset. Otherwise it is returned unmodified.

**fold**(*name, value*)

Headers are folded using the Header folding algorithm, which preserves existing line breaks in the value, and wraps each resulting line to the max_line_length. Non-ASCII binary data are CTE encoded using the unknown-8bit charset.

**fold_binary**(*name, value*)

Headers are folded using the Header folding algorithm, which preserves existing line breaks in the value, and wraps each resulting line to the max_line_length. If cte_type is 7bit, non-ascii binary data is CTE encoded using the unknown-8bit charset. Otherwise the original source header is used,
with its existing line breaks and any (RFC invalid) binary data it may contain.

An instance of `Compat32` is provided as a module constant:

```python
email.policy.compat32
```

An instance of `Compat32`, providing backward compatibility with the behavior of the email package in Python 3.2.

---

**Note:** The documentation below describes new policies that are included in the standard library on a **provisional basis**. Backwards incompatible changes (up to and including removal of the feature) may occur if deemed necessary by the core developers.

```python
class email.policy.EmailPolicy(**kw)
```

This concrete `Policy` provides behavior that is intended to be fully compliant with the current email RFCs. These include (but are not limited to) `RFC 5322`, `RFC 2047`, and the current MIME RFCs.

This policy adds new header parsing and folding algorithms. Instead of simple strings, headers are `str` subclasses with attributes that depend on the type of the field. The parsing and folding algorithm fully implement `RFC 2047` and `RFC 5322`.

In addition to the settable attributes listed above that apply to all policies, this policy adds the following additional attributes:

```python
utf8
```

If `False`, follow `RFC 5322`, supporting non-ASCII characters in headers by encoding them as “encoded words”. If `True`, follow `RFC 6532` and use `utf-8` encoding for headers. Messages formatted in this way may be passed to SMTP servers that
support the SMTPUTF8 extension (RFC 6531).

refold_source
If the value for a header in the Message object originated from a parser (as opposed to being set by a program), this attribute indicates whether or not a generator should refold that value when transforming the message back into stream form. The possible values are:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>all source values use original folding</td>
</tr>
<tr>
<td>long</td>
<td>source values that have any line that is longer than max_line_length will be refolded</td>
</tr>
<tr>
<td>all</td>
<td>all values are refolded.</td>
</tr>
</tbody>
</table>

The default is long.

header_factory
A callable that takes two arguments, name and value, where name is a header field name and value is an unfolded header field value, and returns a string subclass that represents that header. A default header_factory (see headerregistry) is provided that understands some of the RFC 5322 header field types. (Currently address fields and date fields have special treatment, while all other fields are treated as unstructured. This list will be completed before the extension is marked stable.)

content_manager
An object with at least two methods: get_content and set_content. When the get_content() or set_content() method of a Message object is called, it calls the corresponding method of this object, passing it the message object as its first
argument, and any arguments or keywords that were passed to it as additional arguments. By default content_manager is set to raw_data_manager.

*New in version 3.4.*

The class provides the following concrete implementations of the abstract methods of `Policy`:

**header_max_count**(*name*)

Returns the value of the `max_count` attribute of the specialized class used to represent the header with the given name.

**header_source_parse**(*sourcelines*)

The implementation of this method is the same as that for the `Compat32` policy.

**header_store_parse**(*name, value*)

The name is returned unchanged. If the input value has a name attribute and it matches `name` ignoring case, the value is returned unchanged. Otherwise the `name` and `value` are passed to `header_factory`, and the resulting header object is returned as the value. In this case a `ValueError` is raised if the input value contains CR or LF characters.

**header_fetch_parse**(*name, value*)

If the value has a name attribute, it is returned to unmodified. Otherwise the `name`, and the `value` with any CR or LF characters removed, are passed to the `header_factory`, and the resulting header object is returned. Any surrogateescaped bytes get turned into the unicode unknown-character glyph.
**fold**(*name*, *value*)

Header folding is controlled by the `refold_source` policy setting. A value is considered to be a 'source value' if and only if it does not have a name attribute (having a name attribute means it is a header object of some sort). If a source value needs to be refolded according to the policy, it is converted into a header object by passing the `name` and the `value` with any CR and LF characters removed to the header_factory. Folding of a header object is done by calling its `fold` method with the current policy.

Source values are split into lines using `splitlines()`. If the value is not to be refolded, the lines are rejoined using the `linesep` from the policy and returned. The exception is lines containing non-ascii binary data. In that case the value is refolded regardless of the `refold_source` setting, which causes the binary data to be CTE encoded using the unknown-8bit charset.

**fold_binary**(*name*, *value*)

The same as `fold()` if `cte_type` is 7bit, except that the returned value is bytes.

If `cte_type` is 8bit, non-ASCII binary data is converted back into bytes. Headers with binary data are not refolded, regardless of the `refold_header` setting, since there is no way to know whether the binary data consists of single byte characters or multibyte characters.

The following instances of `EmailPolicy` provide defaults suitable for specific application domains. Note that in the future the behavior of these instances (in particular the HTTP instance) may be adjusted to
conform even more closely to the RFCs relevant to their domains.

**email.policy.default**

An instance of EmailPolicy with all defaults unchanged. This policy uses the standard Python \n line endings rather than the RFC-correct \r\n.

**email.policy.SMTP**

Suitable for serializing messages in conformance with the email RFCs. Like default, but with linesep set to \r\n, which is RFC compliant.

**email.policy.SMTPUTF8**

The same as SMTP except that utf8 is True. Useful for serializing messages to a message store without using encoded words in the headers. Should only be used for SMTP transmission if the sender or recipient addresses have non-ASCII characters (the smtplib.SMTP.send_message() method handles this automatically).

**email.policy.HTTP**

Suitable for serializing headers with for use in HTTP traffic. Like SMTP except that max_line_length is set to None (unlimited).

**email.policy.strict**

Convenience instance. The same as default except that raise_on_defect is set to True. This allows any policy to be made strict by writing:

```python
somepolicy + policy.strict
```

With all of these *EmailPolicies*, the effective API of the email
package is changed from the Python 3.2 API in the following ways:

- Setting a header on a `Message` results in that header being parsed and a header object created.
- Fetching a header value from a `Message` results in that header being parsed and a header object created and returned.
- Any header object, or any header that is refolded due to the policy settings, is folded using an algorithm that fully implements the RFC folding algorithms, including knowing where encoded words are required and allowed.

From the application view, this means that any header obtained through the `Message` is a header object with extra attributes, whose string value is the fully decoded unicode value of the header. Likewise, a header may be assigned a new value, or a new header created, using a unicode string, and the policy will take care of converting the unicode string into the correct RFC encoded form.

The header objects and their attributes are described in `headerregistry`. 
19.1.5. **email.headerregistry**: Custom Header Objects

**Note**: The headerregistry module has been included in the standard library on a **provisional basis**. Backwards incompatible changes (up to and including removal of the module) may occur if deemed necessary by the core developers.

*New in version 3.3*: as a **provisional module**.

Headers are represented by customized subclasses of `str`. The particular class used to represent a given header is determined by the `header_factory` of the `policy` in effect when the headers are created. This section documents the particular `header_factory` implemented by the email package for handling **RFC 5322** compliant email messages, which not only provides customized header objects for various header types, but also provides an extension mechanism for applications to add their own custom header types.

When using any of the policy objects derived from `EmailPolicy`, all headers are produced by `HeaderRegistry` and have `BaseHeader` as their last base class. Each header class has an additional base class that is determined by the type of the header. For example, many headers have the class `UnstructuredHeader` as their other base class. The specialized second class for a header is determined by the name of the header, using a lookup table stored in the `HeaderRegistry`. All of this is managed transparently for the typical application program, but interfaces are provided for modifying the default behavior for use by more complex applications.
The sections below first document the header base classes and their attributes, followed by the API for modifying the behavior of `HeaderRegistry`, and finally the support classes used to represent the data parsed from structured headers.

```python
class email.headerregistry.BaseHeader(name, value)
```

`name` and `value` are passed to `BaseHeader` from the `header_factory` call. The string value of any header object is the `value` fully decoded to unicode.

This base class defines the following read-only properties:

**name**

The name of the header (the portion of the field before the `:`). This is exactly the value passed in the `header_factory` call for `name`; that is, case is preserved.

**defects**

A tuple of `HeaderDefect` instances reporting any RFC compliance problems found during parsing. The email package tries to be complete about detecting compliance issues. See the `errors` module for a discussion of the types of defects that may be reported.

**max_count**

The maximum number of headers of this type that can have the same name. A value of None means unlimited. The `BaseHeader` value for this attribute is None; it is expected that specialized header classes will override this value as needed.

`BaseHeader` also provides the following method, which is called by the email library code and should not in general be called by
application programs:

**fold(\*, policy)**

Return a string containing linesep characters as required to correctly fold the header according to policy. A cte_type of 8bit will be treated as if it were 7bit, since strings may not contain binary data.

BaseHeader by itself cannot be used to create a header object. It defines a protocol that each specialized header cooperates with in order to produce the header object. Specifically, BaseHeader requires that the specialized class provide a classmethod() named parse. This method is called as follows:

```python
parse(string, kwds)
```

kwds is a dictionary containing one pre-initialized key, defects. defects is an empty list. The parse method should append any detected defects to this list. On return, the kwds dictionary *must* contain values for at least the keys decoded and defects. decoded should be the string value for the header (that is, the header value fully decoded to unicode). The parse method should assume that string may contain transport encoded parts, but should correctly handle all valid unicode characters as well so that it can parse un-encoded header values.

BaseHeader's __new__ then creates the header instance, and calls its init method. The specialized class only needs to provide an init method if it wishes to set additional attributes beyond those provided by BaseHeader itself. Such an init method should look like this:
```python
def init(self, *args, **kw):
    self._myattr = kw.pop('myattr')
    super().init(*args, **kw)
```

That is, anything extra that the specialized class puts in to the kwds dictionary should be removed and handled, and the remaining contents of kw (and args) passed to the BaseHeader init method.

class email.headerregistry.UnstructuredHeader

An “unstructured” header is the default type of header in RFC 5322. Any header that does not have a specified syntax is treated as unstructured. The classic example of an unstructured header is the Subject header.

In RFC 5322, an unstructured header is a run of arbitrary text in the ASCII character set. RFC 2047, however, has an RFC 5322 compatible mechanism for encoding non-ASCII text as ASCII characters within a header value. When a value containing encoded words is passed to the constructor, the UnstructuredHeader parser converts such encoded words back in to the original unicode, following the RFC 2047 rules for unstructured text. The parser uses heuristics to attempt to decode certain non-compliant encoded words. Defects are registered in such cases, as well as defects for issues such as invalid characters within the encoded words or the non-encoded text.

This header type provides no additional attributes.

class email.headerregistry.DateHeader

RFC 5322 specifies a very specific format for dates within email headers. The DateHeader parser recognizes that date format, as well as recognizing a number of variant forms that are sometimes
found “in the wild”.

This header type provides the following additional attributes:

**datetime**

If the header value can be recognized as a valid date of one form or another, this attribute will contain a `datetime` instance representing that date. If the timezone of the input date is specified as `-0000` (indicating it is in UTC but contains no information about the source timezone), then `datetime` will be a naive `datetime`. If a specific timezone offset is found (including `+0000`), then `datetime` will contain an aware `datetime` that uses `datetime.timezone` to record the timezone offset.

The decoded value of the header is determined by formatting the `datetime` according to the **RFC 5322** rules; that is, it is set to:

```python
email.utils.format_datetime(self.datetime)
```

When creating a DateHeader, `value` may be `datetime` instance. This means, for example, that the following code is valid and does what one would expect:

```python
msg['Date'] = datetime(2011, 7, 15, 21)
```

Because this is a naive `datetime` it will be interpreted as a UTC timestamp, and the resulting value will have a timezone of `-0000`. Much more useful is to use the `localtime()` function from the `utils` module:

```python
msg['Date'] = utils.localtime()
```
This example sets the date header to the current time and date using the current timezone offset.

class email.headerregistry.AddressHeader

Address headers are one of the most complex structured header types. The AddressHeader class provides a generic interface to any address header.

This header type provides the following additional attributes:

**groups**

A tuple of `Group` objects encoding the addresses and groups found in the header value. Addresses that are not part of a group are represented in this list as single-address Groups whose `display_name` is None.

**addresses**

A tuple of `Address` objects encoding all of the individual addresses from the header value. If the header value contains any groups, the individual addresses from the group are included in the list at the point where the group occurs in the value (that is, the list of addresses is “flattened” into a one dimensional list).

The decoded value of the header will have all encoded words decoded to unicode. `idna` encoded domain names are also decoded to unicode. The decoded value is set by joining the `str` value of the elements of the groups attribute with ',', '.

A list of `Address` and `Group` objects in any combination may be used to set the value of an address header. Group objects whose `display_name` is None will be interpreted as single addresses,
which allows an address list to be copied with groups intact by using the list obtained groups attribute of the source header.

```py
class email.headerregistry.SingleAddressHeader
    A subclass of AddressHeader that adds one additional attribute:
    
    **address**
    The single address encoded by the header value. If the header value actually contains more than one address (which would be a violation of the RFC under the default policy), accessing this attribute will result in a ValueError.
```

Many of the above classes also have a Unique variant (for example, UniqueUnstructuredHeader). The only difference is that in the Unique variant, `max_count` is set to 1.

```py
class email.headerregistry.MIMEVersionHeader
    There is really only one valid value for the MIME-Version header, and that is 1.0. For future proofing, this header class supports other valid version numbers. If a version number has a valid value per RFC 2045, then the header object will have non-None values for the following attributes:
    
    **version**
    The version number as a string, with any whitespace and/or comments removed.
    
    **major**
    The major version number as an integer
    
    **minor**
    The minor version number as an integer
```
class email.headerregistry.ParameterizedMIMEHeader

MOME headers all start with the prefix ‘Content-‘. Each specific header has a certain value, described under the class for that header. Some can also take a list of supplemental parameters, which have a common format. This class serves as a base for all the MIME headers that take parameters.

**params**

A dictionary mapping parameter names to parameter values.

class email.headerregistry.ContentTypeHeader

A ParameterizedMIMEHeader class that handles the Content-Type header.

**content_type**

The content type string, in the form maintype/subtype.

**maintype**

**subtype**

class email.headerregistry.ContentDispositionHeader

A ParameterizedMIMEHeader class that handles the Content-Disposition header.

**content-disposition**

inline and attachment are the only valid values in common use.

class email.headerregistry.ContentTransferEncoding

Handles the Content-Transfer-Encoding header.

**cte**
Valid values are 7bit, 8bit, base64, and quoted-printable. See **RFC 2045** for more information.

class
e-mail.headerregistry.HeaderRegistry(base_class=BaseHeader,
default_class=UnstructuredHeader, use_default_map=True)

This is the factory used by **EmailPolicy** by default. HeaderRegistry builds the class used to create a header instance dynamically, using *base_class* and a specialized class retrieved from a registry that it holds. When a given header name does not appear in the registry, the class specified by *default_class* is used as the specialized class. When *use_default_map* is True (the default), the standard mapping of header names to classes is copied into the registry during initialization. *base_class* is always the last class in the generated class’s __bases__ list.

The default mappings are:

<table>
<thead>
<tr>
<th>Field</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>subject</td>
<td>UniqueUnstructuredHeader</td>
</tr>
<tr>
<td>date</td>
<td>UniqueDateHeader</td>
</tr>
<tr>
<td>resent-date</td>
<td>DateHeader</td>
</tr>
<tr>
<td>orig-date</td>
<td>UniqueDateHeader</td>
</tr>
<tr>
<td>sender</td>
<td>UniqueSingleAddressHeader</td>
</tr>
<tr>
<td>resent-sender</td>
<td>SingleAddressHeader</td>
</tr>
<tr>
<td>to</td>
<td>UniqueAddressHeader</td>
</tr>
<tr>
<td>resent-to</td>
<td>AddressHeader</td>
</tr>
<tr>
<td>cc</td>
<td>UniqueAddressHeader</td>
</tr>
<tr>
<td>resent-cc</td>
<td>AddressHeader</td>
</tr>
<tr>
<td>from</td>
<td>UniqueAddressHeader</td>
</tr>
</tbody>
</table>
HeaderRegistry has the following methods:

```python
def map_to_type(self, name, cls):
    name is the name of the header to be mapped. It will be
    converted to lower case in the registry. cls is the specialized
    class to be used, along with base_class, to create the class
    used to instantiate headers that match name.
```

```python
def __getitem__(name):
    Construct and return a class to handle creating a name header.
```

```python
def __call__(name, value):
    Retrieves the specialized header associated with name from
    the registry (using default_class if name does not appear in the
    registry) and composes it with base_class to produce a class,
    calls the constructed class's constructor, passing it the same
    argument list, and finally returns the class instance created
    thereby.
```

The following classes are the classes used to represent data parsed
from structured headers and can, in general, be used by an application
program to construct structured values to assign to specific headers.

```python
class email.headerregistry.Address(display_name='',
    username='',
    domain='',
    addr_spec=None)
```

The class used to represent an email address. The general form of
an address is:

```
[display_name] <username@domain>
```
or:

```python
username@domain
```

where each part must conform to specific syntax rules spelled out in **RFC 5322**.

As a convenience `addr_spec` can be specified instead of `username` and `domain`, in which case `username` and `domain` will be parsed from the `addr_spec`. An `addr_spec` must be a properly RFC quoted string; if it is not Address will raise an error. Unicode characters are allowed and will be properly encoded when serialized. However, per the RFCs, unicode is *not* allowed in the username portion of the address.

**display_name**

The display name portion of the address, if any, with all quoting removed. If the address does not have a display name, this attribute will be an empty string.

**username**

The username portion of the address, with all quoting removed.

**domain**

The domain portion of the address.

**addr_spec**

The `username@domain` portion of the address, correctly quoted for use as a bare address (the second form shown above). This attribute is not mutable.

```python
__str__()
```
The str value of the object is the address quoted according to RFC 5322 rules, but with no Content Transfer Encoding of any non-ASCII characters.

To support SMTP (RFC 5321), Address handles one special case: if username and domain are both the empty string (or None), then the string value of the Address is <>.

```python
class email.headerregistry.Group(display_name=None, addresses=None)
```

The class used to represent an address group. The general form of an address group is:

```
display_name: [address-list];
```

As a convenience for processing lists of addresses that consist of a mixture of groups and single addresses, a Group may also be used to represent single addresses that are not part of a group by setting display_name to None and providing a list of the single address as addresses.

**display_name**

The display_name of the group. If it is None and there is exactly one Address in addresses, then the Group represents a single address that is not in a group.

**addresses**

A possibly empty tuple of Address objects representing the addresses in the group.

```python
__str__()
```

The str value of a Group is formatted according to RFC 5322,
but with no Content Transfer Encoding of any non-ASCII characters. If display_name is none and there is a single Address in the addresses list, the str value will be the same as the str of that single Address.
19.1.6. `email.contentmanager`: Managing MIME Content

**Note:** The contentmanager module has been included in the standard library on a provisional basis. Backwards incompatible changes (up to and including removal of the module) may occur if deemed necessary by the core developers.

New in version 3.4: as a provisional module.

The `message` module provides a class that can represent an arbitrary email message. That basic message model has a useful and flexible API, but it provides only a lower-level API for interacting with the generic parts of a message (the headers, generic header parameters, and the payload, which may be a list of sub-parts). This module provides classes and tools that provide an enhanced and extensible API for dealing with various specific types of content, including the ability to retrieve the content of the message as a specialized object type rather than as a simple bytes object. The module automatically takes care of the RFC-specified MIME details (required headers and parameters, etc.) for the certain common content types content properties, and support for additional types can be added by an application using the extension mechanisms.

This module defines the eponymous “Content Manager” classes. The base `ContentManager` class defines an API for registering content management functions which extract data from `Message` objects or insert data and headers into `Message` objects, thus providing a way of converting between `Message` objects containing data and other representations of that data (Python data types, specialized Python
objects, external files, etc). The module also defines one concrete content manager: `raw_data_manager` converts between MIME content types and str or bytes data. It also provides a convenient API for managing the MIME parameters when inserting content into Messages. It also handles inserting and extracting Message objects when dealing with the message/rfc822 content type.

Another part of the enhanced interface is subclasses of `Message` that provide new convenience API functions, including convenience methods for calling the Content Managers derived from this module.

**Note:** Although `EmailMessage` and `MIMEPart` are currently documented in this module because of the provisional nature of the code, the implementation lives in the `email.message` module.

class email.message.**EmailMessage**(policy=default)

If `policy` is specified (it must be an instance of a `policy` class) use the rules it specifies to udpate and serialize the representation of the message. If `policy` is not set, use the `default` policy, which follows the rules of the email RFCs except for line endings (instead of the RFC mandated \r\n, it uses the Python standard \n line endings). For more information see the `policy` documentation.

This class is a subclass of `Message`. It adds the following methods:

**is_attachment()**

Return True if there is a `Content-Disposition` header and its (case insensitive) value is attachment, False otherwise.

*Changed in version 3.4.2:* `is_attachment` is now a method instead of a property, for consistency with `is_multipart()`.
get_body(preferencelist=('related', 'html', 'plain'))

Return the MIME part that is the best candidate to be the “body” of the message.

preferencelist must be a sequence of strings from the set related, html, and plain, and indicates the order of preference for the content type of the part returned.

Start looking for candidate matches with the object on which the get_body method is called.

If related is not included in preferencelist, consider the root part (or subpart of the root part) of any related encountered as a candidate if the (sub-)part matches a preference.

When encountering a multipart/related, check the start parameter and if a part with a matching Content-ID is found, consider only it when looking for candidate matches. Otherwise consider only the first (default root) part of the multipart/related.

If a part has a Content-Disposition header, only consider the part a candidate match if the value of the header is inline.

If none of the candidates matches any of the preferences in preferencelist, return None.

Notes: (1) For most applications the only preferencelist combinations that really make sense are ('plain',), ('html', 'plain'), and the default, ('related', 'html', 'plain'). (2) Because matching starts with the object on which get_body is called, calling get_body on a multipart/related will return the object itself unless
preferences has a non-default value. (3) Messages (or message parts) that do not specify a Content-Type or whose Content-Type header is invalid will be treated as if they are of type text/plain, which may occasionally cause get_body to return unexpected results.

iter_attachments()
Return an iterator over all of the parts of the message that are not candidate “body” parts. That is, skip the first occurrence of each of text/plain, text/html, multipart/related, or multipart/alternative (unless they are explicitly marked as attachments via Content-Disposition: attachment), and return all remaining parts. When applied directly to a multipart/related, return an iterator over the all the related parts except the root part (ie: the part pointed to by the start parameter, or the first part if there is no start parameter or the start parameter doesn’t match the Content-ID of any of the parts). When applied directly to a multipart/alternative or a non-multipart, return an empty iterator.

iter_parts()
Return an iterator over all of the immediate sub-parts of the message, which will be empty for a non-multipart. (See also walk().)

get_content(*args, content_manager=None, **kw)
Call the get_content method of the content_manager, passing self as the message object, and passing along any other arguments or keywords as additional arguments. If content_manager is not specified, use the content_manager specified by the current policy.
set_content(*args, content_manager=None, **kw)

Call the set_content method of the content_manager, passing self as the message object, and passing along any other arguments or keywords as additional arguments. If content_manager is not specified, use the content_manager specified by the current policy.

make_related(boundary=None)

Convert a non-multipart message into a multipart/related message, moving any existing Content-headers and payload into a (new) first part of the multipart. If boundary is specified, use it as the boundary string in the multipart, otherwise leave the boundary to be automatically created when it is needed (for example, when the message is serialized).

make_alternative(boundary=None)

Convert a non-multipart or a multipart/related into a multipart/alternative, moving any existing Content-headers and payload into a (new) first part of the multipart. If boundary is specified, use it as the boundary string in the multipart, otherwise leave the boundary to be automatically created when it is needed (for example, when the message is serialized).

make_mixed(boundary=None)

Convert a non-multipart, a multipart/related, or a multipart-alternative into a multipart/mixed, moving any existing Content-headers and payload into a (new) first part of the multipart. If boundary is specified, use it as the boundary string in the multipart, otherwise leave the
boundary to be automatically created when it is needed (for example, when the message is serialized).

add_related(*args, content_manager=None, **kw)
If the message is a multipart/related, create a new message object, pass all of the arguments to its set_content() method, and attach() it to the multipart. If the message is a non-multipart, call make_related() and then proceed as above. If the message is any other type of multipart, raise a TypeError. If content_manager is not specified, use the content_manager specified by the current policy. If the added part has no Content-Disposition header, add one with the value inline.

add_alternative(*args, content_manager=None, **kw)
If the message is a multipart/alternative, create a new message object, pass all of the arguments to its set_content() method, and attach() it to the multipart. If the message is a non-multipart or multipart/related, call make_alternative() and then proceed as above. If the message is any other type of multipart, raise a TypeError. If content_manager is not specified, use the content_manager specified by the current policy.

add_attachment(*args, content_manager=None, **kw)
If the message is a multipart/mixed, create a new message object, pass all of the arguments to its set_content() method, and attach() it to the multipart. If the message is a non-multipart, multipart/related, or multipart/alternative, call make_mixed() and then proceed as above. If content_manager is not specified, use the
content_manager specified by the current policy. If the added part has no Content-Disposition header, add one with the value attachment. This method can be used both for explicit attachments (Content-Disposition: attachment) and inline attachments (Content-Disposition: inline), by passing appropriate options to the content_manager.

**clear()**
Remove the payload and all of the headers.

**clear_content()**
Remove the payload and all of the Content- headers, leaving all other headers intact and in their original order.

*class email.message.MIMEPart*(policy=default)*
This class represents a subpart of a MIME message. It is identical to EmailMessage, except that no MIME-Version headers are added when set_content() is called, since sub-parts do not need their own MIME-Version headers.

*class email.contentmanager.ContentManager*
Base class for content managers. Provides the standard registry mechanisms to register converters between MIME content and other representations, as well as the get_content and set_content dispatch methods.

**get_content**(msg, *args, **kw)
Look up a handler function based on the mimetype of msg (see next paragraph), call it, passing through all arguments, and return the result of the call. The expectation is that the handler will extract the payload from msg and return an object that encodes information about the extracted data.
To find the handler, look for the following keys in the registry, stopping with the first one found:

- the string representing the full MIME type (maintype/subtype)
- the string representing the maintype
- the empty string

If none of these keys produce a handler, raise a `KeyError` for the full MIME type.

**set_content**( `msg`, `obj`, *`args`, **`kw` *)

If the maintype is multipart, raise a `TypeError`; otherwise look up a handler function based on the type of `obj` (see next paragraph), call `clear_content()` on the `msg`, and call the handler function, passing through all arguments. The expectation is that the handler will transform and store `obj` into `msg`, possibly making other changes to `msg` as well, such as adding various MIME headers to encode information needed to interpret the stored data.

To find the handler, obtain the type of `obj` (`typ = type(obj)`), and look for the following keys in the registry, stopping with the first one found:

- the type itself (`typ`)
- the type's fully qualified name (`typ.__module__ + '.' + typ.__qualname__`).
- the type's qualname (`typ.__qualname__`)
- the type's name (`typ.__name__`).

If none of the above match, repeat all of the checks above for each of the types in the **MRO** (`typ.__mro__`). Finally, if no
other key yields a handler, check for a handler for the key None. If there is no handler for None, raise a `KeyError` for the fully qualified name of the type.

Also add a `MIME-Version` header if one is not present (see also `MIMEPart`).

```python
add_get_handler(key, handler)
```

Record the function `handler` as the handler for `key`. For the possible values of `key`, see `get_content()`.

```python
add_set_handler(typekey, handler)
```

Record `handler` as the function to call when an object of a type matching `typekey` is passed to `set_content()`. For the possible values of `typekey`, see `set_content()`.
19.1.6.1. Content Manager Instances

Currently the email package provides only one concrete content manager, `raw_data_manager`, although more may be added in the future. `raw_data_manager` is the `content_manager` provided by `EmailPolicy` and its derivatives.

`email.contentmanager.raw_data_manager`

This content manager provides only a minimum interface beyond that provided by `Message` itself: it deals only with text, raw byte strings, and `Message` objects. Nevertheless, it provides significant advantages compared to the base API: `get_content` on a text part will return a unicode string without the application needing to manually decode it, `set_content` provides a rich set of options for controlling the headers added to a part and controlling the content transfer encoding, and it enables the use of the various `add_` methods, thereby simplifying the creation of multipart messages.

`email.contentmanager.get_content(msg, errors='replace')`

Return the payload of the part as either a string (for text parts), a `EmailMessage` object (for message/rfc822 parts), or a bytes object (for all other non-multipart types). Raise a `KeyError` if called on a multipart. If the part is a text part and `errors` is specified, use it as the error handler when decoding the payload to unicode. The default error handler is `replace`.

`email.contentmanager.set_content(msg, subtype="plain", charset='utf-8' cte=None, disposition=None,`
Add the headers and payload to `msg`:

Add a **Content-Type** header with a `maintype/subtype` value.

- For `str`, set the MIME `maintype` to `text`, and set the `subtype` to `subtype` if it is specified, or `plain` if it is not.
- For `bytes`, use the specified `maintype` and `subtype`, or raise a `TypeError` if they are not specified.
- For `Message` objects, set the `maintype` to `message`, and set the `subtype` to `subtype` if it is specified or `rfc822` if it is not. If `subtype` is partial, raise an error (bytes objects must be used to construct message/partial parts).
- For `<list>`, which should be a list of `Message` objects, set the `maintype` to `multipart`, and the `subtype` to `subtype` if it is specified, and `mixed` if it is not. If the message parts in the `<list>` have `MIME-Version` headers, remove them.

If `charset` is provided (which is valid only for `str`), encode the string to bytes using the specified character set. The default is `utf-8`. If the specified `charset` is a known alias for a standard
MIME charset name, use the standard charset instead.

If \texttt{cte} is set, encode the payload using the specified content transfer encoding, and set the \texttt{Content-Transfer-Encoding} header to that value. For \texttt{str} objects, if it is not set use heuristics to determine the most compact encoding. Possible values for \texttt{cte} are \texttt{quoted-printable}, \texttt{base64}, \texttt{7bit}, \texttt{8bit}, and \texttt{binary}. If the input cannot be encoded in the specified encoding (eg: \texttt{7bit}), raise a \texttt{ValueError}. For \texttt{Message}, per \texttt{RFC 2046}, raise an error if a \texttt{cte} of \texttt{quoted-printable} or \texttt{base64} is requested for \texttt{subtype rfc822}, and for any \texttt{cte} other than \texttt{7bit} for \texttt{subtype external-body}. For \texttt{message/rfc822}, use \texttt{8bit} if \texttt{cte} is not specified. For all other values of \texttt{subtype}, use \texttt{7bit}.

\textbf{Note:} A \texttt{cte} of \texttt{binary} does not actually work correctly yet. The \texttt{Message} object as modified by \texttt{set_content} is correct, but \texttt{BytesGenerator} does not serialize it correctly.

If \texttt{disposition} is set, use it as the value of the \texttt{Content-Disposition} header. If not specified, and \texttt{filename} is specified, add the header with the value attachment. If it is not specified and \texttt{filename} is also not specified, do not add the header. The only valid values for \texttt{disposition} are attachment and inline.

If \texttt{filename} is specified, use it as the value of the \texttt{filename} parameter of the \texttt{Content-Disposition} header. There is no default.

If \texttt{cid} is specified, add a \texttt{Content-ID} header with \texttt{cid} as its value.

If \texttt{params} is specified, iterate its \texttt{items} method and use the
resulting (key, value) pairs to set additional parameters on the *Content-Type* header.

If *headers* is specified and is a list of strings of the form headernamename: headervalue or a list of header objects (distinguished from strings by having a name attribute), add the headers to *msg*.
19.1.7. **email.mime**: Creating email and MIME objects from scratch

Ordinarily, you get a message object structure by passing a file or some text to a parser, which parses the text and returns the root message object. However you can also build a complete message structure from scratch, or even individual `Message` objects by hand. In fact, you can also take an existing structure and add new `Message` objects, move them around, etc. This makes a very convenient interface for slicing-and-dicing MIME messages.

You can create a new object structure by creating `Message` instances, adding attachments and all the appropriate headers manually. For MIME messages though, the `email` package provides some convenient subclasses to make things easier.

Here are the classes:

```python
class email.mime.base.MIMEBase(_maintype, _subtype, **_params)
```

Module: `email.mime.base`

This is the base class for all the MIME-specific subclasses of `Message`. Ordinarily you won’t create instances specifically of `MIMEBase`, although you could. `MIMEBase` is provided primarily as a convenient base class for more specific MIME-aware subclasses.

 `_maintype` is the `Content-Type` major type (e.g. `text` or `image`), and `_subtype` is the `Content-Type` minor type (e.g. `plain` or `gif`).
_params is a parameter key/value dictionary and is passed directly to Message.add_header.

The MIMEBase class always adds a Content-Type header (based on _maintype, _subtype, and _params), and a MIME-Version header (always set to 1.0).

class email.mime.nonmultipart.MIMENonMultipart
Module: email.mime.nonmultipart

A subclass of MIMEBase, this is an intermediate base class for MIME messages that are not multipart. The primary purpose of this class is to prevent the use of the attach() method, which only makes sense for multipart messages. If attach() is called, a MultipartConversionError exception is raised.

class email.mime.multipart.MIMEMultipart(_subtype='mixed', boundary=None, _subparts=None, **_params)
Module: email.mime.multipart

A subclass of MIMEBase, this is an intermediate base class for MIME messages that are multipart. Optional _subtype defaults to mixed, but can be used to specify the subtype of the message. A Content-Type header of multipart/_subtype will be added to the message object. A MIME-Version header will also be added.

Optional boundary is the multipart boundary string. When None (the default), the boundary is calculated when needed (for example, when the message is serialized).

_subparts is a sequence of initial subparts for the payload. It must be possible to convert this sequence to a list. You can always
attach new subparts to the message by using the `Message.attach` method.

Additional parameters for the `Content-Type` header are taken from the keyword arguments, or passed into the `_params` argument, which is a keyword dictionary.

```python
class email.mime.application.MIMEApplication(_data, _subtype='octet-stream', _encoder=email.encoders.encode_base64, **_params)
Module: email.mime.application
```

A subclass of `MIMENonMultipart`, the `MIMEApplication` class is used to represent MIME message objects of major type `application`. `_data` is a string containing the raw byte data. Optional `_subtype` specifies the MIME subtype and defaults to `octet-stream`.

Optional `_encoder` is a callable (i.e. function) which will perform the actual encoding of the data for transport. This callable takes one argument, which is the `MIMEApplication` instance. It should use `get_payload()` and `set_payload()` to change the payload to encoded form. It should also add any `Content-Transfer-Encoding` or other headers to the message object as necessary. The default encoding is base64. See the `email.encoders` module for a list of the built-in encoders.

`_params` are passed straight through to the base class constructor.

```python
class email.mime.audio.MIMEAudio(_audiodata, _subtype=None, _encoder=email.encoders.encode_base64, **_params)
Module: email.mime.audio
```
A subclass of MIMENonMultipart, the MIMEAudio class is used to create MIME message objects of major type audio. _audiodata is a string containing the raw audio data. If this data can be decoded by the standard Python module sndhdr, then the subtype will be automatically included in the Content-Type header. Otherwise you can explicitly specify the audio subtype via the _subtype argument. If the minor type could not be guessed and _subtype was not given, then TypeError is raised.

Optional _encoder is a callable (i.e. function) which will perform the actual encoding of the audio data for transport. This callable takes one argument, which is the MIMEAudio instance. It should use get_payload() and set_payload() to change the payload to encoded form. It should also add any Content-Transfer-Encoding or other headers to the message object as necessary. The default encoding is base64. See the email.encoders module for a list of the built-in encoders.

_params are passed straight through to the base class constructor.

class email.mime.image.MIMEImage(_imagedata,
_subtype=None,_encoder=email.encoders.encode_base64,
**_params)
Module: email.mime.image

A subclass of MIMENonMultipart, the MIMEImage class is used to create MIME message objects of major type image. _imagedata is a string containing the raw image data. If this data can be decoded by the standard Python module imghdr, then the subtype will be automatically included in the Content-Type header. Otherwise you can explicitly specify the image subtype via the _subtype argument. If the minor type could not be guessed and
Optional _encoder is a callable (i.e. function) which will perform the actual encoding of the image data for transport. This callable takes one argument, which is the MIMEImage instance. It should use get_payload() and set_payload() to change the payload to encoded form. It should also add any Content-Transfer-Encoding or other headers to the message object as necessary. The default encoding is base64. See the email.encoders module for a list of the built-in encoders.

__params__ are passed straight through to the MIMEBase constructor.

class email.mime.message.MIMEMessage(_msg,
   _subtype='rfc822')
   Module: email.mime.message

A subclass of MIMENonMultipart, the MIMEMessage class is used to create MIME objects of main type message. _msg is used as the payload, and must be an instance of class Message (or a subclass thereof), otherwise a TypeError is raised.

Optional _subtype sets the subtype of the message; it defaults to rfc822.

class email.mime.text.MIMEText(_text, _subtype='plain',
   _charset=None)
   Module: email.mime.text

A subclass of MIMENonMultipart, the MIMEText class is used to create MIME objects of major type text. _text is the string for the payload. _subtype is the minor type and defaults to plain. _charset is the character set of the text and is passed as an argument to the
MIMENonMultipart constructor; it defaults to us-ascii if the string contains only ascii code points, and utf-8 otherwise. The _charset parameter accepts either a string or a Charset instance.

Unless the _charset argument is explicitly set to None, the MIMEText object created will have both a Content-Type header with a charset parameter, and a Content-Transfer-Encoding header. This means that a subsequent set_payload call will not result in an encoded payload, even if a charset is passed in the set_payload command. You can “reset” this behavior by deleting the Content-Transfer-Encoding header, after which a set_payload call will automatically encode the new payload (and add a new Content-Transfer-Encoding header).

*Changed in version 3.5:* _charset also accepts Charset instances.*
19.1. `email` — An email and MIME handling package
19.1.8. `email.header`: Internationalized headers

`RFC 2822` is the base standard that describes the format of email messages. It derives from the older `RFC 822` standard which came into widespread use at a time when most email was composed of ASCII characters only. `RFC 2822` is a specification written assuming email contains only 7-bit ASCII characters.

Of course, as email has been deployed worldwide, it has become internationalized, such that language specific character sets can now be used in email messages. The base standard still requires email messages to be transferred using only 7-bit ASCII characters, so a slew of RFCs have been written describing how to encode email containing non-ASCII characters into `RFC 2822`-compliant format. These RFCs include `RFC 2045`, `RFC 2046`, `RFC 2047`, and `RFC 2231`. The `email` package supports these standards in its `email.header` and `email.charset` modules.

If you want to include non-ASCII characters in your email headers, say in the `Subject` or `To` fields, you should use the `Header` class and assign the field in the `Message` object to an instance of `Header` instead of using a string for the header value. Import the `Header` class from the `email.header` module. For example:

```python
>>> from email.message import Message
>>> from email.header import Header
>>> msg = Message()
>>> h = Header('p\xf6stal', 'iso-8859-1')
>>> msg['Subject'] = h
>>> msg.as_string()
```
Notice here how we wanted the Subject field to contain a non-ASCII character? We did this by creating a Header instance and passing in the character set that the byte string was encoded in. When the subsequent Message instance was flattened, the Subject field was properly RFC 2047 encoded. MIME-aware mail readers would show this header using the embedded ISO-8859-1 character.

Here is the Header class description:

```
class email.header.Header(s=None, charset=None, maxlinelen=None, header_name=None, continuation_ws=' ', errors='strict')
```

Create a MIME-compliant header that can contain strings in different character sets.

Optional s is the initial header value. If None (the default), the initial header value is not set. You can later append to the header with append() method calls. s may be an instance of bytes or str, but see the append() documentation for semantics.

Optional charset serves two purposes: it has the same meaning as the charset argument to the append() method. It also sets the default character set for all subsequent append() calls that omit the charset argument. If charset is not provided in the constructor (the default), the us-ascii character set is used both as s's initial charset and as the default for subsequent append() calls.

The maximum line length can be specified explicitly via maxlinelen. For splitting the first line to a shorter value (to account for the field header which isn't included in s, e.g. Subject) pass in the name of the field in header_name. The default maxlinelen is 76, and the
default value for header_name is None, meaning it is not taken into account for the first line of a long, split header.

Optional continuation_ws must be RFC 2822-compliant folding whitespace, and is usually either a space or a hard tab character. This character will be prepended to continuation lines. continuation_ws defaults to a single space space character.

Optional errors is passed straight through to the append() method.

append(s, charset=None, errors='strict')

Append the string s to the MIME header.

Optional charset, if given, should be a Charset instance (see email.charset) or the name of a character set, which will be converted to a Charset instance. A value of None (the default) means that the charset given in the constructor is used.

s may be an instance of bytes or str. If it is an instance of bytes, then charset is the encoding of that byte string, and a UnicodeError will be raised if the string cannot be decoded with that character set.

If s is an instance of str, then charset is a hint specifying the character set of the characters in the string.

In either case, when producing an RFC 2822-compliant header using RFC 2047 rules, the string will be encoded using the output codec of the charset. If the string cannot be encoded using the output codec, a UnicodeError will be raised.

Optional errors is passed as the errors argument to the decode
call if s is a byte string.

**encode**(splitchars='; ', \t', maxlinelen=None, linesep='\n')

Encode a message header into an RFC-compliant format, possibly wrapping long lines and encapsulating non-ASCII parts in base64 or quoted-printable encodings.

Optional `splitchars` is a string containing characters which should be given extra weight by the splitting algorithm during normal header wrapping. This is in very rough support of RFC 2822's 'higher level syntactic breaks': split points preceded by a splitchar are preferred during line splitting, with the characters preferred in the order in which they appear in the string. Space and tab may be included in the string to indicate whether preference should be given to one over the other as a split point when other split chars do not appear in the line being split. Splitchars does not affect RFC 2047 encoded lines.

`maxlinelen`, if given, overrides the instance's value for the maximum line length.

`linesep` specifies the characters used to separate the lines of the folded header. It defaults to the most useful value for Python application code (\n), but \r\n can be specified in order to produce headers with RFC-compliant line separators.

*Changed in version 3.2: Added the `linesep` argument.*

The **Header** class also provides a number of methods to support standard operators and built-in functions.

**__str__**()

Returns an approximation of the **Header** as a string, using an
unlimited line length. All pieces are converted to unicode using the specified encoding and joined together appropriately. Any pieces with a charset of 'unknown-8bit' are decoded as ASCII using the 'replace' error handler.

*Changed in version 3.2:* Added handling for the 'unknown-8bit' charset.

```python
__eq__(other)
```
This method allows you to compare two `Header` instances for equality.

```python
__ne__(other)
```
This method allows you to compare two `Header` instances for inequality.

The `email.header` module also provides the following convenient functions.

```python
e-mail.header.decode_header(header)
```
Decode a message header value without converting the character set. The header value is in `header`.

This function returns a list of `(decoded_string, charset)` pairs containing each of the decoded parts of the header. `charset` is None for non-encoded parts of the header, otherwise a lower case string containing the name of the character set specified in the encoded string.

Here’s an example:

```python
>>> from email.header import decode_header
```
email.header._make_header(decoded_seq, maxlinelen=None, header_name=None, continuation_ws=' ')

Create a Header instance from a sequence of pairs as returned by decode_header().

decode_header() takes a header value string and returns a sequence of pairs of the format (decoded_string, charset) where charset is the name of the character set.

This function takes one of those sequence of pairs and returns a Header instance. Optional maxlinelen, header_name, and continuation_ws are as in the Header constructor.
19.1.9. **email.charset:** Representing character sets

This module provides a class `Charset` for representing character sets and character set conversions in email messages, as well as a character set registry and several convenience methods for manipulating this registry. Instances of `Charset` are used in several other modules within the `email` package.

Import this class from the `email.charset` module.

```python
class email.charset.Charset(input_charset=DEFAULT_CHARSET)
    Map character sets to their email properties.
```

This class provides information about the requirements imposed on email for a specific character set. It also provides convenience routines for converting between character sets, given the availability of the applicable codecs. Given a character set, it will do its best to provide information on how to use that character set in an email message in an RFC-compliant way.

Certain character sets must be encoded with quoted-printable or base64 when used in email headers or bodies. Certain character sets must be converted outright, and are not allowed in email.

Optional `input_charset` is as described below; it is always coerced to lower case. After being alias normalized it is also used as a lookup into the registry of character sets to find out the header encoding, body encoding, and output conversion codec to be used for the character set. For example, if `input_charset` is `iso-8859-
1, then headers and bodies will be encoded using quoted-printable and no output conversion codec is necessary. If input_charset is euc-jp, then headers will be encoded with base64, bodies will not be encoded, but output text will be converted from the euc-jp character set to the iso-2022-jp character set.

Charset instances have the following data attributes:

**input_charset**
The initial character set specified. Common aliases are converted to their official email names (e.g. latin_1 is converted to iso-8859-1). Defaults to 7-bit us-ascii.

**header_encoding**
If the character set must be encoded before it can be used in an email header, this attribute will be set to Charset.QP (for quoted-printable), Charset.BASE64 (for base64 encoding), or Charset.SHORTEST for the shortest of QP or BASE64 encoding. Otherwise, it will be None.

**body_encoding**
Same as header_encoding, but describes the encoding for the mail message's body, which indeed may be different than the header encoding. Charset.SHORTEST is not allowed for body_encoding.

**output_charset**
Some character sets must be converted before they can be used in email headers or bodies. If the input_charset is one of them, this attribute will contain the name of the character set output will be converted to. Otherwise, it will be None.
**input_codec**

The name of the Python codec used to convert the `input_charset` to Unicode. If no conversion codec is necessary, this attribute will be None.

**output_codec**

The name of the Python codec used to convert Unicode to the `output_charset`. If no conversion codec is necessary, this attribute will have the same value as the `input_codec`.

*Charset* instances also have the following methods:

**get_body_encoding()**

Return the content transfer encoding used for body encoding.

This is either the string quoted-printable or base64 depending on the encoding used, or it is a function, in which case you should call the function with a single argument, the Message object being encoded. The function should then set the `Content-Transfer-Encoding` header itself to whatever is appropriate.

Returns the string quoted-printable if `body_encoding` is QP, returns the string base64 if `body_encoding` is BASE64, and returns the string 7bit otherwise.

**get_output_charset()**

Return the output character set.

This is the `output_charset` attribute if that is not None, otherwise it is `input_charset`.

**header_encode(string)**
Header-encode the string `string`.

The type of encoding (base64 or quoted-printable) will be based on the `header_encoding` attribute.

**header_encode_lines**(*string, maxlengths*)

Header-encode a `string` by converting it first to bytes.

This is similar to `header_encode()` except that the string is fit into maximum line lengths as given by the argument `maxlengths`, which must be an iterator: each element returned from this iterator will provide the next maximum line length.

**body_encode**(*string*)

Body-encode the string `string`.

The type of encoding (base64 or quoted-printable) will be based on the `body_encoding` attribute.

The `Charset` class also provides a number of methods to support standard operations and built-in functions.

**__str__**()

Returns `input_charset` as a string coerced to lower case. **__repr__**() is an alias for **__str__**.

**__eq__**(other)

This method allows you to compare two `Charset` instances for equality.

**__ne__**(other)

This method allows you to compare two `Charset` instances for inequality.
The `email.charset` module also provides the following functions for adding new entries to the global character set, alias, and codec registries:

`email.charset.add_charset(charset, header_enc=None, body_enc=None, output_charset=None)`

Add character properties to the global registry.

`charset` is the input character set, and must be the canonical name of a character set.

Optional `header_enc` and `body_enc` is either `Charset.QP` for quoted-printable, `Charset.BASE64` for base64 encoding, `Charset.SHORTEST` for the shortest of quoted-printable or base64 encoding, or `None` for no encoding. `SHORTEST` is only valid for `header_enc`. The default is `None` for no encoding.

Optional `output_charset` is the character set that the output should be in. Conversions will proceed from input charset, to Unicode, to the output charset when the method `Charset.convert()` is called. The default is to output in the same character set as the input.

Both `input_charset` and `output_charset` must have Unicode codec entries in the module’s character set-to-codec mapping; use `add_codec()` to add codecs the module does not know about. See the `codecs` module's documentation for more information.

The global character set registry is kept in the module global dictionary `CHARSETS`.

`email.charset.add_alias(alias, canonical)`

Add a character set alias. `alias` is the alias name, e.g. `latin-1`. 
canonical is the character set's canonical name, e.g. iso-8859-1.

The global charset alias registry is kept in the module global dictionary ALIASES.

email.charset.add_codec(charset, codecname)
Add a codec that map characters in the given character set to and from Unicode.

charset is the canonical name of a character set. codecname is the name of a Python codec, as appropriate for the second argument to the str's encode() method.
19.1. **email** — An email and MIME handling package
19.1.10. **email.encoders:** Encoders

When creating `Message` objects from scratch, you often need to encode the payloads for transport through compliant mail servers. This is especially true for `image/*` and `text/*` type messages containing binary data.

The `email` package provides some convenient encodings in its `encoders` module. These encoders are actually used by the `MIMEAudio` and `MIMEImage` class constructors to provide default encodings. All encoder functions take exactly one argument, the message object to encode. They usually extract the payload, encode it, and reset the payload to this newly encoded value. They should also set the `Content-Transfer-Encoding` header as appropriate.

Note that these functions are not meaningful for a multipart message. They must be applied to individual subparts instead, and will raise a `TypeError` if passed a message whose type is multipart.

Here are the encoding functions provided:

```python
email.encoders.encode_quopri(msg)
```

Encodes the payload into quoted-printable form and sets the `Content-Transfer-Encoding` header to quoted-printable [1]. This is a good encoding to use when most of your payload is normal printable data, but contains a few unprintable characters.

```python
email.encoders.encode_base64(msg)
```

Encodes the payload into base64 form and sets the `Content-Transfer-Encoding` header to base64 [1].
Transfer-Encoding header to base64. This is a good encoding to use when most of your payload is unprintable data since it is a more compact form than quoted-printable. The drawback of base64 encoding is that it renders the text non-human readable.

```
email.encoders.encode_7or8bit(msg)
```

This doesn’t actually modify the message’s payload, but it does set the Content-Transfer-Encoding header to either 7bit or 8bit as appropriate, based on the payload data.

```
email.encoders.encode_noop(msg)
```

This does nothing; it doesn’t even set the Content-Transfer-Encoding header.

**Footnotes**

[1] Note that encoding with `encode_quopri()` also encodes all tabs and space characters in the data.
19.1.11. `email.errors`: Exception and Defect classes

The following exception classes are defined in the `email.errors` module:

* `exception email.errors.MessageError`
  This is the base class for all exceptions that the `email` package can raise. It is derived from the standard `Exception` class and defines no additional methods.

* `exception email.errors.MessageParseError`
  This is the base class for exceptions raised by the `Parser` class. It is derived from `MessageError`.

* `exception email.errors.HeaderParseError`
  Raised under some error conditions when parsing the RFC 2822 headers of a message, this class is derived from `MessageParseError`. It can be raised from the `Parser.parse` or `Parser.parsestr` methods.

  Situations where it can be raised include finding an envelope header after the first RFC 2822 header of the message, finding a continuation line before the first RFC 2822 header is found, or finding a line in the headers which is neither a header or a continuation line.

* `exception email.errors.BoundaryError`
  Raised under some error conditions when parsing the RFC 2822 headers of a message, this class is derived from
**MessageParseError**. It can be raised from the `Parser.parse` or `Parser.parsestr` methods.

Situations where it can be raised include not being able to find the starting or terminating boundary in a `multipart/*` message when strict parsing is used.

**exception** `email.errors.MultipartConversionError`  
Raised when a payload is added to a `Message` object using `add_payload()`, but the payload is already a scalar and the message’s `Content-Type` main type is not either `multipart` or missing. `MultipartConversionError` multiply inherits from `MessageError` and the built-in `TypeError`.

Since `Message.add_payload()` is deprecated, this exception is rarely raised in practice. However the exception may also be raised if the `attach()` method is called on an instance of a class derived from `MIMENonMultipart` (e.g. `MIMEImage`).

Here’s the list of the defects that the `FeedParser` can find while parsing messages. Note that the defects are added to the message where the problem was found, so for example, if a message nested inside a `multipart/alternative` had a malformed header, that nested message object would have a defect, but the containing messages would not.

All defect classes are subclassed from `email.errors.MessageDefect`, but this class is not an exception!

- **NoBoundaryInMultipartDefect** – A message claimed to be a multipart, but had no `boundary` parameter.
- **StartBoundaryNotFoundDefect** – The start boundary
claimed in the *Content-Type* header was never found.

- **CloseBoundaryNotFoundDefect** – A start boundary was found, but no corresponding close boundary was ever found.

  *New in version 3.3.*

- **FirstHeaderLineIsContinuationDefect** – The message had a continuation line as its first header line.

- **MisplacedEnvelopeHeaderDefect** - A “Unix From” header was found in the middle of a header block.

- **MissingHeaderBodySeparatorDefect** - A line was found while parsing headers that had no leading white space but contained no ‘:’. Parsing continues assuming that the line represents the first line of the body.

  *New in version 3.3.*

- **MalformedHeaderDefect** – A header was found that was missing a colon, or was otherwise malformed.

  *Deprecated since version 3.3:* This defect has not been used for several Python versions.

- **MultipartInvariantViolationDefect** – A message claimed to be a *multipart*, but no subparts were found. Note that when a message has this defect, its *is_multipart()* method may return false even though its content type claims to be *multipart*.

- **InvalidBase64PaddingDefect** – When decoding a block of base64 encoded bytes, the padding was not correct. Enough
padding is added to perform the decode, but the resulting decoded bytes may be invalid.

- **InvalidBase64CharactersDefect** – When decoding a block of base64 encoded bytes, characters outside the base64 alphabet were encountered. The characters are ignored, but the resulting decoded bytes may be invalid.
19.1. `email` — An email and MIME handling package
19.1.12. **email.utils:**
Miscellaneous utilities

There are several useful utilities provided in the `email.utils` module:

**email.utils.quote(str)**
Return a new string with backslashes in `str` replaced by two backslashes, and double quotes replaced by backslash-double quote.

**email.utils.unquote(str)**
Return a new string which is an *unquoted* version of `str`. If `str` ends and begins with double quotes, they are stripped off. Likewise if `str` ends and begins with angle brackets, they are stripped off.

**email.utils.parseaddr(address)**
Parse address – which should be the value of some address-containing field such as `To` or `Cc` – into its constituent *realname* and *email address* parts. Returns a tuple of that information, unless the parse fails, in which case a 2-tuple of (’, ’) is returned.

**email.utils.formataddr(pair, charset='utf-8')**
The inverse of `parseaddr()`, this takes a 2-tuple of the form (realname, email_address) and returns the string value suitable for a `To` or `Cc` header. If the first element of `pair` is false, then the second element is returned unmodified.

Optional *charset* is the character set that will be used in the RFC 2047 encoding of the realname if the realname contains non-
ASCII characters. Can be an instance of `str` or a `Charset`. Defaults to utf-8.

*Changed in version 3.3:* Added the `charset` option.

`email.utils.getaddresses(fieldvalues)`

This method returns a list of 2-tuples of the form returned by `parseaddr()`. `fieldvalues` is a sequence of header field values as might be returned by `Message.get_all`. Here's a simple example that gets all the recipients of a message:

```python
from email.utils import getaddresses

tos = msg.get_all('to', [])
ccs = msg.get_all('cc', [])
resent_tos = msg.get_all('resent-to', [])
resent_ccs = msg.get_all('resent-cc', [])
all_recipients = getaddresses(tos + ccs + resent_tos + resent_ccs)
```

`email.utils.parsedate(date)`

Attempts to parse a date according to the rules in RFC 2822. However, some mailers don't follow that format as specified, so `parsedate()` tries to guess correctly in such cases. `date` is a string containing an RFC 2822 date, such as "Mon, 20 Nov 1995 19:12:08 -0500". If it succeeds in parsing the date, `parsedate()` returns a 9-tuple that can be passed directly to `time.mktime()``; otherwise None will be returned. Note that indexes 6, 7, and 8 of the result tuple are not usable.

`email.utils.parsedate_tz(date)`

Performs the same function as `parsedate()`, but returns either None or a 10-tuple; the first 9 elements make up a tuple that can
be passed directly to `time.mktime()`, and the tenth is the offset of the date's timezone from UTC (which is the official term for Greenwich Mean Time) [1]. If the input string has no timezone, the last element of the tuple returned is None. Note that indexes 6, 7, and 8 of the result tuple are not usable.

email.utils.**parsedate_to_datetime**(date)

The inverse of `format_datetime()`. Performs the same function as `parsedate()`, but on success returns a `datetime`. If the input date has a timezone of -0000, the datetime will be a naive datetime, and if the date is conforming to the RFCs it will represent a time in UTC but with no indication of the actual source timezone of the message the date comes from. If the input date has any other valid timezone offset, the datetime will be an aware datetime with the corresponding a `timezone tzinfo`.

*New in version 3.3.*

email.utils.**mktime_tz**(tuple)

Turn a 10-tuple as returned by `parsedate_tz()` into a UTC timestamp (seconds since the Epoch). If the timezone item in the tuple is None, assume local time.

email.utils.**formatdate**(timeval=None, localtime=False, usegmt=False)

Returns a date string as per RFC 2822, e.g.:

```plaintext
Fri, 09 Nov 2001 01:08:47 -0000
```

Optional `timeval` if given is a floating point time value as accepted by `time.gmtime()` and `time.localtime()`, otherwise the current time is used.
Optional `localtime` is a flag that when True, interprets `timeval`, and returns a date relative to the local timezone instead of UTC, properly taking daylight savings time into account. The default is False meaning UTC is used.

Optional `usegmt` is a flag that when True, outputs a date string with the timezone as an ascii string GMT, rather than a numeric -0000. This is needed for some protocols (such as HTTP). This only applies when `localtime` is False. The default is False.

```python
email.utils.format_datetime(dt, usegmt=False)
```

Like `formatdate`, but the input is a `datetime` instance. If it is a naive datetime, it is assumed to be “UTC with no information about the source timezone”, and the conventional -0000 is used for the timezone. If it is an aware datetime, then the numeric timezone offset is used. If it is an aware timezone with offset zero, then `usegmt` may be set to True, in which case the string GMT is used instead of the numeric timezone offset. This provides a way to generate standards conformant HTTP date headers.

*New in version 3.3.*

```python
email.utils.localtime(dt=None)
```

Return local time as an aware datetime object. If called without arguments, return current time. Otherwise `dt` argument should be a `datetime` instance, and it is converted to the local time zone according to the system time zone database. If `dt` is naive (that is, `dt.tzinfo` is None), it is assumed to be in local time. In this case, a positive or zero value for `isdst` causes `localtime` to presume initially that summer time (for example, Daylight Saving Time) is or is not (respectively) in effect for the specified time. A negative value for `isdst` causes the `localtime` to attempt to divine whether...
summer time is in effect for the specified time.

New in version 3.3.

e-mail.utils.make_msgid(idstring=None, domain=None)

Returns a string suitable for an RFC 2822-compliant Message-ID header. Optional idstring if given, is a string used to strengthen the uniqueness of the message id. Optional domain if given provides the portion of the msgid after the '@'. The default is the local hostname. It is not normally necessary to override this default, but may be useful in certain cases, such as constructing distributed system that uses a consistent domain name across multiple hosts.

Changed in version 3.2: Added the domain keyword.

e-mail.utils.decode_rfc2231(s)

Decode the string s according to RFC 2231.

e-mail.utils.encode_rfc2231(s, charset=None, language=None)

Encode the string s according to RFC 2231. Optional charset and language, if given is the character set name and language name to use. If neither is given, s is returned as-is. If charset is given but language is not, the string is encoded using the empty string for language.

e-mail.utils-collapse_rfc2231_value(value, errors='replace', fallback_charset='us-ascii')

When a header parameter is encoded in RFC 2231 format, Message.get_param may return a 3-tuple containing the character set, language, and value. collapse_rfc2231_value() turns this into a unicode string. Optional errors is passed to the errors argument of str's
**encode()** method; it defaults to 'replace'. Optional *fallback_charset* specifies the character set to use if the one in the **RFC 2231** header is not known by Python; it defaults to 'us-ascii'.

For convenience, if the *value* passed to **collapse_rfc2231_value()** is not a tuple, it should be a string and it is returned unquoted.

**email.utils.decode_params(params)**

Decode parameters list according to **RFC 2231**. *params* is a sequence of 2-tuples containing elements of the form *(content-type, string-value)*.

**Footnotes**

[1] Note that the sign of the timezone offset is the opposite of the sign of the *time.timezone* variable for the same timezone; the latter variable follows the POSIX standard while this module follows **RFC 2822**.
19.1. **email** — An email and MIME handling package
19.1.13. **email.iterators**: Iterators

Iterating over a message object tree is fairly easy with the `Message.walk` method. The `email.iterators` module provides some useful higher level iterations over message object trees.

`email.iterators.body_line_iterator(msg, decode=False)`

This iterates over all the payloads in all the subparts of `msg`, returning the string payloads line-by-line. It skips over all the subpart headers, and it skips over any subpart with a payload that isn’t a Python string. This is somewhat equivalent to reading the flat text representation of the message from a file using `readline()`, skipping over all the intervening headers.

Optional `decode` is passed through to `Message.get_payload`.

`email.iterators.typed_subpart_iterator(msg, maintype='text', subtype=None)`

This iterates over all the subparts of `msg`, returning only those subparts that match the MIME type specified by `maintype` and `subtype`.

Note that `subtype` is optional; if omitted, then subpart MIME type matching is done only with the main type. `maintype` is optional too; it defaults to `text`.

Thus, by default `typed_subpart_iterator()` returns each subpart that has a MIME type of `text/*`. 
The following function has been added as a useful debugging tool. It should not be considered part of the supported public interface for the package.

```
email.iterators._structure(msg, fp=None, level=0, include_default=False)
```

Prints an indented representation of the content types of the message object structure. For example:

```
>>> msg = email.message_from_file(somefile)
>>> _structure(msg)
multipart/mixed
  text/plain
  text/plain
  multipart/digest
    message/rfc822
      text/plain
    message/rfc822
      text/plain
    message/rfc822
      text/plain
    message/rfc822
      text/plain
    message/rfc822
      text/plain
  text/plain
```

Optional `fp` is a file-like object to print the output to. It must be suitable for Python's `print()` function. `level` is used internally. `include_default`, if true, prints the default type as well.
19.1.14. **email**: Examples

Here are a few examples of how to use the `email` package to read, write, and send simple email messages, as well as more complex MIME messages.

First, let's see how to create and send a simple text message:

```python
# Import smtplib for the actual sending function
import smtplib

# Import the email modules we'll need
from email.mime.text import MIMEText

# Open a plain text file for reading.  For this example,
# the text file contains only ASCII characters.
with open(textfile) as fp:
    # Create a text/plain message
    msg = MIMEText(fp.read())

# me == the sender's email address
# you == the recipient's email address
msg['Subject'] = 'The contents of %s' % textfile
msg['From'] = me
msg['To'] = you

# Send the message via our own SMTP server.
s = smtplib.SMTP('localhost')
s.send_message(msg)
s.quit()
```

And parsing RFC822 headers can easily be done by the `parse(filename)` or `parsestr(message_as_string)` methods of the
Parser() class:

```python
# Import the email modules we'll need
from email.parser import Parser

# If the e-mail headers are in a file, uncomment these two lines:
# with open(messagefile) as fp:
#     headers = Parser().parse(fp)

# Or for parsing headers in a string, use:
headers = Parser().parsestr('From: <user@example.com>
    To: <someone_else@example.com>
    Subject: Test message
    
    Body would go here

# Now the header items can be accessed as a dictionary:
print('To: %s' % headers['to'])
print('From: %s' % headers['from'])
print('Subject: %s' % headers['subject'])
```

Here's an example of how to send a MIME message containing a bunch of family pictures that may be residing in a directory:

```python
# Import smtplib for the actual sending function
import smtplib

# Here are the email package modules we'll need
from email.mime.image import MIMEImage
from email.mime.multipart import MIMEMultipart
COMMASPACE = ',', '

# Create the container (outer) email message.
msg = MIMEMultipart()
msg['Subject'] = 'Our family reunion'
```
# me == the sender's email address
# family = the list of all recipients' email addresses
msg['From'] = me
msg['To'] = COMMASPACE.join(family)
msg.preamble = 'Our family reunion

# Assume we know that the image files are all in PNG format
for file in pngfiles:
    # Open the files in binary mode. Let the MIMEImage class automatically
    # guess the specific image type.
    with open(file, 'rb') as fp:
        img = MIMEImage(fp.read())
    msg.attach(img)

# Send the email via our own SMTP server.
s = smtplib.SMTP('localhost')
s.send_message(msg)
s.quit()

Here's an example of how to send the entire contents of a directory as an email message: [1]

#!/usr/bin/env python3

"""Send the contents of a directory as a MIME message"

import os
import sys
import smtplib
# For guessing MIME type based on file name extension
import mimetypes

from argparse import ArgumentParser

from email import encoders
from email.message import Message
from email.mime.audio import MIMEAudio
from email.mime.base import MIMEBase
from email.mime.image import MIMEImage
from email.mime.multipart import MIMEMultipart
from email.mime.text import MIMEText

COMMASPACE = ',


def main():
    parser = ArgumentParser(description="Send the contents of a directory as a MIME message. Unless the -o option is given, the email is sent by SMTP server, which then does the normal delivery process. Your local machine must be running an SMTP server.
"
    parser.add_argument('-d', '--directory',
        help="Mail the contents of the specified directory, otherwise use the current directory. Only the regular files in the directory are sent, and we don't recurse to subdirectories.
"
    parser.add_argument('-o', '--output',
        metavar='FILE',
        help="Print the composed message to FILE instead of sending the message to the SMTP server.
"
    parser.add_argument('-s', '--sender', required=True,
        help='The value of the From: header (required)
"
    parser.add_argument('-r', '--recipient', required=True,
        action='append', metavar='RECIPIENT',
        default=[], dest='recipients',
        help='A To: header value (at least one required)
"
    args = parser.parse_args()
directory = args.directory
    if not directory:
        directory = '.
    # Create the enclosing (outer) message
    outer = MIMEMultipart()
outer['Subject'] = 'Contents of directory %s' %
outer['To'] = COMMASPACE.join(args.recipients)
outer['From'] = args.sender
outer.preamble = 'You will not see this in a MIME-aware mail reader.'

for filename in os.listdir(directory):
    path = os.path.join(directory, filename)
    if not os.path.isfile(path):
        continue
    # Guess the content type based on the file's extension.
    # This will be ignored, although we should check for simple things like
    # gzip'd or compressed files.
    ctype, encoding = mimetypes.guess_type(path)
    if ctype is None or encoding is not None:
        # No guess could be made, or the file is encoded (compressed).
        ctype = 'application/octet-stream'
    maintype, subtype = ctype.split('/', 1)
    if maintype == 'text':
        with open(path) as fp:
            # Note: we should handle calculating the charset
            msg = MIMEText(fp.read(), _subtype=subtype)
    elif maintype == 'image':
        with open(path, 'rb') as fp:
            msg = MIMEImage(fp.read(), _subtype=subtype)
    elif maintype == 'audio':
        with open(path, 'rb') as fp:
            msg = MIMEAudio(fp.read(), _subtype=subtype)
    else:
        with open(path, 'rb') as fp:
            msg = MIMEBase(maintype, subtype)
            msg.set_payload(fp.read())
            # Encode the payload using Base64
            encoders.encode_base64(msg)
            # Set the filename parameter
            msg.add_header('Content-Disposition', 'attachment', filename=filename)
    outer.attach(msg)
# Now send or store the message
composed = outer.as_string()
if args.output:
with open(args.output, 'w') as fp:
fp.write(composed)
else:
with smtplib.SMTP('localhost') as s:
s.sendmail(args.sender, args.recipients,

if __name__ == '__main__':
main()

Here’s an example of how to unpack a MIME message like the one
above, into a directory of files:
#!/usr/bin/env python3
"""Unpack a MIME message into a directory of files."""
import
import
import
import
import

os
sys
email
errno
mimetypes

from argparse import ArgumentParser

def main():
parser = ArgumentParser(description="""\
Unpack a MIME message into a directory of files.
""")
parser.add_argument('-d', '--directory', required
help="""Unpack the MIME message into
directory, which will be created if i


```python
import email
import os
import sys
import mimetypes

parser = ArgumentParser('msgfile')
args = parser.parse_args()

with open(args.msgfile) as fp:
    msg = email.message_from_file(fp)

try:
    os.mkdir(args.directory)
except FileExistsError:
    pass

counter = 1
for part in msg.walk():
    if part.get_content_maintype() == 'multipart'
        continue

    filename = part.get_filename()
    if not filename:
        ext = mimetypes.guess_extension(part.get_content_type())
        if not ext:
            ext = '.bin'
        filename = 'part-%03d%s' % (counter, ext)
        counter += 1
        with open(os.path.join(args.directory, filename)) as fp:
            fp.write(part.get_payload(decode=True))
```

Here’s an example of how to create an HTML message with an alternative plain text version: [2]
#!/usr/bin/env python3

import smtplib

from email.mime.multipart import MIMEMultipart
from email.mime.text import MIMEText

# me == my email address
# you == recipient's email address
me = "my@email.com"
you = "your@email.com"

# Create message container - the correct MIME type is multipart/alternative.
msg = MIMEMultipart('alternative')
msg['Subject'] = "Link"
msg['From'] = me
msg['To'] = you

# Create the body of the message (a plain-text and an HTML version).
text = "Hi!\nHow are you?\nHere is the link you wanted:\n"
<html>
  <head></head>
  <body>
    <p>Hi!<br>How are you?<br>Here is the <a href="https://www.python.org">link</a> you wanted.
  </p>
  </body>
</html>

# Record the MIME types of both parts - text/plain and text/html.
part1 = MIMEText(text, 'plain')
part2 = MIMEText(html, 'html')

# Attach parts into message container.
msg.attach(part1)
msg.attach(part2)
According to RFC 2046, the last part of a multipart message, in this case the HTML message, is best and preferred.

msg.attach(part1)
msg.attach(part2)

Send the message via local SMTP server.
s = smtplib.SMTP('localhost')
sendmail function takes 3 arguments: sender's address, recipient's address and message to send - here it is sent as one string.
s.sendmail(me, you, msg.as_string())
s.quit()
19.1.14.1. Examples using the Provisional API

Here is a reworking of the last example using the provisional API. To make things a bit more interesting, we include a related image in the html part, and we save a copy of what we are going to send to disk, as well as sending it.

This example also shows how easy it is to include non-ASCII, and simplifies the sending of the message using the send_message() method of the smtplib module.

```python
#!/usr/bin/env python3

import smtplib
from email.message import EmailMessage
from email.headerregistry import Address
from email.utils import make_msgid

# Create the base text message.
msg = EmailMessage()
msg['Subject'] = "Ayons asperges pour le déjeuner"
msg['From'] = Address("Pepé Le Pew", "pepe@example.com")
msg['To'] = (Address("Penelope Pussycat", "penelope@example.com")
            Address("Fabrette Pussycat", "fabrette@example.com")
msg.set_content(""
Salut!
--Pepé
```
# Add the html version. This converts the message into a container, with the original text message as the first part and the new html message as the second part.

```python
asparagus_cid = make_msgid()
msg.add_alternative("""
<html>
<head></head>
<body>
    <p>Salut!</p>
    <p>Cela ressemble à un excellent recipie</p>
    </a> déjeuner.
</p>
    <img src="cid:{asparagus_cid}" />
</body>
</html>""",
```

```python
.format(asparagus_cid=asparagus_cid[1:-1]), subtype=
```

# note that we needed to peel the <> off the msgid for use in the html.

# Now add the related image to the html part.
```

```python
with open("roasted-asparagus.jpg", 'rb') as img:
    msg.get_payload()[1].add_related(img.read(), 'image',
```

```python
cid=asparagus_cid
```

# Make a local copy of what we are going to send.
```

```python
with open('outgoing.msg', 'wb') as f:
    f.write(bytes(msg))
```

# Send the message via local SMTP server.
```

```python
with smtplib.SMTP('localhost') as s:
    s.send_message(msg)
```

If we were instead sent the message from the last example, here is
one way we could process it:

```python
import os
import sys
import tempfile
import mimetypes
import webbrowser

# Import the email modules we'll need
from email import policy
from email.parser import BytesParser

# An imaginary module that would make this work and be safe.
from imaginary import magic_html_parser

# In a real program you'd get the filename from the
with open('outgoing.msg', 'rb') as fp:
    msg = BytesParser(policy=policy.default).parse(fp)

# Now the header items can be accessed as a dictionary,
# be converted to unicode:
print('To:', msg['to'])
print('From:', msg['from'])
print('Subject:', msg['subject'])

# If we want to print a preview of the message content,
# the least formatted payload is and print the first
# if the message has no plain text part printing the
# is probably useless, but this is just a conceptual
simplest = msg.get_body(preferencelist=('plain', 'html'))
print()
print('').join(simplest.get_content().splitlines(keepends=True))

ans = input("View full message?")
if ans.lower()[0] == 'n':
    sys.exit()
```
# We can extract the richest alternative in order to display it:

```python
r = msg.get_body()
partfiles = {}
if 'text' in r['content-type'].maintype:
    if 'plain' in r['content-type'].subtype:
        for line in r.get_content().splitlines:
            print(line)
            sys.exit()
    elif 'html' in r['content-type'].subtype:
        body = r
else:
    print("Don't know how to display {}".format(r))
    sys.exit()
elif 'multipart' in r['content-type'].content_type:
    body = r
    for part in r.iter_attachments():
        fn = part.get_filename()
        if fn:
            extension = os.path.splitext(part.get_filename())
        else:
            extension = mimetypes.guess_extension(part)
    with tempfile.NamedTemporaryFile(suffix=extension) as f:
        f.write(part.get_content())
        # again strip the <> to go from email form
        # to the filenames in partfiles. It also
        # of the html. It could be written using html.parser.
        f.write(magic_html_parser(body.get_content(), partfiles))
        webbrowser.open(f.name)
        os.remove(f.name)
for fn in partfiles.values():
    os.remove(fn)
```

Of course, there are lots of email messages that could break this simple-minded program, but it will handle the most common ones.

Up to the prompt, the output from the above is:

To: Penelope Pussycat <"penelope@example.com">, Fabrette Pussycat <"fabrette@example.com">
From: Pepé Le Pew <pepe@example.com>
Subject: Ayons asperges pour le déjeuner

Salut!


Footnotes

[1] Thanks to Matthew Dixon Cowles for the original inspiration and examples.

19.2. json — JSON encoder and decoder

JSON (JavaScript Object Notation), specified by RFC 7159 (which obsoletes RFC 4627) and by ECMA-404, is a lightweight data interchange format inspired by JavaScript object literal syntax (although it is not a strict subset of JavaScript [1]).

json exposes an API familiar to users of the standard library marshal and pickle modules.

Encoding basic Python object hierarchies:

```python
>>> import json
>>> json.dumps(['foo', {'bar': ('baz', None, 1.0, 2)}, {
"foo": {
"bar": [
"baz", null, 1.0,
2]
}]
>>> print(json.dumps("\"foo\bar\"
"\"foo\bar"
>>> print(json.dumps('\u1234'))
"\u1234"
>>> print(json.dumps('\\'))
"\"
>>> print(json.dumps({"c": 0, "b": 0, "a": 0}, sort_ {"a": 0, "b": 0, "c": 0}
>>> from io import StringIO
>>> io = StringIO()
>>> json.dump(['streaming API'], io)
>>> io.getvalue()
'\"["streaming API"]\"
```

Compact encoding:
>>> import json
>>> json.dumps([1,2,3,{'4': 5, '6': 7}], separators=
'[1,2,3,{"4":5,"6":7}]'

Pretty printing:
>>> import json
>>> print(json.dumps({'4': 5, '6': 7}, sort_keys=True
{
"4": 5,
"6": 7
}

Decoding JSON:
>>> import json
>>> json.loads('["foo", {"bar":["baz", null, 1.0, 2]}]'
['foo', {'bar': ['baz', None, 1.0, 2]}]
>>> json.loads('"\\"foo\\bar"')
'"foo\x08ar'
>>> from io import StringIO
>>> io = StringIO('["streaming API"]')
>>> json.load(io)
['streaming API']

Specializing JSON object decoding:

>>> import json
>>> def as_complex(dct):
...
if '__complex__' in dct:
...
return complex(dct['real'], dct['imag'])
...
return dct
...
>>> json.loads('{"__complex__": true, "real": 1, "imag": 2}'


Extending JSONEncoder:

```python
>>> import json
>>> class ComplexEncoder(json.JSONEncoder):
...     def default(self, obj):
...         if isinstance(obj, complex):
...             return [obj.real, obj.imag]
...         # Let the base class default method raise
...         return json.JSONEncoder.default(self, obj)

>>> json.dumps(2 + 1j, cls=ComplexEncoder)
'[2.0, 1.0]'
>>> ComplexEncoder().encode(2 + 1j)
'[2.0, 1.0]'
>>> list(ComplexEncoder().iterencode(2 + 1j))
['[2.0', ', ', '1.0', ', ']
```

Using json.tool from the shell to validate and pretty-print:

```bash
$ echo '{"json":"obj"}' | python -m json.tool
{
    "json": "obj"
}
$ echo '{1.2:3.4}' | python -m json.tool
Expecting property name enclosed in double quotes:
```

See Command Line Interface for detailed documentation.
Note: JSON is a subset of YAML 1.2. The JSON produced by this module’s default settings (in particular, the default separators value) is also a subset of YAML 1.0 and 1.1. This module can thus also be used as a YAML serializer.
19.2.1. Basic Usage

```python
json.dump(obj, fp, skipkeys=False, ensure_ascii=True, check_circular=True, allow_nan=True, cls=None, indent=None, separators=None, default=None, sort_keys=False, **kw)
```

Serialize `obj` as a JSON formatted stream to `fp` (a `.write()`-supporting file-like object) using this conversion table.

If `skipkeys` is True (default: False), then dict keys that are not of a basic type (`str`, `int`, `float`, `bool`, `None`) will be skipped instead of raising a `TypeError`.

The `json` module always produces `str` objects, not `bytes` objects. Therefore, `fp.write()` must support `str` input.

If `ensure_ascii` is True (the default), the output is guaranteed to have all incoming non-ASCII characters escaped. If `ensure_ascii` is False, these characters will be output as-is.

If `check_circular` is False (default: True), then the circular reference check for container types will be skipped and a circular reference will result in an `OverflowError` (or worse).

If `allow_nan` is False (default: True), then it will be a `ValueError` to serialize out of range `float` values (`nan`, `inf`, `-inf`) in strict compliance of the JSON specification, instead of using the JavaScript equivalents (`NaN`, `Infinity`, `-Infinity`).

If `indent` is a non-negative integer or string, then JSON array elements and object members will be pretty-printed with that indent level. An indent level of 0, negative, or "" will only insert newlines.
None (the default) selects the most compact representation. Using a positive integer indent indents that many spaces per level. If `indent` is a string (such as "\t"), that string is used to indent each level.

*Changed in version 3.2:* Allow strings for `indent` in addition to integers.

If specified, `separators` should be an `(item_separator, key_separator)` tuple. The default is (`', ', ':'`) if `indent` is `None` and (`', ', ':'`) otherwise. To get the most compact JSON representation, you should specify (`', ', ':'`) to eliminate whitespace.

*Changed in version 3.4:* Use (`', ', ':'`) as default if `indent` is not `None`.

`default(obj)` is a function that should return a serializable version of `obj` or raise `TypeError`. The default simply raises `TypeError`.

If `sort_keys` is `True` (default: `False`), then the output of dictionaries will be sorted by key.

To use a custom `JSONEncoder` subclass (e.g. one that overrides the default() method to serialize additional types), specify it with the `cls` kwarg; otherwise `JSONEncoder` is used.

```python
json.dumps(obj, skipkeys=False, ensure_ascii=True, check_circular=True, allow_nan=True, cls=None, indent=None, separators=None, default=None, sort_keys=False, **kw)
```

Serialize `obj` to a JSON formatted `str` using this conversion table. The arguments have the same meaning as in `dump()`.
Note: Unlike `pickle` and `marshal`, JSON is not a framed protocol, so trying to serialize multiple objects with repeated calls to `dump()` using the same `fp` will result in an invalid JSON file.

Note: Keys in key/value pairs of JSON are always of the type `str`. When a dictionary is converted into JSON, all the keys of the dictionary are coerced to strings. As a result of this, if a dictionary is converted into JSON and then back into a dictionary, the dictionary may not equal the original one. That is, `loads(dumps(x)) != x` if `x` has non-string keys.

`json.load(fp, cls=None, object_hook=None, parse_float=None, parse_int=None, parse_constant=None, object_pairs_hook=None, **kw)`

Deserialize `fp` (a `.read()`-supporting file-like object containing a JSON document) to a Python object using this conversion table.

`object_hook` is an optional function that will be called with the result of any object literal decoded (a `dict`). The return value of `object_hook` will be used instead of the `dict`. This feature can be used to implement custom decoders (e.g. JSON-RPC class hinting).

`object_pairs_hook` is an optional function that will be called with the result of any object literal decoded with an ordered list of pairs. The return value of `object_pairs_hook` will be used instead of the `dict`. This feature can be used to implement custom decoders that rely on the order that the key and value pairs are decoded (for example, `collections.OrderedDict()` will remember the order of insertion). If `object_hook` is also defined, the `object_pairs_hook` takes priority.
Changed in version 3.1: Added support for `object_pairs_hook`.

`parse_float`, if specified, will be called with the string of every JSON float to be decoded. By default, this is equivalent to `float(num_str)`. This can be used to use another datatype or parser for JSON floats (e.g. `decimal.Decimal`).

`parse_int`, if specified, will be called with the string of every JSON int to be decoded. By default, this is equivalent to `int(num_str)`. This can be used to use another datatype or parser for JSON integers (e.g. `float`).

`parse_constant`, if specified, will be called with one of the following strings: '-Infinity', 'Infinity', 'NaN'. This can be used to raise an exception if invalid JSON numbers are encountered.

Changed in version 3.1: `parse_constant` doesn’t get called on ‘null’, ‘true’, ‘false’ anymore.

To use a custom `JSONDecoder` subclass, specify it with the `cls` kwarg; otherwise `JSONDecoder` is used. Additional keyword arguments will be passed to the constructor of the class.

If the data being deserialized is not a valid JSON document, a `JSONDecodeError` will be raised.

```python
json.loads(s, encoding=None, cls=None, object_hook=None, parse_float=None, parse_int=None, parse_constant=None, object_pairs_hook=None, **kw)
```

Deserialize `s` (a `str` instance containing a JSON document) to a Python object using this conversion table.

The other arguments have the same meaning as in `load()`,
except `encoding` which is ignored and deprecated.

If the data being deserialized is not a valid JSON document, a `JSONDecodeError` will be raised.
19.2.2. Encoders and Decoders

class json.JSONDecoder(object_hook=None, parse_float=None, parse_int=None, parse_constant=None, strict=True, object_pairs_hook=None)

    Simple JSON decoder.

    Performs the following translations in decoding by default:

<table>
<thead>
<tr>
<th>JSON</th>
<th>Python</th>
</tr>
</thead>
<tbody>
<tr>
<td>object</td>
<td>dict</td>
</tr>
<tr>
<td>array</td>
<td>list</td>
</tr>
<tr>
<td>string</td>
<td>str</td>
</tr>
<tr>
<td>number (int)</td>
<td>int</td>
</tr>
<tr>
<td>number (real)</td>
<td>float</td>
</tr>
<tr>
<td>true</td>
<td>True</td>
</tr>
<tr>
<td>false</td>
<td>False</td>
</tr>
<tr>
<td>null</td>
<td>None</td>
</tr>
</tbody>
</table>

It also understands NaN, Infinity, and -Infinity as their corresponding float values, which is outside the JSON spec.

*object_hook*, if specified, will be called with the result of every JSON object decoded and its return value will be used in place of the given *dict*. This can be used to provide custom deserializations (e.g. to support JSON-RPC class hinting).

*object_pairs_hook*, if specified will be called with the result of every JSON object decoded with an ordered list of pairs. The return value of *object_pairs_hook* will be used instead of the *dict*. This feature
can be used to implement custom decoders that rely on the order that the key and value pairs are decoded (for example, collections.OrderedDict() will remember the order of insertion). If object_hook is also defined, the object_pairs_hook takes priority.

*Changed in version 3.1:* Added support for object_pairs_hook.

*parse_float*, if specified, will be called with the string of every JSON float to be decoded. By default, this is equivalent to float(num_str). This can be used to use another datatype or parser for JSON floats (e.g. decimal.Decimal).

*parse_int*, if specified, will be called with the string of every JSON int to be decoded. By default, this is equivalent to int(num_str). This can be used to use another datatype or parser for JSON integers (e.g. float).

*parse_constant*, if specified, will be called with one of the following strings: '-Infinity', 'Infinity', 'NaN', 'null', 'true', 'false'. This can be used to raise an exception if invalid JSON numbers are encountered.

If strict is False (True is the default), then control characters will be allowed inside strings. Control characters in this context are those with character codes in the 0-31 range, including '\t' (tab), '\n', '\r' and '\0'.

If the data being deserialized is not a valid JSON document, a JSONDecodeError will be raised.

**decode(s)**

Return the Python representation of s (a str instance
containing a JSON document).

`JSONDecodeError` will be raised if the given JSON document is not valid.

**raw_decode(s)**

Decode a JSON document from `s` (a `str` beginning with a JSON document) and return a 2-tuple of the Python representation and the index in `s` where the document ended.

This can be used to decode a JSON document from a string that may have extraneous data at the end.

```python
class json.JSONEncoder(skipkeys=False, ensure_ascii=True, check_circular=True, allow_nan=True, sort_keys=False, indent=None, separators=None, default=None)
```

Extensible JSON encoder for Python data structures.

Supports the following objects and types by default:

<table>
<thead>
<tr>
<th>Python</th>
<th>JSON</th>
</tr>
</thead>
<tbody>
<tr>
<td>dict</td>
<td>object</td>
</tr>
<tr>
<td>list, tuple</td>
<td>array</td>
</tr>
<tr>
<td>str</td>
<td>string</td>
</tr>
<tr>
<td>int, float, int- &amp; float-derived Enums</td>
<td>number</td>
</tr>
<tr>
<td>True</td>
<td>true</td>
</tr>
<tr>
<td>False</td>
<td>false</td>
</tr>
<tr>
<td>None</td>
<td>null</td>
</tr>
</tbody>
</table>

*Changed in version 3.4:* Added support for int- and float-derived Enum classes.
To extend this to recognize other objects, subclass and implement a `default()` method with another method that returns a serializable object for `o` if possible, otherwise it should call the superclass implementation (to raise `TypeError`).

If `skipkeys` is False (the default), then it is a `TypeError` to attempt encoding of keys that are not str, int, float or None. If `skipkeys` is True, such items are simply skipped.

If `ensure_ascii` is True (the default), the output is guaranteed to have all incoming non-ASCII characters escaped. If `ensure_ascii` is False, these characters will be output as-is.

If `check_circular` is True (the default), then lists, dicts, and custom encoded objects will be checked for circular references during encoding to prevent an infinite recursion (which would cause an `OverflowError`). Otherwise, no such check takes place.

If `allow_nan` is True (the default), then NaN, Infinity, and -Infinity will be encoded as such. This behavior is not JSON specification compliant, but is consistent with most JavaScript based encoders and decoders. Otherwise, it will be a `ValueError` to encode such floats.

If `sort_keys` is True (default False), then the output of dictionaries will be sorted by key; this is useful for regression tests to ensure that JSON serializations can be compared on a day-to-day basis.

If `indent` is a non-negative integer or string, then JSON array elements and object members will be pretty-printed with that indent level. An indent level of 0, negative, or "" will only insert newlines. None (the default) selects the most compact representation. Using
a positive integer indent indents that many spaces per level. If \textit{indent} is a string (such as "\t"), that string is used to indent each level.

\textit{Changed in version 3.2:} Allow strings for \textit{indent} in addition to integers.

If specified, \textit{separators} should be an \texttt{(item\_separator, key\_separator)} tuple. The default is \texttt{(', ', ': ')} if \textit{indent} is None and \texttt{(', ', ': ')} otherwise. To get the most compact JSON representation, you should specify \texttt{(', ', ': ')} to eliminate whitespace.

\textit{Changed in version 3.4:} Use \texttt{(', ', ': ')} as default if \textit{indent} is not None.

If specified, \textit{default} is a function that gets called for objects that can't otherwise be serialized. It should return a JSON encodable version of the object or raise a \texttt{TypeError}.

\texttt{default(o)}

Implement this method in a subclass such that it returns a serializable object for \texttt{o}, or calls the base implementation (to raise a \texttt{TypeError}).

For example, to support arbitrary iterators, you could implement \texttt{default} like this:

\begin{verbatim}
def default(self, o):
    try:
        iterable = iter(o)
    except TypeError:
        pass
    else:
        \end{verbatim}
return list(iterable)
# Let the base class default method raise the
return json.JSONEncoder.default(self, o)

**encode(o)**

Return a JSON string representation of a Python data structure, o. For example:

```python
>>> json.JSONEncoder().encode({"foo": ["bar", "baz"]})
"{"foo": ["bar", "baz"]}
```

**iterencode(o)**

Encode the given object, o, and yield each string representation as available. For example:

```python
for chunk in json.JSONEncoder().iterencode(bigobject):
    mysocket.write(chunk)
```
19.2.3. Exceptions

`exception json.JSONDecodeError(msg, doc, pos, end=None)`

Subclass of `ValueError` with the following additional attributes:

**msg**
- The unformatted error message.

**doc**
- The JSON document being parsed.

**pos**
- The start index of `doc` where parsing failed.

**lineno**
- The line corresponding to `pos`.

**colno**
- The column corresponding to `pos`.

*New in version 3.5.*
19.2.4. Standard Compliance and Interoperability

The JSON format is specified by RFC 7159 and by ECMA-404. This section details this module’s level of compliance with the RFC. For simplicity, JSONEncoder and JSONDecoder subclasses, and parameters other than those explicitly mentioned, are not considered.

This module does not comply with the RFC in a strict fashion, implementing some extensions that are valid JavaScript but not valid JSON. In particular:

- Infinite and NaN number values are accepted and output;
- Repeated names within an object are accepted, and only the value of the last name-value pair is used.

Since the RFC permits RFC-compliant parsers to accept input texts that are not RFC-compliant, this module’s deserializer is technically RFC-compliant under default settings.

19.2.4.1. Character Encodings

The RFC requires that JSON be represented using either UTF-8, UTF-16, or UTF-32, with UTF-8 being the recommended default for maximum interoperability.

As permitted, though not required, by the RFC, this module’s serializer sets ensure_ascii=True by default, thus escaping the output so that the resulting strings only contain ASCII characters.

Other than the ensure_ascii parameter, this module is defined strictly in terms of conversion between Python objects and Unicode
strings, and thus does not otherwise directly address the issue of character encodings.

The RFC prohibits adding a byte order mark (BOM) to the start of a JSON text, and this module’s serializer does not add a BOM to its output. The RFC permits, but does not require, JSON deserializers to ignore an initial BOM in their input. This module’s deserializer raises a ValueError when an initial BOM is present.

The RFC does not explicitly forbid JSON strings which contain byte sequences that don’t correspond to valid Unicode characters (e.g. unpaired UTF-16 surrogates), but it does note that they may cause interoperability problems. By default, this module accepts and outputs (when present in the original str) code points for such sequences.

19.2.4.2. Infinite and NaN Number Values

The RFC does not permit the representation of infinite or NaN number values. Despite that, by default, this module accepts and outputs Infinity, -Infinity, and NaN as if they were valid JSON number literal values:

```python
>>> # Neither of these calls raises an exception, but
>>> json.dumps(float('-inf'))
'Infinity'
>>> json.dumps(float('nan'))
'NaN'
>>> # Same when deserializing
>>> json.loads('-Infinity')
-inf
>>> json.loads('NaN')
nan
```
In the serializer, the `allow_nan` parameter can be used to alter this behavior. In the deserializer, the `parse_constant` parameter can be used to alter this behavior.

### 19.2.4.3. Repeated Names Within an Object

The RFC specifies that the names within a JSON object should be unique, but does not mandate how repeated names in JSON objects should be handled. By default, this module does not raise an exception; instead, it ignores all but the last name-value pair for a given name:

```python
>>> weird_json = '{"x": 1, "x": 2, "x": 3}'
>>> json.loads(weird_json)
{'x': 3}
```

The `object_pairs_hook` parameter can be used to alter this behavior.

### 19.2.4.4. Top-level Non-Object, Non-Array Values

The old version of JSON specified by the obsolete RFC 4627 required that the top-level value of a JSON text must be either a JSON object or array (Python `dict` or `list`), and could not be a JSON null, boolean, number, or string value. RFC 7159 removed that restriction, and this module does not and has never implemented that restriction in either its serializer or its deserializer.

Regardless, for maximum interoperability, you may wish to voluntarily adhere to the restriction yourself.

### 19.2.4.5. Implementation Limitations
Some JSON deserializer implementations may set limits on:

- the size of accepted JSON texts
- the maximum level of nesting of JSON objects and arrays
- the range and precision of JSON numbers
- the content and maximum length of JSON strings

This module does not impose any such limits beyond those of the relevant Python datatypes themselves or the Python interpreter itself.

When serializing to JSON, beware any such limitations in applications that may consume your JSON. In particular, it is common for JSON numbers to be deserialized into IEEE 754 double precision numbers and thus subject to that representation’s range and precision limitations. This is especially relevant when serializing Python int values of extremely large magnitude, or when serializing instances of “exotic” numerical types such as `decimal.Decimal`.
19.2.5. Command Line Interface

The json.tool module provides a simple command line interface to validate and pretty-print JSON objects.

If the optional infile and outfile arguments are not specified, sys.stdin and sys.stdout will be used respectively:

```
$ echo '{"json": "obj"}' | python -m json.tool
{
    "json": "obj"
}
$ echo '{1.2:3.4}' | python -m json.tool
Expecting property name enclosed in double quotes: }
```

*Changed in version 3.5:* The output is now in the same order as the input. Use the `-sort-keys` option to sort the output of dictionaries alphabetically by key.

19.2.5.1. Command line options

**infile**

The JSON file to be validated or pretty-printed:

```
$ python -m json.tool mp_films.json
[
    {
        "title": "And Now for Something Completely Different",
        "year": 1971
    },
    {
        "title": "Monty Python and the Holy Grail"
    }
]```
If `infile` is not specified, read from `sys.stdin`.

`outfile`

Write the output of the `infile` to the given `outfile`. Otherwise, write it to `sys.stdout`.

`--sort-keys`

Sort the output of dictionaries alphabetically by key.

*New in version 3.5.*

`-h, --help`

Show the help message.

**Footnotes**

As noted in the errata for RFC 7159, JSON permits literal U+2028 (LINE SEPARATOR) and U+2029 (PARAGRAPH SEPARATOR) characters in strings, whereas JavaScript (as of ECMAScript Edition 5.1) does not.

[1]
Mailcap files are used to configure how MIME-aware applications such as mail readers and Web browsers react to files with different MIME types. (The name “mailcap” is derived from the phrase “mail capability”.) For example, a mailcap file might contain a line like `video/mpeg; xmpeg %s`. Then, if the user encounters an email message or Web document with the MIME type `video/mpeg`, `%s` will be replaced by a filename (usually one belonging to a temporary file) and the `xmpeg` program can be automatically started to view the file.

The mailcap format is documented in RFC 1524, “A User Agent Configuration Mechanism For Multimedia Mail Format Information,” but is not an Internet standard. However, mailcap files are supported on most Unix systems.

```
mailcap.findmatch(caps, MIMEtype, key='view', filename='/dev/null', plist=[])  
```

Return a 2-tuple; the first element is a string containing the command line to be executed (which can be passed to `os.system()`), and the second element is the mailcap entry for a given MIME type. If no matching MIME type can be found, (None, None) is returned.

`key` is the name of the field desired, which represents the type of activity to be performed; the default value is `‘view’, since in the
most common case you simply want to view the body of the MIME-typed data. Other possible values might be 'compose' and 'edit', if you wanted to create a new body of the given MIME type or alter the existing body data. See RFC 1524 for a complete list of these fields.

filename is the filename to be substituted for %s in the command line; the default value is '/dev/null' which is almost certainly not what you want, so usually you'll override it by specifying a filename.

plist can be a list containing named parameters; the default value is simply an empty list. Each entry in the list must be a string containing the parameter name, an equals sign ('='), and the parameter's value. Mailcap entries can contain named parameters like %{foo}, which will be replaced by the value of the parameter named 'foo'. For example, if the command line showpartial % {id} %{number} %{total} was in a mailcap file, and plist was set to ['id=1', 'number=2', 'total=3'], the resulting command line would be 'showpartial 1 2 3'.

In a mailcap file, the “test” field can optionally be specified to test some external condition (such as the machine architecture, or the window system in use) to determine whether or not the mailcap line applies. findmatch() will automatically check such conditions and skip the entry if the check fails.

mailcap.getcaps()

Returns a dictionary mapping MIME types to a list of mailcap file entries. This dictionary must be passed to the findmatch() function. An entry is stored as a list of dictionaries, but it shouldn't be necessary to know the details of this representation.
The information is derived from all of the mailcap files found on the system. Settings in the user's mailcap file $HOME/.mailcap will override settings in the system mailcap files /etc/mailcap, /usr/etc/mailcap, and /usr/local/etc/mailcap.

An example usage:

```python
>>> import mailcap
>>> d=mailcap.getcaps()
>>> mailcap.findmatch(d, 'video/mpeg', filename='tmp1223')
('xmpeg tmp1223', {'view': 'xmpeg %s'})
```
19. Internet Data Handling
19.4. `mailbox` — Manipulate mailboxes in various formats

This module defines two classes, `Mailbox` and `Message`, for accessing and manipulating on-disk mailboxes and the messages they contain. `Mailbox` offers a dictionary-like mapping from keys to messages. `Message` extends the `email.message` module's `Message` class with format-specific state and behavior. Supported mailbox formats are Maildir, mbox, MH, Babyl, and MMDF.

See also:

Module `email`

Represent and manipulate messages.
19.4.1. **Mailbox objects**

```python
class mailbox.Mailbox

A mailbox, which may be inspected and modified.
```

The `Mailbox` class defines an interface and is not intended to be instantiated. Instead, format-specific subclasses should inherit from `Mailbox` and your code should instantiate a particular subclass.

The `Mailbox` interface is dictionary-like, with small keys corresponding to messages. Keys are issued by the `Mailbox` instance with which they will be used and are only meaningful to that `Mailbox` instance. A key continues to identify a message even if the corresponding message is modified, such as by replacing it with another message.

Messages may be added to a `Mailbox` instance using the set-like method `add()` and removed using a `del` statement or the set-like methods `remove()` and `discard()`.

`Mailbox` interface semantics differ from dictionary semantics in some noteworthy ways. Each time a message is requested, a new representation (typically a `Message` instance) is generated based upon the current state of the mailbox. Similarly, when a message is added to a `Mailbox` instance, the provided message representation's contents are copied. In neither case is a reference to the message representation kept by the `Mailbox` instance.

The default `Mailbox` iterator iterates over message representations, not keys as the default dictionary iterator does. Moreover, modification of a mailbox during iteration is safe and
well-defined. Messages added to the mailbox after an iterator is created will not be seen by the iterator. Messages removed from the mailbox before the iterator yields them will be silently skipped, though using a key from an iterator may result in a `KeyError` exception if the corresponding message is subsequently removed.

**Warning:** Be very cautious when modifying mailboxes that might be simultaneously changed by some other process. The safest mailbox format to use for such tasks is Maildir; try to avoid using single-file formats such as mbox for concurrent writing. If you're modifying a mailbox, you must lock it by calling the `lock()` and `unlock()` methods before reading any messages in the file or making any changes by adding or deleting a message. Failing to lock the mailbox runs the risk of losing messages or corrupting the entire mailbox.

`Mailbox` instances have the following methods:

**add**(*message*)

Add *message* to the mailbox and return the key that has been assigned to it.

Parameter *message* may be a `Message` instance, an `email.message.Message` instance, a string, a byte string, or a file-like object (which should be open in binary mode). If *message* is an instance of the appropriate format-specific `Message` subclass (e.g., if it's an `mboxMessage` instance and this is an `mbox` instance), its format-specific information is used. Otherwise, reasonable defaults for format-specific information are used.

*Changed in version 3.2:* Support for binary input was added.
**remove(key)**
**__delitem__(key)**
**discard(key)**

Delete the message corresponding to *key* from the mailbox.

If no such message exists, a **KeyError** exception is raised if the method was called as **remove()** or **__delitem__()** but no exception is raised if the method was called as **discard()**. The behavior of **discard()** may be preferred if the underlying mailbox format supports concurrent modification by other processes.

**__setitem__(key, message)**

Replace the message corresponding to *key* with *message*. Raise a **KeyError** exception if no message already corresponds to *key*.

As with **add()**, parameter *message* may be a **Message** instance, an **email.message.Message** instance, a string, a byte string, or a file-like object (which should be open in binary mode). If *message* is an instance of the appropriate format-specific **Message** subclass (e.g., if it's an **mboxMessage** instance and this is an **mbox** instance), its format-specific information is used. Otherwise, the format-specific information of the message that currently corresponds to *key* is left unchanged.

**iterkeys()**
**keys()**

Return an iterator over all keys if called as **iterkeys()** or return a list of keys if called as **keys()**.
itervalues()
__iter__()
values()

Return an iterator over representations of all messages if called as itervalues() or __iter__() or return a list of such representations if called as values(). The messages are represented as instances of the appropriate format-specific Message subclass unless a custom message factory was specified when the Mailbox instance was initialized.

**Note:** The behavior of __iter__() is unlike that of dictionaries, which iterate over keys.

iteritems()
items()

Return an iterator over (key, message) pairs, where key is a key and message is a message representation, if called as iteritems() or return a list of such pairs if called as items(). The messages are represented as instances of the appropriate format-specific Message subclass unless a custom message factory was specified when the Mailbox instance was initialized.

get(key, default=None)
__getitem__(key)

Return a representation of the message corresponding to key. If no such message exists, default is returned if the method was called as get() and a KeyError exception is raised if the method was called as __getitem__(). The message is represented as an instance of the appropriate format-specific Message subclass unless a custom message factory was
specified when the Mailbox instance was initialized.

**get_message(key)**

Return a representation of the message corresponding to *key* as an instance of the appropriate format-specific Message subclass, or raise a **KeyError** exception if no such message exists.

**get_bytes(key)**

Return a byte representation of the message corresponding to *key*, or raise a **KeyError** exception if no such message exists.

*New in version 3.2.*

**get_string(key)**

Return a string representation of the message corresponding to *key*, or raise a **KeyError** exception if no such message exists. The message is processed through `email.message.Message` to convert it to a 7bit clean representation.

**get_file(key)**

Return a file-like representation of the message corresponding to *key*, or raise a **KeyError** exception if no such message exists. The file-like object behaves as if open in binary mode. This file should be closed once it is no longer needed.

*Changed in version 3.2:* The file object really is a binary file; previously it was incorrectly returned in text mode. Also, the file-like object now supports the context management protocol: you can use a `with` statement to automatically close it.
Note: Unlike other representations of messages, file-like representations are not necessarily independent of the Mailbox instance that created them or of the underlying mailbox. More specific documentation is provided by each subclass.

__contains__(key)
Return True if key corresponds to a message, False otherwise.

__len__()
Return a count of messages in the mailbox.

clear()
Delete all messages from the mailbox.

pop(key, default=None)
Return a representation of the message corresponding to key and delete the message. If no such message exists, return default. The message is represented as an instance of the appropriate format-specific Message subclass unless a custom message factory was specified when the Mailbox instance was initialized.

popitem()
Return an arbitrary (key, message) pair, where key is a key and message is a message representation, and delete the corresponding message. If the mailbox is empty, raise a KeyError exception. The message is represented as an instance of the appropriate format-specific Message subclass unless a custom message factory was specified when the
Mailbox instance was initialized.

**update**(*arg*)
Parameter *arg* should be a *key-to-message* mapping or an iterable of *(key, message)* pairs. Updates the mailbox so that, for each given *key* and *message*, the message corresponding to *key* is set to *message* as if by using **__setitem__**( ). As with **__setitem__**( ), each *key* must already correspond to a message in the mailbox or else a **KeyError** exception will be raised, so in general it is incorrect for *arg* to be a Mailbox instance.

**Note:** Unlike with dictionaries, keyword arguments are not supported.

**flush()**
Write any pending changes to the filesystem. For some Mailbox subclasses, changes are always written immediately and **flush()** does nothing, but you should still make a habit of calling this method.

**lock()**
Acquire an exclusive advisory lock on the mailbox so that other processes know not to modify it. An **ExternalClashError** is raised if the lock is not available. The particular locking mechanisms used depend upon the mailbox format. You should always lock the mailbox before making any modifications to its contents.

**unlock()**
Release the lock on the mailbox, if any.
close()
Flush the mailbox, unlock it if necessary, and close any open files. For some Mailbox subclasses, this method does nothing.

19.4.1.1. Maildir

class mailbox.Maildir(dirname, factory=None, create=True)
A subclass of Mailbox for mailboxes in Maildir format. Parameter factory is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If factory is None, MaildirMessage is used as the default message representation. If create is True, the mailbox is created if it does not exist.

It is for historical reasons that dirname is named as such rather than path.

Maildir is a directory-based mailbox format invented for the qmail mail transfer agent and now widely supported by other programs. Messages in a Maildir mailbox are stored in separate files within a common directory structure. This design allows Maildir mailboxes to be accessed and modified by multiple unrelated programs without data corruption, so file locking is unnecessary.

Maildir mailboxes contain three subdirectories, namely: tmp, new, and cur. Messages are created momentarily in the tmp subdirectory and then moved to the new subdirectory to finalize delivery. A mail user agent may subsequently move the message to the cur subdirectory and store information about the state of the message in a special “info” section appended to its file name.

Folders of the style introduced by the Courier mail transfer agent
are also supported. Any subdirectory of the main mailbox is considered a folder if "." is the first character in its name. Folder names are represented by `Maildir` without the leading ".". Each folder is itself a Maildir mailbox but should not contain other folders. Instead, a logical nesting is indicated using "." to delimit levels, e.g., “Archived.2005.07”.

**Note:** The Maildir specification requires the use of a colon (':') in certain message file names. However, some operating systems do not permit this character in file names, If you wish to use a Maildir-like format on such an operating system, you should specify another character to use instead. The exclamation point ("!'") is a popular choice. For example:

```
import mailbox
mailbox.Maildir.colon = '!'  
```

The colon attribute may also be set on a per-instance basis.

`Maildir` instances have all of the methods of `Mailbox` in addition to the following:

**list_folders()**

Return a list of the names of all folders.

**get_folder(folder)**

Return a `Maildir` instance representing the folder whose name is `folder`. A `NoSuchMailboxError` exception is raised if the folder does not exist.

**add_folder(folder)**

Create a folder whose name is `folder` and return a `Maildir` instance representing it.
**remove_folder**(*folder*)
Delete the folder whose name is *folder*. If the folder contains any messages, a *NotEmptyError* exception will be raised and the folder will not be deleted.

**clean()**
Delete temporary files from the mailbox that have not been accessed in the last 36 hours. The Maildir specification says that mail-reading programs should do this occasionally.

Some Mailbox methods implemented by Maildir deserve special remarks:

**add**(message)
**__setitem__**(key, message)
**update**(arg)

**Warning:** These methods generate unique file names based upon the current process ID. When using multiple threads, undetected name clashes may occur and cause corruption of the mailbox unless threads are coordinated to avoid using these methods to manipulate the same mailbox simultaneously.

**flush()**
All changes to Maildir mailboxes are immediately applied, so this method does nothing.

**lock()**
**unlock()**
Maildir mailboxes do not support (or require) locking, so these methods do nothing.
close()

Maildir instances do not keep any open files and the underlying mailboxes do not support locking, so this method does nothing.

get_file(key)

Depending upon the host platform, it may not be possible to modify or remove the underlying message while the returned file remains open.

See also:

maildir man page from qmail
The original specification of the format.

Using maildir format
Notes on Maildir by its inventor. Includes an updated name-creation scheme and details on “info” semantics.

maildir man page from Courier
Another specification of the format. Describes a common extension for supporting folders.

19.4.1.2. mbox

class mailbox.mbox(path, factory=None, create=True)

A subclass of Mailbox for mailboxes in mbox format. Parameter factory is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If factory is None, mboxMessage is used as the default message representation. If create is True, the mailbox is created if it does not exist.
The mbox format is the classic format for storing mail on Unix systems. All messages in an mbox mailbox are stored in a single file with the beginning of each message indicated by a line whose first five characters are “From ”.

Several variations of the mbox format exist to address perceived shortcomings in the original. In the interest of compatibility, mbox implements the original format, which is sometimes referred to as mboxo. This means that the Content-Length header, if present, is ignored and that any occurrences of “From ” at the beginning of a line in a message body are transformed to “>From ” when storing the message, although occurrences of “>From ” are not transformed to “From ” when reading the message.

Some Mailbox methods implemented by mbox deserve special remarks:

**get_file**(key)

Using the file after calling flush() or close() on the mbox instance may yield unpredictable results or raise an exception.

**lock**

**unlock**

Three locking mechanisms are used—dot locking and, if available, the flock() and lockf() system calls.

See also:

**mbox man page from qmail**

A specification of the format and its variations.

**mbox man page from tin**

Another specification of the format, with details on locking.
Configuring Netscape Mail on Unix: Why The Content-Length Format is Bad

An argument for using the original mbox format rather than a variation.

“mbox” is a family of several mutually incompatible mailbox formats

A history of mbox variations.

19.4.1.3. MH

class mailbox.MH(path, factory=None, create=True)

A subclass of Mailbox for mailboxes in MH format. Parameter factory is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If factory is None, MHMessage is used as the default message representation. If create is True, the mailbox is created if it does not exist.

MH is a directory-based mailbox format invented for the MH Message Handling System, a mail user agent. Each message in an MH mailbox resides in its own file. An MH mailbox may contain other MH mailboxes (called folders) in addition to messages. Folders may be nested indefinitely. MH mailboxes also support sequences, which are named lists used to logically group messages without moving them to sub-folders. Sequences are defined in a file called .mh_sequences in each folder.

The MH class manipulates MH mailboxes, but it does not attempt to emulate all of mh's behaviors. In particular, it does not modify and is not affected by the context or .mh_profile files that are used by mh to store its state and configuration.
MH instances have all of the methods of Mailbox in addition to the following:

**list_folders()**
Return a list of the names of all folders.

**get_folder(folder)**
Return an MH instance representing the folder whose name is `folder`. A NoSuchMailboxError exception is raised if the folder does not exist.

**add_folder(folder)**
Create a folder whose name is `folder` and return an MH instance representing it.

**remove_folder(folder)**
Delete the folder whose name is `folder`. If the folder contains any messages, a NotEmptyError exception will be raised and the folder will not be deleted.

**get_sequences()**
Return a dictionary of sequence names mapped to key lists. If there are no sequences, the empty dictionary is returned.

**set_sequences(sequences)**
Re-define the sequences that exist in the mailbox based upon `sequences`, a dictionary of names mapped to key lists, like returned by get_sequences().

**pack()**
Rename messages in the mailbox as necessary to eliminate gaps in numbering. Entries in the sequences list are updated
correspondingly.

**Note:** Already-issued keys are invalidated by this operation and should not be subsequently used.

Some **Mailbox** methods implemented by **MH** deserve special remarks:

```python
code
remove(key)
__delitem__(key)
discard(key)
```

These methods immediately delete the message. The MH convention of marking a message for deletion by prepending a comma to its name is not used.

```
lock()
unlock()
```

Three locking mechanisms are used—dot locking and, if available, the `flock()` and `lockf()` system calls. For MH mailboxes, locking the mailbox means locking the `.mh_sequences` file and, only for the duration of any operations that affect them, locking individual message files.

```
get_file(key)
```

Depending upon the host platform, it may not be possible to remove the underlying message while the returned file remains open.

```
flush()
```

All changes to MH mailboxes are immediately applied, so this method does nothing.
close()

MH instances do not keep any open files, so this method is equivalent to unlock().

See also:

nmh - Message Handling System
Home page of nmh, an updated version of the original mh.

MH & nmh: Email for Users & Programmers
A GPL-licensed book on mh and nmh, with some information on the mailbox format.

19.4.1.4. Babylon

class mailbox.Babylon(path, factory=None, create=True)
A subclass of Mailbox for mailboxes in Babylon format. Parameter factory is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If factory is None, BabylonMessage is used as the default message representation. If create is True, the mailbox is created if it does not exist.

Babylon is a single-file mailbox format used by the Rmail mail user agent included with Emacs. The beginning of a message is indicated by a line containing the two characters Control-Underscore ('\037') and Control-L ('\014'). The end of a message is indicated by the start of the next message or, in the case of the last message, a line containing a Control-Underscore ('\037') character.

Messages in a Babylon mailbox have two sets of headers, original
headers and so-called visible headers. Visible headers are typically a subset of the original headers that have been reformatted or abridged to be more attractive. Each message in a Babyl mailbox also has an accompanying list of labels, or short strings that record extra information about the message, and a list of all user-defined labels found in the mailbox is kept in the Babyl options section.

Babyl instances have all of the methods of Mailbox in addition to the following:

get_labels()

Return a list of the names of all user-defined labels used in the mailbox.

Note: The actual messages are inspected to determine which labels exist in the mailbox rather than consulting the list of labels in the Babyl options section, but the Babyl section is updated whenever the mailbox is modified.

Some Mailbox methods implemented by Babyl deserve special remarks:

get_file(key)

In Babyl mailboxes, the headers of a message are not stored contiguously with the body of the message. To generate a file-like representation, the headers and body are copied together into an io.BytesIO instance, which has an API identical to that of a file. As a result, the file-like object is truly independent of the underlying mailbox but does not save memory compared to a string representation.

lock()
unlock()

Three locking mechanisms are used—dot locking and, if available, the flock() and lockf() system calls.

See also:

Format of Version 5 Babyl Files
A specification of the Babyl format.

Reading Mail with Rmail
The Rmail manual, with some information on Babyl semantics.

19.4.1.5. MMDF

class mailbox.MMDF(path, factory=None, create=True)

A subclass of Mailbox for mailboxes in MMDF format. Parameter factory is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If factory is None, MMDFMessage is used as the default message representation. If create is True, the mailbox is created if it does not exist.

MMDF is a single-file mailbox format invented for the Multichannel Memorandum Distribution Facility, a mail transfer agent. Each message is in the same form as an mbox message but is bracketed before and after by lines containing four Control-A ('\001') characters. As with the mbox format, the beginning of each message is indicated by a line whose first five characters are “From ”, but additional occurrences of “From ” are not transformed to “>From ” when storing messages because the extra message separator lines prevent mistaking such occurrences for the starts of subsequent messages.
Some Mailbox methods implemented by MMDF deserve special remarks:

**get_file**(key)

Using the file after calling `flush()` or `close()` on the MMDF instance may yield unpredictable results or raise an exception.

**lock()**

**unlock()**

Three locking mechanisms are used—dot locking and, if available, the `flock()` and `lockf()` system calls.

---

**See also:**

**mmdf man page from tin**

A specification of MMDF format from the documentation of tin, a newsreader.

**MMDF**

A Wikipedia article describing the Multichannel Memorandum Distribution Facility.
19.4.2. Message objects

class mailbox.Message(message=None)


If message is omitted, the new instance is created in a default, empty state. If message is an email.message.Message instance, its contents are copied; furthermore, any format-specific information is converted insofar as possible if message is a Message instance. If message is a string, a byte string, or a file, it should contain an RFC 2822-compliant message, which is read and parsed. Files should be open in binary mode, but text mode files are accepted for backward compatibility.

The format-specific state and behaviors offered by subclasses vary, but in general it is only the properties that are not specific to a particular mailbox that are supported (although presumably the properties are specific to a particular mailbox format). For example, file offsets for single-file mailbox formats and file names for directory-based mailbox formats are not retained, because they are only applicable to the original mailbox. But state such as whether a message has been read by the user or marked as important is retained, because it applies to the message itself.

There is no requirement that Message instances be used to represent messages retrieved using Mailbox instances. In some situations, the time and memory required to generate Message representations might not be acceptable. For such situations, Mailbox instances also offer string and file-like representations,
and a custom message factory may be specified when a Mailbox instance is initialized.

19.4.2.1. MaildirMessage

class mailbox.MaildirMessage(message=None)
A message with Maildir-specific behaviors. Parameter message has the same meaning as with the Message constructor.

Typically, a mail user agent application moves all of the messages in the new subdirectory to the cur subdirectory after the first time the user opens and closes the mailbox, recording that the messages are old whether or not they’ve actually been read. Each message in cur has an “info” section added to its file name to store information about its state. (Some mail readers may also add an “info” section to messages in new.) The “info” section may take one of two forms: it may contain “2,” followed by a list of standardized flags (e.g., “2,FR”) or it may contain “1,” followed by so-called experimental information. Standard flags for Maildir messages are as follows:

<table>
<thead>
<tr>
<th>Flag</th>
<th>Meaning</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>Draft</td>
<td>Under composition</td>
</tr>
<tr>
<td>F</td>
<td>Flagged</td>
<td>Marked as important</td>
</tr>
<tr>
<td>P</td>
<td>Passed</td>
<td>Forwarded, resent, or bounced</td>
</tr>
<tr>
<td>R</td>
<td>Replied</td>
<td>Replied to</td>
</tr>
<tr>
<td>S</td>
<td>Seen</td>
<td>Read</td>
</tr>
<tr>
<td>T</td>
<td>Trashed</td>
<td>Marked for subsequent deletion</td>
</tr>
</tbody>
</table>

MaildirMessage instances offer the following methods:
get_subdir()
Return either “new” (if the message should be stored in the new subdirectory) or “cur” (if the message should be stored in the cur subdirectory).

Note: A message is typically moved from new to cur after its mailbox has been accessed, whether or not the message is has been read. A message msg has been read if "S" in msg.get_flags() is True.

set_subdir(subdir)
Set the subdirectory the message should be stored in. Parameter subdir must be either “new” or “cur”.

get_flags()
Return a string specifying the flags that are currently set. If the message complies with the standard Maildir format, the result is the concatenation in alphabetical order of zero or one occurrence of each of 'D', 'F', 'P', 'R', 'S', and 'T'. The empty string is returned if no flags are set or if “info” contains experimental semantics.

set_flags(flags)
Set the flags specified by flags and unset all others.

add_flag(flag)
Set the flag(s) specified by flag without changing other flags. To add more than one flag at a time, flag may be a string of more than one character. The current “info” is overwritten whether or not it contains experimental information rather than flags.

remove_flag(flag)
Unset the flag(s) specified by *flag* without changing other flags. To remove more than one flag at a time, *flag* maybe a string of more than one character. If “info” contains experimental information rather than flags, the current “info” is not modified.

**get_date()**

Return the delivery date of the message as a floating-point number representing seconds since the epoch.

**set_date(date)**

Set the delivery date of the message to *date*, a floating-point number representing seconds since the epoch.

**get_info()**

Return a string containing the “info” for a message. This is useful for accessing and modifying “info” that is experimental (i.e., not a list of flags).

**set_info(info)**

Set “info” to *info*, which should be a string.

When a MaildirMessage instance is created based upon an mboxMessage or MMDFMessage instance, the Status and X-Status headers are omitted and the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>mboxMessage or MMDFMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>“cur” subdirectory</td>
<td>O flag</td>
</tr>
<tr>
<td>F flag</td>
<td>F flag</td>
</tr>
<tr>
<td>R flag</td>
<td>A flag</td>
</tr>
<tr>
<td>S flag</td>
<td>R flag</td>
</tr>
<tr>
<td>T flag</td>
<td>D flag</td>
</tr>
</tbody>
</table>
When a `MaildirMessage` instance is created based upon an `MHMessage` instance, the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>MHMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>“cur” subdirectory</td>
<td>“unseen” sequence</td>
</tr>
<tr>
<td>“cur” subdirectory and S flag</td>
<td>no “unseen” sequence</td>
</tr>
<tr>
<td>F flag</td>
<td>“flagged” sequence</td>
</tr>
<tr>
<td>R flag</td>
<td>“replied” sequence</td>
</tr>
</tbody>
</table>

When a `MaildirMessage` instance is created based upon a `BabylMessage` instance, the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>BabylMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>“cur” subdirectory</td>
<td>“unseen” label</td>
</tr>
<tr>
<td>“cur” subdirectory and S flag</td>
<td>no “unseen” label</td>
</tr>
<tr>
<td>P flag</td>
<td>“forwarded” or “resent” label</td>
</tr>
<tr>
<td>R flag</td>
<td>“answered” label</td>
</tr>
<tr>
<td>T flag</td>
<td>“deleted” label</td>
</tr>
</tbody>
</table>

19.4.2.2. `mboxMessage`

`class mailbox.mboxMessage(message=None)`

A message with mbox-specific behaviors. Parameter `message` has the same meaning as with the `Message` constructor.

Messages in an mbox mailbox are stored together in a single file. The sender’s envelope address and the time of delivery are typically stored in a line beginning with “From ” that is used to indicate the start of a message, though there is considerable
variation in the exact format of this data among mbox implementations. Flags that indicate the state of the message, such as whether it has been read or marked as important, are typically stored in `Status` and `X-Status` headers.

Conventional flags for mbox messages are as follows:

<table>
<thead>
<tr>
<th>Flag</th>
<th>Meaning</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Read</td>
<td>Read</td>
</tr>
<tr>
<td>O</td>
<td>Old</td>
<td>Previously detected by MUA</td>
</tr>
<tr>
<td>D</td>
<td>Deleted</td>
<td>Marked for subsequent deletion</td>
</tr>
<tr>
<td>F</td>
<td>Flagged</td>
<td>Marked as important</td>
</tr>
<tr>
<td>A</td>
<td>Answered</td>
<td>Replied to</td>
</tr>
</tbody>
</table>

The “R” and “O” flags are stored in the `Status` header, and the “D”, “F”, and “A” flags are stored in the `X-Status` header. The flags and headers typically appear in the order mentioned.

`mboxMessage` instances offer the following methods:

**get_from()**

Return a string representing the “From ” line that marks the start of the message in an mbox mailbox. The leading “From ” and the trailing newline are excluded.

**set_from(from_, time_=None)**

Set the “From ” line to `from_`, which should be specified without a leading “From ” or trailing newline. For convenience, `time_` may be specified and will be formatted appropriately and appended to `from_`. If `time_` is specified, it should be a `time.struct_time` instance, a tuple suitable for passing to
time.strftime(), or True (to use time.gmtime()).

get_flags()
Return a string specifying the flags that are currently set. If the message complies with the conventional format, the result is the concatenation in the following order of zero or one occurrence of each of 'R', 'O', 'D', 'F', and 'A'.

set_flags(flags)
Set the flags specified by flags and unset all others. Parameter flags should be the concatenation in any order of zero or more occurrences of each of 'R', 'O', 'D', 'F', and 'A'.

add_flag(flag)
Set the flag(s) specified by flag without changing other flags. To add more than one flag at a time, flag may be a string of more than one character.

remove_flag(flag)
Unset the flag(s) specified by flag without changing other flags. To remove more than one flag at a time, flag maybe a string of more than one character.

When an mboxMessage instance is created based upon a MaildirMessage instance, a “From ” line is generated based upon the MaildirMessage instance's delivery date, and the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>MaildirMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>R flag</td>
<td>S flag</td>
</tr>
<tr>
<td>O flag</td>
<td>“cur” subdirectory</td>
</tr>
<tr>
<td>D flag</td>
<td>T flag</td>
</tr>
<tr>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>F flag</td>
<td>F flag</td>
</tr>
<tr>
<td>A flag</td>
<td>R flag</td>
</tr>
</tbody>
</table>

When an `mboxMessage` instance is created based upon an `MHMessage` instance, the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>MHMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>R flag and O flag</td>
<td>no “unseen” sequence</td>
</tr>
<tr>
<td>O flag</td>
<td>“unseen” sequence</td>
</tr>
<tr>
<td>F flag</td>
<td>“flagged” sequence</td>
</tr>
<tr>
<td>A flag</td>
<td>“replied” sequence</td>
</tr>
</tbody>
</table>

When an `mboxMessage` instance is created based upon a `BabylMessage` instance, the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>BabylMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>R flag and O flag</td>
<td>no “unseen” label</td>
</tr>
<tr>
<td>O flag</td>
<td>“unseen” label</td>
</tr>
<tr>
<td>D flag</td>
<td>“deleted” label</td>
</tr>
<tr>
<td>A flag</td>
<td>“answered” label</td>
</tr>
</tbody>
</table>

When a `Message` instance is created based upon an `MMDFMessage` instance, the “From ” line is copied and all flags directly correspond:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>MMDFMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>R flag</td>
<td>R flag</td>
</tr>
<tr>
<td>O flag</td>
<td>O flag</td>
</tr>
</tbody>
</table>
19.4.2.3. **MHMessage**

```python
class mailbox.MHMessage(message=None)
```

A message with MH-specific behaviors. Parameter `message` has the same meaning as with the `Message` constructor.

MH messages do not support marks or flags in the traditional sense, but they do support sequences, which are logical groupings of arbitrary messages. Some mail reading programs (although not the standard `mh` and `nmh`) use sequences in much the same way flags are used with other formats, as follows:

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>unseen</td>
<td>Not read, but previously detected by MUA</td>
</tr>
<tr>
<td>replied</td>
<td>Replied to</td>
</tr>
<tr>
<td>flagged</td>
<td>Marked as important</td>
</tr>
</tbody>
</table>

`MHMessage` instances offer the following methods:

```python
def get_sequences()
    Return a list of the names of sequences that include this message.

def set_sequences(sequences)
    Set the list of sequences that include this message.

def add_sequence(sequence)
```
Add *sequence* to the list of sequences that include this message.

**remove_sequence**(*sequence*)

Remove *sequence* from the list of sequences that include this message.

When an **MHMessage** instance is created based upon a **MaildirMessage** instance, the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>MaildirMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>“unseen” sequence</td>
<td>no S flag</td>
</tr>
<tr>
<td>“replied” sequence</td>
<td>R flag</td>
</tr>
<tr>
<td>“flagged” sequence</td>
<td>F flag</td>
</tr>
</tbody>
</table>

When an **MHMessage** instance is created based upon an **mboxMessage** or **MMDFMessage** instance, the *Status* and *X-Status* headers are omitted and the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>mboxMessage or MMDFMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>“unseen” sequence</td>
<td>no R flag</td>
</tr>
<tr>
<td>“replied” sequence</td>
<td>A flag</td>
</tr>
<tr>
<td>“flagged” sequence</td>
<td>F flag</td>
</tr>
</tbody>
</table>

When an **MHMessage** instance is created based upon a **BabylMessage** instance, the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>BabylMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>“unseen” sequence</td>
<td>“unseen” label</td>
</tr>
</tbody>
</table>
19.4.2.4. **BabylMessage**

```python
class mailbox.BabylMessage(message=None)
```

A message with Babyl-specific behaviors. Parameter `message` has the same meaning as with the `Message` constructor.

Certain message labels, called *attributes*, are defined by convention to have special meanings. The attributes are as follows:

<table>
<thead>
<tr>
<th>Label</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>unseen</td>
<td>Not read, but previously detected by MUA</td>
</tr>
<tr>
<td>deleted</td>
<td>Marked for subsequent deletion</td>
</tr>
<tr>
<td>filed</td>
<td>Copied to another file or mailbox</td>
</tr>
<tr>
<td>answered</td>
<td>Replied to</td>
</tr>
<tr>
<td>forwarded</td>
<td>Forwarded</td>
</tr>
<tr>
<td>edited</td>
<td>Modified by the user</td>
</tr>
<tr>
<td>resent</td>
<td>Resent</td>
</tr>
</tbody>
</table>

By default, Rmail displays only visible headers. The `BabylMessage` class, though, uses the original headers because they are more complete. Visible headers may be accessed explicitly if desired.

`BabylMessage` instances offer the following methods:

- **get_labels()**
  Return a list of labels on the message.

- **set_labels(labels)**
Set the list of labels on the message to `labels`.

`add_label(label)`
Add `label` to the list of labels on the message.

`remove_label(label)`
Remove `label` from the list of labels on the message.

`get_visible()`
Return an `Message` instance whose headers are the message’s visible headers and whose body is empty.

`set_visible(visible)`
Set the message’s visible headers to be the same as the headers in `message`. Parameter `visible` should be a `Message` instance, an `email.message.Message` instance, a string, or a file-like object (which should be open in text mode).

`update_visible()`
When a `BabylMessage` instance’s original headers are modified, the visible headers are not automatically modified to correspond. This method updates the visible headers as follows: each visible header with a corresponding original header is set to the value of the original header, each visible header without a corresponding original header is removed, and any of `Date`, `From`, `Reply-To`, `To`, `CC`, and `Subject` that are present in the original headers but not the visible headers are added to the visible headers.

When a `BabylMessage` instance is created based upon a `MaildirMessage` instance, the following conversions take place:
<table>
<thead>
<tr>
<th>Resulting state</th>
<th>MaildirMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>“unseen” label</td>
<td>no S flag</td>
</tr>
<tr>
<td>“deleted” label</td>
<td>T flag</td>
</tr>
<tr>
<td>“answered” label</td>
<td>R flag</td>
</tr>
<tr>
<td>“forwarded” label</td>
<td>P flag</td>
</tr>
</tbody>
</table>

When a `BabylMessage` instance is created based upon an `mboxMessage` or `MMDFMessage` instance, the `Status` and `X-Status` headers are omitted and the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>mboxMessage or MMDFMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>“unseen” label</td>
<td>no R flag</td>
</tr>
<tr>
<td>“deleted” label</td>
<td>D flag</td>
</tr>
<tr>
<td>“answered” label</td>
<td>A flag</td>
</tr>
</tbody>
</table>

When a `BabylMessage` instance is created based upon an `MHMessage` instance, the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>MHMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>“unseen” label</td>
<td>“unseen” sequence</td>
</tr>
<tr>
<td>“answered” label</td>
<td>“replied” sequence</td>
</tr>
</tbody>
</table>

19.4.2.5. **MMDFMessage**

```python
class mailbox.MMDFMessage(message=None)
```

A message with MMDF-specific behaviors. Parameter `message` has the same meaning as with the `Message` constructor.

As with message in an mbox mailbox, MMDF messages are stored
with the sender’s address and the delivery date in an initial line beginning with “From ”. Likewise, flags that indicate the state of the message are typically stored in Status and X-Status headers.

Conventional flags for MMDF messages are identical to those of mbox message and are as follows:

<table>
<thead>
<tr>
<th>Flag</th>
<th>Meaning</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Read</td>
<td>Read</td>
</tr>
<tr>
<td>O</td>
<td>Old</td>
<td>Previously detected by MUA</td>
</tr>
<tr>
<td>D</td>
<td>Deleted</td>
<td>Marked for subsequent deletion</td>
</tr>
<tr>
<td>F</td>
<td>Flagged</td>
<td>Marked as important</td>
</tr>
<tr>
<td>A</td>
<td>Answered</td>
<td>Replied to</td>
</tr>
</tbody>
</table>

The “R” and “O” flags are stored in the Status header, and the “D”, “F”, and “A” flags are stored in the X-Status header. The flags and headers typically appear in the order mentioned.

**MMDFMessage** instances offer the following methods, which are identical to those offered by **mboxMessage**:

**get_from()**

Return a string representing the “From ” line that marks the start of the message in an mbox mailbox. The leading “From ” and the trailing newline are excluded.

**set_from**(from_, time_=None)

Set the “From ” line to from_, which should be specified without a leading “From ” or trailing newline. For convenience, time_ may be specified and will be formatted appropriately and appended to from_. If time_ is specified, it should be a
time.struct_time instance, a tuple suitable for passing to time.strftime(), or True (to use time.gmtime()).

get_flags()
Return a string specifying the flags that are currently set. If the message complies with the conventional format, the result is the concatenation in the following order of zero or one occurrence of each of 'R', 'O', 'D', 'F', and 'A'.

set_flags(flags)
Set the flags specified by flags and unset all others. Parameter flags should be the concatenation in any order of zero or more occurrences of each of 'R', 'O', 'D', 'F', and 'A'.

add_flag(flag)
Set the flag(s) specified by flag without changing other flags. To add more than one flag at a time, flag may be a string of more than one character.

remove_flag(flag)
Unset the flag(s) specified by flag without changing other flags. To remove more than one flag at a time, flag maybe a string of more than one character.

When an MMDFMessage instance is created based upon a MaildirMessage instance, a “From” line is generated based upon the MaildirMessage instance’s delivery date, and the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>MaildirMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>R flag</td>
<td>S flag</td>
</tr>
<tr>
<td>O flag</td>
<td>“cur” subdirectory</td>
</tr>
<tr>
<td>D flag</td>
<td>T flag</td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>F flag</td>
<td>F flag</td>
</tr>
<tr>
<td>A flag</td>
<td>R flag</td>
</tr>
</tbody>
</table>

When an *MMDFMessage* instance is created based upon an *MHMessage* instance, the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>MHMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>R flag and O flag</td>
<td>no “unseen” sequence</td>
</tr>
<tr>
<td>O flag</td>
<td>“unseen” sequence</td>
</tr>
<tr>
<td>F flag</td>
<td>“flagged” sequence</td>
</tr>
<tr>
<td>A flag</td>
<td>“replied” sequence</td>
</tr>
</tbody>
</table>

When an *MMDFMessage* instance is created based upon a *BabylMessage* instance, the following conversions take place:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>BabylMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>R flag and O flag</td>
<td>no “unseen” label</td>
</tr>
<tr>
<td>O flag</td>
<td>“unseen” label</td>
</tr>
<tr>
<td>D flag</td>
<td>“deleted” label</td>
</tr>
<tr>
<td>A flag</td>
<td>“answered” label</td>
</tr>
</tbody>
</table>

When an *MMDFMessage* instance is created based upon an *mboxMessage* instance, the “From ” line is copied and all flags directly correspond:

<table>
<thead>
<tr>
<th>Resulting state</th>
<th>mboxMessage state</th>
</tr>
</thead>
<tbody>
<tr>
<td>R flag</td>
<td>R flag</td>
</tr>
<tr>
<td>O flag</td>
<td>O flag</td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>D flag</td>
<td>D flag</td>
</tr>
<tr>
<td>F flag</td>
<td>F flag</td>
</tr>
<tr>
<td>A flag</td>
<td>A flag</td>
</tr>
</tbody>
</table>
19.4.3. Exceptions

The following exception classes are defined in the `mailbox` module:

**exception mailbox.Error**

The based class for all other module-specific exceptions.

**exception mailbox.NoSuchMailboxError**

Raised when a mailbox is expected but is not found, such as when instantiating a `Mailbox` subclass with a path that does not exist (and with the `create` parameter set to `False`), or when opening a folder that does not exist.

**exception mailbox.NotEmptyError**

Raised when a mailbox is not empty but is expected to be, such as when deleting a folder that contains messages.

**exception mailbox.ExternalClashError**

Raised when some mailbox-related condition beyond the control of the program causes it to be unable to proceed, such as when failing to acquire a lock that another program already holds a lock, or when a uniquely-generated file name already exists.

**exception mailbox.FormatError**

Raised when the data in a file cannot be parsed, such as when an `MH` instance attempts to read a corrupted `.mh_sequences` file.
19.4.4. Examples

A simple example of printing the subjects of all messages in a mailbox that seem interesting:

```python
global import mailbox
for message in mailbox.mbox('~/mbox'):
    subject = message['subject']  # Could possibly be None.
    if subject and 'python' in subject.lower():
        print(subject)
```

To copy all mail from a Babylon mailbox to an MH mailbox, converting all of the format-specific information that can be converted:

```python
global import mailbox
import mailbox
import email.errors

list_names = ('python-list', 'python-dev', 'python-bugs')
```
boxes = {name: mailbox.mbox('~/email/%s' % name) for name in list_names}

for key in inbox.iterkeys():
    try:
        message = inbox[key]
    except email.errors.MessageParseError:
        continue  # The message is malformed.

    for name in list_names:
        list_id = message['list-id']
        if list_id and name in list_id:
            # Get mailbox to use
            box = boxes[name]

            # Write copy to disk before removing original.
            # If there's a crash, you might duplicate that, but
            # that's better than losing a message completely.
            box.lock()
            box.add(message)
            box.flush()
            box.unlock()

            # Remove original message
            inbox.lock()
            inbox.discard(key)
            inbox.flush()
            inbox.unlock()
            break  # Found destination,

for box in boxes.itervalues():
    box.close()
19.5. **mimetypes** — Map filenames to MIME types

**Source code:** Lib/mimetypes.py

The `mimetypes` module converts between a filename or URL and the MIME type associated with the filename extension. Conversions are provided from filename to MIME type and from MIME type to filename extension; encodings are not supported for the latter conversion.

The module provides one class and a number of convenience functions. The functions are the normal interface to this module, but some applications may be interested in the class as well.

The functions described below provide the primary interface for this module. If the module has not been initialized, they will call `init()` if they rely on the information `init()` sets up.

```python
mimetypes.guess_type(url, strict=True)
```

Guess the type of a file based on its filename or URL, given by `url`. The return value is a tuple `(type, encoding)` where `type` is None if the type can't be guessed (missing or unknown suffix) or a string of the form 'type/subtype', usable for a MIME `content-type` header.

`encoding` is None for no encoding or the name of the program used to encode (e.g. `compress` or `gzip`). The encoding is suitable for use as a `Content-Encoding` header, not as a `Content-Transfer-Encoding` header. The mappings are table driven. Encoding suffixes are case sensitive; type suffixes are first tried case
sensitively, then case insensitively.

The optional strict argument is a flag specifying whether the list of known MIME types is limited to only the official types registered with IANA. When strict is True (the default), only the IANA types are supported; when strict is False, some additional non-standard but commonly used MIME types are also recognized.

`mimetypes.guess_all_extensions(type, strict=True)`

Guess the extensions for a file based on its MIME type, given by type. The return value is a list of strings giving all possible filename extensions, including the leading dot ('.'). The extensions are not guaranteed to have been associated with any particular data stream, but would be mapped to the MIME type type by `guess_type()`.

The optional strict argument has the same meaning as with the `guess_type()` function.

`mimetypes.guess_extension(type, strict=True)`

Guess the extension for a file based on its MIME type, given by type. The return value is a string giving a filename extension, including the leading dot ('.'). The extension is not guaranteed to have been associated with any particular data stream, but would be mapped to the MIME type type by `guess_type()` If no extension can be guessed for type, None is returned.

The optional strict argument has the same meaning as with the `guess_type()` function.

Some additional functions and data items are available for controlling the behavior of the module.
mimetypes.init(files=None)

Initialize the internal data structures. If given, files must be a sequence of file names which should be used to augment the default type map. If omitted, the file names to use are taken from knownfiles; on Windows, the current registry settings are loaded. Each file named in files or knownfiles takes precedence over those named before it. Calling init() repeatedly is allowed.

Specifying an empty list for files will prevent the system defaults from being applied: only the well-known values will be present from a built-in list.

Changed in version 3.2: Previously, Windows registry settings were ignored.

mimetypes.read_mime_types(filename)

Load the type map given in the file filename, if it exists. The type map is returned as a dictionary mapping filename extensions, including the leading dot ('.'), to strings of the form 'type/subtype'. If the file filename does not exist or cannot be read, None is returned.

mimetypes.add_type(type, ext, strict=True)

Add a mapping from the MIME type type to the extension ext. When the extension is already known, the new type will replace the old one. When the type is already known the extension will be added to the list of known extensions.

When strict is True (the default), the mapping will be added to the official MIME types, otherwise to the non-standard ones.

mimetypes.inited
Flag indicating whether or not the global data structures have been initialized. This is set to True by `init()`.

`mimetypes.knownfiles`
List of type map file names commonly installed. These files are typically named `mime.types` and are installed in different locations by different packages.

`mimetypes.suffix_map`
Dictionary mapping suffixes to suffixes. This is used to allow recognition of encoded files for which the encoding and the type are indicated by the same extension. For example, the `.tgz` extension is mapped to `.tar.gz` to allow the encoding and type to be recognized separately.

`mimetypes.encodings_map`
Dictionary mapping filename extensions to encoding types.

`mimetypes.types_map`
Dictionary mapping filename extensions to MIME types.

`mimetypes.common_types`
Dictionary mapping filename extensions to non-standard, but commonly found MIME types.

An example usage of the module:

```python
>>> import mimetypes
>>> mimetypes.init()
>>> mimetypes.knownfiles
['/etc/mime.types', '/etc/httpd/mime.types', ... ]
>>> mimetypes.suffix_map['.tgz']
'.tar.gz'
>>> mimetypes.encodings_map['.gz']
```
'gzip'

```python
>>> mimetypes.types_map['.tgz']
'application/x-tar-gz'
```
19.5.1. MimeTypes Objects

The MimeTypes class may be useful for applications which may want more than one MIME-type database; it provides an interface similar to the one of the mimetypes module.

```python
class mimetypes.MimeTypes(filenames=(), strict=True)
```

This class represents a MIME-types database. By default, it provides access to the same database as the rest of this module. The initial database is a copy of that provided by the module, and may be extended by loading additional mime.types-style files into the database using the `read()` or `readfp()` methods. The mapping dictionaries may also be cleared before loading additional data if the default data is not desired.

The optional `filenames` parameter can be used to cause additional files to be loaded “on top” of the default database.

**MimeTypes.suffix_map**

Dictionary mapping suffixes to suffixes. This is used to allow recognition of encoded files for which the encoding and the type are indicated by the same extension. For example, the `.tgz` extension is mapped to `.tar.gz` to allow the encoding and type to be recognized separately. This is initially a copy of the global `suffix_map` defined in the module.

**MimeTypes.encodings_map**

Dictionary mapping filename extensions to encoding types. This is initially a copy of the global `encodings_map` defined in the module.
MimeTypes.types_map

Tuple containing two dictionaries, mapping filename extensions to MIME types: the first dictionary is for the non-standards types and the second one is for the standard types. They are initialized by common_types and types_map.

MimeTypes.types_map_inv

Tuple containing two dictionaries, mapping MIME types to a list of filename extensions: the first dictionary is for the non-standards types and the second one is for the standard types. They are initialized by common_types and types_map.

MimeTypes.guess_extension(type, strict=True)

Similar to the guess_extension() function, using the tables stored as part of the object.

MimeTypes.guess_type(url, strict=True)

Similar to the guess_type() function, using the tables stored as part of the object.

MimeTypes.guess_all_extensions(type, strict=True)

Similar to the guess_all_extensions() function, using the tables stored as part of the object.

MimeTypes.read(filename, strict=True)

Load MIME information from a file named filename. This uses readfp() to parse the file.

If strict is True, information will be added to list of standard types, else to the list of non-standard types.

MimeTypes.readfp(fp, strict=True)
Load MIME type information from an open file `fp`. The file must have the format of the standard `mime.types` files.

If `strict` is True, information will be added to the list of standard types, else to the list of non-standard types.

MimeTypes.\texttt{read\_windows\_registry}(\texttt{strict=True})

Load MIME type information from the Windows registry. Availability: Windows.

If `strict` is True, information will be added to the list of standard types, else to the list of non-standard types.

\textit{New in version 3.2.}
19.6. **base64** — Base16, Base32, Base64, Base85 Data Encodings

This module provides functions for encoding binary data to printable ASCII characters and decoding such encodings back to binary data. It provides encoding and decoding functions for the encodings specified in **RFC 3548**, which defines the Base16, Base32, and Base64 algorithms, and for the de-facto standard Ascii85 and Base85 encodings.

The **RFC 3548** encodings are suitable for encoding binary data so that it can safely sent by email, used as parts of URLs, or included as part of an HTTP POST request. The encoding algorithm is not the same as the **uuencode** program.

There are two **RFC 3548** interfaces provided by this module. The modern interface supports encoding and decoding ASCII byte string objects using all three **RFC 3548** defined alphabets (normal, URL-safe, and filesystem-safe). Additionally, the decoding functions of the modern interface also accept Unicode strings containing only ASCII characters. The legacy interface provides for encoding and decoding to and from file-like objects as well as byte strings, but only using the Base64 standard alphabet.

*Changed in version 3.3:* ASCII-only Unicode strings are now accepted by the decoding functions of the modern interface.

*Changed in version 3.4:* Any **bytes-like objects** are now accepted by all encoding and decoding functions in this module. Ascii85/Base85 support added.
The modern interface provides:

\texttt{base64.b64encode}(s, \texttt{altchars=None})

Encode a byte string using Base64.

\textit{s} is the string to encode. Optional \texttt{altchars} must be a string of at least length 2 (additional characters are ignored) which specifies an alternative alphabet for the + and / characters. This allows an application to e.g. generate URL or filesystem safe Base64 strings. The default is None, for which the standard Base64 alphabet is used.

The encoded byte string is returned.

\texttt{base64.b64decode}(s, \texttt{altchars=None, validate=False})

Decode a Base64 encoded byte string.

\textit{s} is the byte string to decode. Optional \texttt{altchars} must be a string of at least length 2 (additional characters are ignored) which specifies the alternative alphabet used instead of the + and / characters.

The decoded string is returned. A \texttt{binascii.Error} exception is raised if \textit{s} is incorrectly padded.

If \texttt{validate} is False (the default), non-base64-alphabet characters are discarded prior to the padding check. If \texttt{validate} is True, non-base64-alphabet characters in the input result in a \texttt{binascii.Error}.

\texttt{base64.standard_b64encode}(s)

Encode byte string \textit{s} using the standard Base64 alphabet.

\texttt{base64.standard_b64decode}(s)
Decode byte string s using the standard Base64 alphabet.

`base64.urlsafe_b64encode(s)`

Encode byte string s using a URL-safe alphabet, which substitutes - instead of + and _ instead of / in the standard Base64 alphabet. The result can still contain =.

`base64.urlsafe_b64decode(s)`

Decode byte string s using a URL-safe alphabet, which substitutes - instead of + and _ instead of / in the standard Base64 alphabet.

`base64.b32encode(s)`

Encode a byte string using Base32. s is the string to encode. The encoded string is returned.

`base64.b32decode(s, casefold=False, map01=None)`

Decode a Base32 encoded byte string.

s is the byte string to decode. Optional casefold is a flag specifying whether a lowercase alphabet is acceptable as input. For security purposes, the default is False.

RFC 3548 allows for optional mapping of the digit 0 (zero) to the letter O (oh), and for optional mapping of the digit 1 (one) to either the letter l (eye) or letter L (el). The optional argument map01 when not None, specifies which letter the digit 1 should be mapped to (when map01 is not None, the digit 0 is always mapped to the letter O). For security purposes the default is None, so that 0 and 1 are not allowed in the input.

The decoded byte string is returned. A `binascii.Error` is raised if s is incorrectly padded or if there are non-alphabet characters present in the string.
base64.\texttt{b16encode}(s)

Encode a byte string using Base16.

\texttt{s} is the string to encode. The encoded byte string is returned.

base64.\texttt{b16decode}(s, \texttt{casefold}=False)

Decode a Base16 encoded byte string.

\texttt{s} is the string to decode. Optional \texttt{casefold} is a flag specifying whether a lowercase alphabet is acceptable as input. For security purposes, the default is False.

The decoded byte string is returned. A \texttt{TypeError} is raised if \texttt{s} were incorrectly padded or if there are non-alphabet characters present in the string.

base64.\texttt{a85encode}(s, *, \texttt{foldspaces}=False, \texttt{wrapcol}=0, \texttt{pad}=False, \texttt{adobe}=False)

Encode a byte string using Ascii85.

\texttt{s} is the string to encode. The encoded byte string is returned.

\texttt{foldspaces} is an optional flag that uses the special short sequence ‘y’ instead of 4 consecutive spaces (ASCII 0x20) as supported by ‘btoa’. This feature is not supported by the “standard” Ascii85 encoding.

\texttt{wrapcol} controls whether the output should have newline (‘n’) characters added to it. If this is non-zero, each output line will be at most this many characters long.

\texttt{pad} controls whether the input string is padded to a multiple of 4 before encoding. Note that the \texttt{btoa} implementation always pads.
adobe controls whether the encoded byte sequence is framed with <~ and ~>, which is used by the Adobe implementation.

New in version 3.4.

`.a85decode(s, *, foldspaces=False, adobe=False, ignorechars=b'tnr')`

Decode an Ascii85 encoded byte string.

s is the byte string to decode.

foldspaces is a flag that specifies whether the ‘y’ short sequence should be accepted as shorthand for 4 consecutive spaces (ASCII 0x20). This feature is not supported by the “standard” Ascii85 encoding.

adobe controls whether the input sequence is in Adobe Ascii85 format (i.e. is framed with <~ and ~>).

ignorechars should be a byte string containing characters to ignore from the input. This should only contain whitespace characters, and by default contains all whitespace characters in ASCII.

New in version 3.4.

`.b85encode(s, pad=False)`

Encode a byte string using base85, as used in e.g. git-style binary diffs.

If pad is true, the input is padded with “\0” so its length is a multiple of 4 characters before encoding.

New in version 3.4.
Decode base85-encoded byte string. Padding is implicitly removed, if necessary.

*New in version 3.4.*

**Note:** Both Base85 and Ascii85 have an expansion factor of 5 to 4 (5 Base85 or Ascii85 characters can encode 4 binary bytes), while the better-known Base64 has an expansion factor of 6 to 4. They are therefore more efficient when space expensive. They differ by details such as the character map used for encoding.

The legacy interface:

**base64.decode(input, output)**

Decode the contents of the binary `input` file and write the resulting binary data to the `output` file. `input` and `output` must be *file objects*. `input` will be read until `input.read()` returns an empty bytes object.

**base64.decodebytes(s)**

**base64.decodestring(s)**

Decode the byte string `s`, which must contain one or more lines of base64 encoded data, and return a byte string containing the resulting binary data. `decodestring` is a deprecated alias.

*New in version 3.1.*

**base64.encode(input, output)**

Encode the contents of the binary `input` file and write the resulting base64 encoded data to the `output` file. `input` and `output` must be *file objects*. `input` will be read until `input.read()` returns an
empty bytes object. \texttt{encode()} returns the encoded data plus a trailing newline character (b'\n').

\texttt{base64.encodebytes(s)}
\texttt{base64.encodestring(s)}

Encode the byte string \textit{s}, which can contain arbitrary binary data, and return a byte string containing one or more lines of base64-encoded data. \texttt{encodebytes()} returns a string containing one or more lines of base64-encoded data always including an extra trailing newline (b'\n'). \texttt{encodestring} is a deprecated alias.

An example usage of the module:

\begin{verbatim}
>>> import base64
>>> encoded = base64.b64encode(b'data to be encoded')
>>> encoded
b'ZGF0YSB0byBiZSBlbmNvZGVk'
>>> data = base64.b64decode(encoded)
>>> data
b'data to be encoded'
\end{verbatim}

See also:

\textbf{Module \texttt{binascii}}

Support module containing ASCII-to-binary and binary-to-ASCII conversions.

\textbf{RFC 1521 - MIME (Multipurpose Internet Mail Extensions) Part One: Mechanisms for Specifying and Describing the Format of Internet Message Bodies}

Section 5.2, “Base64 Content-Transfer-Encoding,” provides the definition of the base64 encoding.
19.7. `binhex` — Encode and decode binhex4 files

This module encodes and decodes files in binhex4 format, a format allowing representation of Macintosh files in ASCII. Only the data fork is handled.

The `binhex` module defines the following functions:

`binhex.binhex(input, output)`

Convert a binary file with filename `input` to binhex file `output`. The `output` parameter can either be a filename or a file-like object (any object supporting a `write()` and `close()` method).

`binhex.hexbin(input, output)`

Decode a binhex file `input`. `input` may be a filename or a file-like object supporting `read()` and `close()` methods. The resulting file is written to a file named `output`, unless the argument is `None` in which case the output filename is read from the binhex file.

The following exception is also defined:

`exception binhex.Error`

Exception raised when something can’t be encoded using the binhex format (for example, a filename is too long to fit in the filename field), or when input is not properly encoded binhex data.

See also:

Module `binascii`

Support module containing ASCII-to-binary and binary-to-ASCII
conversions.
19.7.1. Notes

There is an alternative, more powerful interface to the coder and decoder, see the source for details.

If you code or decode textfiles on non-Macintosh platforms they will still use the old Macintosh newline convention (carriage-return as end of line).

As of this writing, \texttt{hexbin()} appears to not work in all cases.
19.8. **binascii** — Convert between binary and ASCII

The `binascii` module contains a number of methods to convert between binary and various ASCII-encoded binary representations. Normally, you will not use these functions directly but use wrapper modules like `uu`, `base64`, or `binhex` instead. The `binascii` module contains low-level functions written in C for greater speed that are used by the higher-level modules.

**Note:** `a2b_*` functions accept Unicode strings containing only ASCII characters. Other functions only accept bytes-like objects (such as `bytes`, `bytearray` and other objects that support the buffer protocol).

*Changed in version 3.3:* ASCII-only unicode strings are now accepted by the `a2b_*` functions.

The `binascii` module defines the following functions:

- `binascii.a2b_uu(string)`
  
  Convert a single line of uuencoded data back to binary and return the binary data. Lines normally contain 45 (binary) bytes, except for the last line. Line data may be followed by whitespace.

- `binascii.b2a_uu(data)`
  
  Convert binary data to a line of ASCII characters, the return value is the converted line, including a newline char. The length of `data` should be at most 45.
binascii.\texttt{a2b\_base64(string)}

Convert a block of base64 data back to binary and return the binary data. More than one line may be passed at a time.

binascii.\texttt{b2a\_base64(data)}

Convert binary data to a line of ASCII characters in base64 coding. The return value is the converted line, including a newline char. The length of data should be at most 57 to adhere to the base64 standard.

binascii.\texttt{a2b\_qp(data, header=False)}

Convert a block of quoted-printable data back to binary and return the binary data. More than one line may be passed at a time. If the optional argument header is present and true, underscores will be decoded as spaces.

binascii.\texttt{b2a\_qp(data, quotetabs=False, istext=True, header=False)}

Convert binary data to a line(s) of ASCII characters in quoted-printable encoding. The return value is the converted line(s). If the optional argument quotetabs is present and true, all tabs and spaces will be encoded. If the optional argument istext is present and true, newlines are not encoded but trailing whitespace will be encoded. If the optional argument header is present and true, spaces will be encoded as underscores per RFC1522. If the optional argument header is present and false, newline characters will be encoded as well; otherwise linefeed conversion might corrupt the binary data stream.

binascii.\texttt{a2b\_hqx(string)}

Convert binhex4 formatted ASCII data to binary, without doing RLE-decompression. The string should contain a complete number
of binary bytes, or (in case of the last portion of the binhex4 data) have the remaining bits zero.

\texttt{binascii.rledecode_hqx(data)}

Perform RLE-decompression on the data, as per the binhex4 standard. The algorithm uses \texttt{0x90} after a byte as a repeat indicator, followed by a count. A count of \texttt{0} specifies a byte value of \texttt{0x90}. The routine returns the decompressed data, unless data input data ends in an orphaned repeat indicator, in which case the \texttt{Incomplete} exception is raised.

*Changed in version 3.2:* Accept only bytestring or bytearray objects as input.

\texttt{binascii.rlecode_hqx(data)}

Perform binhex4 style RLE-compression on \texttt{data} and return the result.

\texttt{binascii.b2a_hqx(data)}

Perform hexbin4 binary-to-ASCII translation and return the resulting string. The argument should already be RLE-coded, and have a length divisible by 3 (except possibly the last fragment).

\texttt{binascii.crc_hqx(data, crc)}

Compute the binhex4 crc value of \texttt{data}, starting with an initial \texttt{crc} and returning the result.

\texttt{binascii.crc32(data[, crc])}

Compute CRC-32, the 32-bit checksum of data, starting with an initial \texttt{crc}. This is consistent with the ZIP file checksum. Since the algorithm is designed for use as a checksum algorithm, it is not suitable for use as a general hash algorithm. Use as follows:
print(binascii.crc32(b"hello world"))
# Or, in two pieces:
crc = binascii.crc32(b"hello")
crc = binascii.crc32(b" world", crc) & 0xffffffff
print('crc32 = {:#010x}'.format(crc))

**Note:** To generate the same numeric value across all Python versions and platforms use crc32(data) & 0xffffffff. If you are only using the checksum in packed binary format this is not necessary as the return value is the correct 32bit binary representation regardless of sign.

**binascii.b2a_hex(data)**
**binascii.hexlify(data)**

Return the hexadecimal representation of the binary data. Every byte of data is converted into the corresponding 2-digit hex representation. The returned bytes object is therefore twice as long as the length of data.

**binascii.a2b_hex(hexstr)**
**binascii.unhexlify(hexstr)**

Return the binary data represented by the hexadecimal string hexstr. This function is the inverse of b2a_hex(). hexstr must contain an even number of hexadecimal digits (which can be upper or lower case), otherwise a TypeError is raised.

**exception binascii.Error**

Exception raised on errors. These are usually programming errors.

**exception binascii.Incomplete**

Exception raised on incomplete data. These are usually not programming errors, but may be handled by reading a little more
data and trying again.

See also:

**Module base64**
Support for base64 encoding used in MIME email messages.

**Module binhex**
Support for the binhex format used on the Macintosh.

**Module uu**
Support for UU encoding used on Unix.

**Module quopri**
Support for quoted-printable encoding used in MIME email messages.
19.9. **quopri** — Encode and decode MIME quoted-printable data

**Source code:** Lib/quopri.py

This module performs quoted-printable transport encoding and decoding, as defined in [RFC 1521](https://tools.ietf.org/html/rfc1521): “MIME (Multipurpose Internet Mail Extensions) Part One: Mechanisms for Specifying and Describing the Format of Internet Message Bodies”. The quoted-printable encoding is designed for data where there are relatively few nonprintable characters; the base64 encoding scheme available via the `base64` module is more compact if there are many such characters, as when sending a graphics file.

**quopri.decode**(*input*, *output*, *header=False*)

Decode the contents of the *input* file and write the resulting decoded binary data to the *output* file. *input* and *output* must be binary file objects. If the optional argument *header* is present and true, underscore will be decoded as space. This is used to decode “Q”-encoded headers as described in [RFC 1522](https://tools.ietf.org/html/rfc1522): “MIME (Multipurpose Internet Mail Extensions) Part Two: Message Header Extensions for Non-ASCII Text”.

**quopri.encode**(*input*, *output*, *quotetabs*, *header=False*)

Encode the contents of the *input* file and write the resulting quoted-printable data to the *output* file. *input* and *output* must be binary file objects. *quotetabs*, a flag which controls whether to encode embedded spaces and tabs must be provided and when true it
encodes such embedded whitespace, and when false it leaves them unencoded. Note that spaces and tabs appearing at the end of lines are always encoded, as per RFC 1521. header is a flag which controls if spaces are encoded as underscores as per RFC 1522.

quopri.decodestring(s, header=False)
   Like decode(), except that it accepts a source bytes and returns the corresponding decoded bytes.

quopri.encodestring(s, quotetabs=False, header=False)
   Like encode(), except that it accepts a source bytes and returns the corresponding encoded bytes. By default, it sends a False value to quotetabs parameter of the encode() function.

See also:
Module base64
   Encode and decode MIME base64 data
19.10. uu — Encode and decode uuencode files

Source code: Lib/uu.py

This module encodes and decodes files in uuencode format, allowing arbitrary binary data to be transferred over ASCII-only connections. Wherever a file argument is expected, the methods accept a file-like object. For backwards compatibility, a string containing a pathname is also accepted, and the corresponding file will be opened for reading and writing; the pathname '-' is understood to mean the standard input or output. However, this interface is deprecated; it's better for the caller to open the file itself, and be sure that, when required, the mode is 'rb' or 'wb' on Windows.

This code was contributed by Lance Ellinghouse, and modified by Jack Jansen.

The uu module defines the following functions:

uu.encode(in_file, out_file, name=None, mode=None)

Uuencode file in_file into file out_file. The uuencoded file will have the header specifying name and mode as the defaults for the results of decoding the file. The default defaults are taken from in_file, or '-' and 0o666 respectively.

uu.decode(in_file, out_file=None, mode=None, quiet=False)

This call decodes uuencoded file in_file placing the result on file out_file. If out_file is a pathname, mode is used to set the permission bits if the file must be created. Defaults for out_file and
mode are taken from the uuencode header. However, if the file specified in the header already exists, a uu.Error is raised.

decode() may print a warning to standard error if the input was produced by an incorrect uuencoder and Python could recover from that error. Setting quiet to a true value silences this warning.

exception uu.Error
Subclass of Exception, this can be raised by uu.decode() under various situations, such as described above, but also including a badly formatted header, or truncated input file.

See also:
Module binascii
Support module containing ASCII-to-binary and binary-to-ASCII conversions.
20. Structured Markup Processing Tools

Python supports a variety of modules to work with various forms of structured data markup. This includes modules to work with the Standard Generalized Markup Language (SGML) and the Hypertext Markup Language (HTML), and several interfaces for working with the Extensible Markup Language (XML).

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20.1. **html** — HyperText Markup Language support

**Source code:** `Lib/html/__init__.py`

This module defines utilities to manipulate HTML.

**html.escape(s, quote=True)**

Convert the characters `&`, `<` and `>` in string `s` to HTML-safe sequences. Use this if you need to display text that might contain such characters in HTML. If the optional flag `quote` is true, the characters `"` and `'` are also translated; this helps for inclusion in an HTML attribute value delimited by quotes, as in `<a href="...">`.

*New in version 3.2.*

**html.unescape(s)**

Convert all named and numeric character references (e.g. `&gt;`, `&#62;`, `&x3e;`) in the string `s` to the corresponding unicode characters. This function uses the rules defined by the HTML 5 standard for both valid and invalid character references, and the list of HTML 5 named character references.

*New in version 3.4.*

Submodules in the `html` package are:

- **html.parser** – HTML/XHTML parser with lenient parsing mode
• **html.entities** – HTML entity definitions
20.2. `html.parser` — Simple HTML and XHTML parser

Source code: `Lib/html/parser.py`

This module defines a class `HTMLParser` which serves as the basis for parsing text files formatted in HTML (HyperText Mark-up Language) and XHTML.

```python
class html.parser.HTMLParser(*, convert_charrefs=True)
```

Create a parser instance to parse invalid markup.

If `convert_charrefs` is True (the default), all character references (except the ones in `script`/`style` elements) are automatically converted to the corresponding Unicode characters.

An `HTMLParser` instance is fed HTML data and calls handler methods when start tags, end tags, text, comments, and other markup elements are encountered. The user should subclass `HTMLParser` and override its methods to implement the desired behavior.

This parser does not check that end tags match start tags or call the end-tag handler for elements which are closed implicitly by closing an outer element.

*Changed in version 3.4:* `convert_charrefs` keyword argument added.

*Changed in version 3.5:* The default value for argument
convert_charrefs is now True.
20.2.1. Example HTML Parser Application

As a basic example, below is a simple HTML parser that uses the `HTMLParser` class to print out start tags, end tags, and data as they are encountered:

```python
from html.parser import HTMLParser

class MyHTMLParser(HTMLParser):
    def handle_starttag(self, tag, attrs):
        print("Encountered a start tag:", tag)
    def handle_endtag(self, tag):
        print("Encountered an end tag:", tag)
    def handle_data(self, data):
        print("Encountered some data:", data)

parser = MyHTMLParser()
parsed.feed('<html><head><title>Test</title></head>''<body><h1>Parse me!</h1></body></html>
```

The output will then be:

```
Encountered a start tag: html
Encountered a start tag: head
Encountered a start tag: title
Encountered some data: Test
Encountered an end tag: title
Encountered an end tag: head
Encountered a start tag: body
Encountered a start tag: h1
Encountered some data: Parse me!
Encountered an end tag: h1
Encountered an end tag: body
Encountered an end tag: html
```
20.2.2. **HTMLParser** Methods

**HTMLParser** instances have the following methods:

**HTMLParser**.\(\text{feed}(data)\)

Feed some text to the parser. It is processed insofar as it consists of complete elements; incomplete data is buffered until more data is fed or close() is called. \(data\) must be \text{str}.

**HTMLParser**.\(\text{close}()\)

Force processing of all buffered data as if it were followed by an end-of-file mark. This method may be redefined by a derived class to define additional processing at the end of the input, but the redefined version should always call the **HTMLParser** base class method close().

**HTMLParser**.\(\text{reset}()\)

Reset the instance. Loses all unprocessed data. This is called implicitly at instantiation time.

**HTMLParser**.\(\text{getpos}()\)

Return current line number and offset.

**HTMLParser**.\(\text{get_starttag_text}()\)

Return the text of the most recently opened start tag. This should not normally be needed for structured processing, but may be useful in dealing with HTML “as deployed” or for re-generating input with minimal changes (whitespace between attributes can be preserved, etc.).

The following methods are called when data or markup elements are
encountered and they are meant to be overridden in a subclass. The base class implementations do nothing (except for `handle_startendtag()`):

**HTMLParser**. `handle_starttag(tag, attrs)`

This method is called to handle the start of a tag (e.g. `<div id="main">`).

The `tag` argument is the name of the tag converted to lower case. The `attrs` argument is a list of (name, value) pairs containing the attributes found inside the tag's <> brackets. The name will be translated to lower case, and quotes in the value have been removed, and character and entity references have been replaced.

For instance, for the tag `<A HREF="http://www.cwi.nl/">`, this method would be called as `handle_starttag('a', [('href', 'http://www.cwi.nl/')]).`

All entity references from `html.entities` are replaced in the attribute values.

**HTMLParser**. `handle_endtag(tag)`

This method is called to handle the end tag of an element (e.g. `</div>`).

The `tag` argument is the name of the tag converted to lower case.

**HTMLParser**. `handle_startendtag(tag, attrs)`

Similar to `handle_starttag()`, but called when the parser encounters an XHTML-style empty tag (`<img ... />`). This method may be overridden by subclasses which require this particular lexical information; the default implementation simply
calls `handle_starttag()` and `handle_endtag()`.

**HTMLParser**. `handle_data(data)`

This method is called to process arbitrary data (e.g. text nodes and the content of `<script>`...`</script>` and `<style>`...`</style>`).

**HTMLParser**. `handle_entityref(name)`

This method is called to process a named character reference of the form `&name;` (e.g. `&gt;`), where `name` is a general entity reference (e.g. 'gt'). This method is never called if `convert_charrefs` is True.

**HTMLParser**. `handle_charref(name)`

This method is called to process decimal and hexadecimal numeric character references of the form `&#NNN;` and `&#xNNN;`. For example, the decimal equivalent for `&gt;` is `&#62;`, whereas the hexadecimal is `&#x3E;`; in this case the method will receive '62' or 'x3E'. This method is never called if `convert_charrefs` is True.

**HTMLParser**. `handle_comment(data)`

This method is called when a comment is encountered (e.g. `<!-- comment -->`).

For example, the comment `<!-- comment -->` will cause this method to be called with the argument ' comment '.

The content of Internet Explorer conditional comments (condcoms) will also be sent to this method, so, for `<![if IE 9]>IE9-specific content<![endif]-->`, this method will receive '[[if IE 9]>IE9-specific content<![endif]'.

**HTMLParser**. `handle_decl(decl)`

This method is called to handle an HTML doctype declaration (e.g. `<!DOCTYPE html>`).

The `decl` parameter will be the entire contents of the declaration inside the `<!...>` markup (e.g. 'DOCTYPE html').

**HTMLParser**. `handle_pi(data)`

Method called when a processing instruction is encountered. The `data` parameter will contain the entire processing instruction. For example, for the processing instruction `<?proc color='red'>`, this method would be called as `handle_pi("proc color='red'"">`. It is intended to be overridden by a derived class; the base class implementation does nothing.

**Note:** The `HTMLParser` class uses the SGML syntactic rules for processing instructions. An XHTML processing instruction using the trailing '?' will cause the '?' to be included in `data`.

**HTMLParser**. `unknown_decl(data)`

This method is called when an unrecognized declaration is read by the parser.

The `data` parameter will be the entire contents of the declaration inside the `<![...]>` markup. It is sometimes useful to be overridden by a derived class. The base class implementation does nothing.
20.2.3. Examples

The following class implements a parser that will be used to illustrate more examples:

```python
from html.parser import HTMLParser
from html.entities import name2codepoint

class MyHTMLParser(HTMLParser):
    def handle_starttag(self, tag, attrs):
        print("Start tag:", tag)
        for attr in attrs:
            print("attr:", attr)
    def handle_endtag(self, tag):
        print("End tag:", tag)
    def handle_data(self, data):
        print(\"Data:", data)
    def handle_comment(self, data):
        print(\"Comment:", data)
    def handle_entityref(self, name):
        c = chr(name2codepoint[name])
        print("Named ent:", c)
    def handle_charref(self, name):
        if name.startswith('x'):
            c = chr(int(name[1:], 16))
        else:
            c = chr(int(name))
        print("Num ent:", c)
    def handle_decl(self, data):
        print("Decl:", data)

parser = MyHTMLParser()
```

Parsing a doctype:
Decl : DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01//EN"
  "http://www.w3.org/TR/html4/strict.dtd"

Parsing an element with a few attributes and a title:

```python
>>> parser.feed('<img src="python-logo.png" alt="The Python logo">')
Start tag: img
  attr: ('src', 'python-logo.png')
  attr: ('alt', 'The Python logo')
```

```python
>>> parser.feed('<h1>Python</h1>')
Start tag: h1
Data : Python
End tag : h1
```

The content of script and style elements is returned as is, without further parsing:

```python
>>> parser.feed('<style type="text/css">#python { color: green }</style>')
Start tag: style
  attr: ('type', 'text/css')
Data : #python { color: green }
End tag : style
```

```python
>>> parser.feed('<script type="text/javascript">alert("<strong>hello!</strong>"};</script>')
Start tag: script
  attr: ('type', 'text/javascript')
Data : alert("<strong>hello!</strong>"};
End tag : script
```

Parsing comments:
Parsing named and numeric character references and converting them to the correct char (note: these 3 references are all equivalent to '>):

```python
>>> parser.feed('&gt;&amp;#62;&amp;#x3E;')
Named ent: >
Num ent : >
```

Feeding incomplete chunks to `feed()` works, but `handle_data()` might be called more than once (unless `convert_charrefs` is set to `True`):

```python
>>> for chunk in ['<sp', 'an>buff', 'ered ', 'text</s', ...
    parser.feed(chunk)
...
Start tag: span
Data : buff
Data : ered
Data : text
End tag : span
```

Parsing invalid HTML (e.g. unquoted attributes) also works:

```python
>>> parser.feed('<p><a class=link href=#main>tag soup
Start tag: p
Start tag: a
    attr: ('class', 'link')
    attr: ('href', '#main')
Data : tag soup
```
20.3. html.entities — Definitions of HTML general entities

Source code: Lib/html/entities.py

This module defines four dictionaries, html5, name2codepoint, codepoint2name, and entitydefs.

html.entities.html5
A dictionary that maps HTML5 named character references [1] to
the equivalent Unicode character(s), e.g. html5['gt;'] == '>'. Note that the trailing semicolon is included in the name (e.g. 'gt;'), however some of the names are accepted by the standard even without the semicolon: in this case the name is present with
and without the ';'. See also html.unescape().

New in version 3.3.

html.entities.entitydefs
A dictionary mapping XHTML 1.0 entity definitions to their
replacement text in ISO Latin-1.

html.entities.name2codepoint
A dictionary that maps HTML entity names to the Unicode code
points.

html.entities.codepoint2name
A dictionary that maps Unicode code points to HTML entity names.
Footnotes

20.4. XML Processing Modules

Python’s interfaces for processing XML are grouped in the xml package.

**Warning:** The XML modules are not secure against erroneous or maliciously constructed data. If you need to parse untrusted or unauthenticated data see the XML vulnerabilities and The defusedxml and defusedexpat Packages sections.

It is important to note that modules in the xml package require that there be at least one SAX-compliant XML parser available. The Expat parser is included with Python, so the xml.parsers.expat module will always be available.

The documentation for the xml.dom and xml.sax packages are the definition of the Python bindings for the DOM and SAX interfaces.

The XML handling submodules are:

- `xml.etree.ElementTree`: the ElementTree API, a simple and lightweight XML processor
- `xml.dom`: the DOM API definition
- `xml.dom.minidom`: a minimal DOM implementation
- `xml.dom.pulldom`: support for building partial DOM trees
- `xml.sax`: SAX2 base classes and convenience functions
- `xml.parsers.expat`: the Expat parser binding
20.4.1. XML vulnerabilities

The XML processing modules are not secure against maliciously constructed data. An attacker can abuse XML features to carry out denial of service attacks, access local files, generate network connections to other machines, or circumvent firewalls.

The following table gives an overview of the known attacks and whether the various modules are vulnerable to them.

<table>
<thead>
<tr>
<th>kind</th>
<th>sax</th>
<th>etree</th>
<th>minidom</th>
<th>pulldom</th>
<th>xmlrpc</th>
</tr>
</thead>
<tbody>
<tr>
<td>billion laughs</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>quadratic blowup</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>external entity expansion</td>
<td>Yes</td>
<td>No (1)</td>
<td>No (2)</td>
<td>Yes</td>
<td>No (3)</td>
</tr>
<tr>
<td>DTD retrieval</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>decompression bomb</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

1. `xml.etree.ElementTree` doesn't expand external entities and raises a `ParserError` when an entity occurs.
2. `xml.dom.minidom` doesn't expand external entities and simply returns the unexpanded entity verbatim.
3. `xmlrpc` doesn't expand external entities and omits them.

billion laughs / exponential entity expansion

The Billion Laughs attack – also known as exponential entity expansion – uses multiple levels of nested entities. Each entity refers to another entity several times, and the final entity definition contains a small string. The exponential expansion results in several gigabytes of text and consumes lots of memory and CPU
quadratic blowup entity expansion

A quadratic blowup attack is similar to a Billion Laughs attack; it abuses entity expansion, too. Instead of nested entities it repeats one large entity with a couple of thousand chars over and over again. The attack isn’t as efficient as the exponential case but it avoids triggering parser countermeasures that forbid deeply-nested entities.

decompression bomb

Decompression bombs (aka ZIP bomb) apply to all XML libraries that can parse compressed XML streams such as gzipped HTTP streams or LZMA-compressed files. For an attacker it can reduce the amount of transmitted data by three magnitudes or more.

The documentation for defusedxml on PyPI has further information about all known attack vectors with examples and references.
20.4.2. The defusedxml and defusedexpat Packages

defusedxml is a pure Python package with modified subclasses of all stdlib XML parsers that prevent any potentially malicious operation. Use of this package is recommended for any server code that parses untrusted XML data. The package also ships with example exploits and extended documentation on more XML exploits such as XPath injection.

defusedexpat provides a modified libexpat and a patched pyexpat module that have countermeasures against entity expansion DoS attacks. The defusedexpat module still allows a sane and configurable amount of entity expansions. The modifications may be included in some future release of Python, but will not be included in any bugfix releases of Python because they break backward compatibility.
20.5. `xml.etree.ElementTree` — The ElementTree XML API

The `xml.etree.ElementTree` module implements a simple and efficient API for parsing and creating XML data.

*Changed in version 3.3:* This module will use a fast implementation whenever available. The `xml.etree.cElementTree` module is deprecated.

**Warning:** The `xml.etree.ElementTree` module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see XML vulnerabilities.
20.5.1. Tutorial

This is a short tutorial for using `xml.etree.ElementTree` (ET in short). The goal is to demonstrate some of the building blocks and basic concepts of the module.

20.5.1.1. XML tree and elements

XML is an inherently hierarchical data format, and the most natural way to represent it is with a tree. ET has two classes for this purpose - `ElementTree` represents the whole XML document as a tree, and `Element` represents a single node in this tree. Interactions with the whole document (reading and writing to/from files) are usually done on the `ElementTree` level. Interactions with a single XML element and its sub-elements are done on the `Element` level.

20.5.1.2. Parsing XML

We'll be using the following XML document as the sample data for this section:

```xml
<?xml version="1.0"?>
<data>
  <country name="Liechtenstein">
    <rank>1</rank>
    <year>2008</year>
    <gdppc>141100</gdppc>
    <neighbor name="Austria" direction="E"/>
    <neighbor name="Switzerland" direction="W"/>
  </country>
  <country name="Singapore">
    <rank>4</rank>
  </country>
</data>
```
We can import this data by reading from a file:

```python
import xml.etree.ElementTree as ET
tree = ET.parse('country_data.xml')
root = tree.getroot()
```

Or directly from a string:

```python
root = ET.fromstring(country_data_as_string)
```

`fromstring()` parses XML from a string directly into an `Element`, which is the root element of the parsed tree. Other parsing functions may create an `ElementTree`. Check the documentation to be sure.

As an `Element`, `root` has a tag and a dictionary of attributes:

```python
>>> root.tag
'data'
>>> root.attrib
{}
```

It also has children nodes over which we can iterate:
Children are nested, and we can access specific child nodes by index:

```python
>>> root[0][1].text
'2008'
```

**Note:** Not all elements of the XML input will end up as elements of the parsed tree. Currently, this module skips over any XML comments, processing instructions, and document type declarations in the input. Nevertheless, trees built using this module's API rather than parsing from XML text can have comments and processing instructions in them; they will be included when generating XML output. A document type declaration may be accessed by passing a custom `TreeBuilder` instance to the `XMLParser` constructor.

### 20.5.1.3. Pull API for non-blocking parsing

Most parsing functions provided by this module require the whole document to be read at once before returning any result. It is possible to use an `XMLParser` and feed data into it incrementally, but it is a push API that calls methods on a callback target, which is too low-level and inconvenient for most needs. Sometimes what the user really wants is to be able to parse XML incrementally, without blocking operations, while enjoying the convenience of fully constructed `Element` objects.
The most powerful tool for doing this is **XMLPullParser**. It does not require a blocking read to obtain the XML data, and is instead fed with data incrementally with **XMLPullParser.feed()** calls. To get the parsed XML elements, call **XMLPullParser.read_events()**. Here is an example:

```python
>>> parser = ET.XMLPullParser(['start', 'end'])
>>> parser.feed('<mytag>sometext')</n
>>> list(parser.read_events())
[('start', <Element 'mytag' at 0x7fa66db2be58>)]

>>> parser.feed(' more text</mytag>')

>>> for event, elem in parser.read_events():
...     print(event)
...     print(elem.tag, 'text=' , elem.text)
...     end
```

The obvious use case is applications that operate in a non-blocking fashion where the XML data is being received from a socket or read incrementally from some storage device. In such cases, blocking reads are unacceptable.

Because it's so flexible, **XMLPullParser** can be inconvenient to use for simpler use-cases. If you don’t mind your application blocking on reading XML data but would still like to have incremental parsing capabilities, take a look at **iterparse()**. It can be useful when you're reading a large XML document and don’t want to hold it wholly in memory.

### 20.5.1.4. Finding interesting elements

**Element** has some useful methods that help iterate recursively over all the sub-tree below it (its children, their children, and so on). For
example, `Element.iter()`:

```python
>>> for neighbor in root.iter('neighbor):
...   print(neighbor.attrib)
...
{'name': 'Austria', 'direction': 'E'}
{'name': 'Switzerland', 'direction': 'W'}
{'name': 'Malaysia', 'direction': 'N'}
{'name': 'Costa Rica', 'direction': 'W'}
{'name': 'Colombia', 'direction': 'E'}
```

`Element.findall()` finds only elements with a tag which are direct children of the current element. `Element.find()` finds the first child with a particular tag, and `Element.text` accesses the element's text content. `Element.get()` accesses the element's attributes:

```python
>>> for country in root.findall('country'):
...   rank = country.find('rank').text
...   name = country.get('name')
...   print(name, rank)
...
Liechtenstein 1
Singapore 4
Panama 68
```

More sophisticated specification of which elements to look for is possible by using XPath.

20.5.1.5. Modifying an XML File

`ElementTree` provides a simple way to build XML documents and write them to files. The `ElementTree.write()` method serves this purpose.
Once created, an `Element` object may be manipulated by directly changing its fields (such as `Element.text`), adding and modifying attributes (`Element.set()` method), as well as adding new children (for example with `Element.append()`).

Let's say we want to add one to each country's rank, and add an updated attribute to the rank element:

```python
>>> for rank in root.iter('rank):
...    new_rank = int(rank.text) + 1
...    rank.text = str(new_rank)
...    rank.set('updated', 'yes')
...
>>> tree.write('output.xml')
```

Our XML now looks like this:

```xml
<?xml version="1.0"?>
<data>
  <country name="Liechtenstein">
    <rank updated="yes">2</rank>
    <year>2008</year>
    <gdppc>141100</gdppc>
    <neighbor name="Austria" direction="E"/>
    <neighbor name="Switzerland" direction="W"/>
  </country>
  <country name="Singapore">
    <rank updated="yes">5</rank>
    <year>2011</year>
    <gdppc>59900</gdppc>
    <neighbor name="Malaysia" direction="N"/>
  </country>
  <country name="Panama">
    <rank updated="yes">69</rank>
    <year>2011</year>
  </country>
</data>
```
We can remove elements using `Element.remove()`. Let’s say we want to remove all countries with a rank higher than 50:

```python
gdpcc = 13600
<neighbor name="Costa Rica" direction="W"/>
<neighbor name="Colombia" direction="E"/>
</country>
</data>
```  

```python
for country in root.findall('country'):
    rank = int(country.find('rank').text)
    if rank > 50:
        root.remove(country)
```  

```python
>>> tree.write('output.xml')
```

Our XML now looks like this:

```xml
<?xml version="1.0"?>
<data>
    <country name="Liechtenstein">
        <rank updated="yes">2</rank>
        <year>2008</year>
        <gdppc>141100</gdppc>
        <neighbor name="Austria" direction="E"/>
        <neighbor name="Switzerland" direction="W"/>
    </country>
    <country name="Singapore">
        <rank updated="yes">5</rank>
        <year>2011</year>
        <gdppc>59900</gdppc>
        <neighbor name="Malaysia" direction="N"/>
    </country>
</data>
```
20.5.1.6. Building XML documents

The SubElement() function also provides a convenient way to create new sub-elements for a given element:

```python
>>> a = ET.Element('a')
>>> b = ET.SubElement(a, 'b')
>>> c = ET.SubElement(a, 'c')
>>> d = ET.SubElement(c, 'd')
>>> ET.dump(a)
<a><b /></c><d /></a>
```

20.5.1.7. Parsing XML with Namespaces

If the XML input has namespaces, tags and attributes with prefixes in the form prefix:sometag get expanded to {uri}sometag where the prefix is replaced by the full URI. Also, if there is a default namespace, that full URI gets prepended to all of the non-prefixed tags.

Here is an XML example that incorporates two namespaces, one with the prefix “fictional” and the other serving as the default namespace:

```xml
<?xml version="1.0"?>
<actors xmlns:fictional="http://characters.example.com"
       xmlns="http://people.example.com">
  <actor>
    <name>John Cleese</name>
    <fictional:character>Lancelot</fictional:character>
    <fictional:character>Archie Leach</fictional:character>
  </actor>
  <actor>
    <name>Eric Idle</name>
    <fictional:character>Sir Robin</fictional:character>
  </actor>
</actors>
```
One way to search and explore this XML example is to manually add the URI to every tag or attribute in the xpath of a find() or findall():

```python
root = fromstring(xml_text)
for actor in root.findall('{http://people.example.com}actor'):
    name = actor.find('{http://people.example.com}name').text
    print(name)
    for char in actor.findall('{http://characters.example.com}character'):
        print('  |-->', char.text)
```

A better way to search the namespaced XML example is to create a dictionary with your own prefixes and use those in the search functions:

```python
ns = {'real_person': 'http://people.example.com',
      'role': 'http://characters.example.com'}

for actor in root.findall('real_person:actor', ns):
    name = actor.find('real_person:name', ns).text
    print(name)
    for char in actor.findall('role:character', ns):
        print('  |-->', char.text)
```

These two approaches both output:

```
John Cleese
  |--> Lancelot
```
20.5.1.8. Additional resources

See http://effbot.org/zone/element-index.htm for tutorials and links to other docs.
20.5.2. XPath support

This module provides limited support for XPath expressions for locating elements in a tree. The goal is to support a small subset of the abbreviated syntax; a full XPath engine is outside the scope of the module.

20.5.2.1. Example

Here's an example that demonstrates some of the XPath capabilities of the module. We'll be using the countrydata XML document from the Parsing XML section:

```python
import xml.etree.ElementTree as ET

root = ET.fromstring(countrydata)

# Top-level elements
root.findall(".")

# All 'neighbor' grand-children of 'country' children elements
root.findall("./country/neighbor")

# Nodes with name='Singapore' that have a 'year' child
root.findall("./year/..[@name='Singapore']")

# 'year' nodes that are children of nodes with name='Singapore'
root.findall("./*[@name='Singapore']/year")

# All 'neighbor' nodes that are the second child of
root.findall("./neighbor[2]")
```
20.5.2.2. Supported XPath syntax

<table>
<thead>
<tr>
<th>Syntax</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>tag</code></td>
<td>Selects all child elements with the given tag. For example, spam selects all child elements named spam, and spam/egg selects all grandchildren named egg in all children named spam.</td>
</tr>
<tr>
<td><code>*</code></td>
<td>Selects all child elements. For example, */egg selects all grandchildren named egg.</td>
</tr>
<tr>
<td><code>.</code></td>
<td>Selects the current node. This is mostly useful at the beginning of the path, to indicate that it’s a relative path.</td>
</tr>
<tr>
<td><code>//</code></td>
<td>Selects all subelements, on all levels beneath the current element. For example, .//egg selects all egg elements in the entire tree.</td>
</tr>
<tr>
<td><code>..</code></td>
<td>Selects the parent element. Returns None if the path attempts to reach the ancestors of the start element (the element <code>find</code> was called on).</td>
</tr>
<tr>
<td><code>[@attrib]</code></td>
<td>Selects all elements that have the given attribute.</td>
</tr>
<tr>
<td><code>[@attrib='value']</code></td>
<td>Selects all elements for which the given attribute has the given value. The value cannot contain quotes.</td>
</tr>
<tr>
<td><code>[tag]</code></td>
<td>Selects all elements that have a child named tag. Only immediate children are supported.</td>
</tr>
<tr>
<td><code>[tag='text']</code></td>
<td>Selects all elements that have a child named tag whose complete text content,</td>
</tr>
</tbody>
</table>
including descendants, equals the given text.

| position | Selects all elements that are located at the given position. The position can be either an integer (1 is the first position), the expression last() (for the last position), or a position relative to the last position (e.g. last()-1). |

Predicates (expressions within square brackets) must be preceded by a tag name, an asterisk, or another predicate. position predicates must be preceded by a tag name.
20.5.3. Reference

20.5.3.1. Functions

```python
xml.etree.ElementTree.Comment(text=None)
```

Comment element factory. This factory function creates a special element that will be serialized as an XML comment by the standard serializer. The comment string can be either a bytestring or a Unicode string. `text` is a string containing the comment string. Returns an element instance representing a comment.

Note that `XMLParser` skips over comments in the input instead of creating comment objects for them. An `ElementTree` will only contain comment nodes if they have been inserted into the tree using one of the `Element` methods.

```python
xml.etree.ElementTree.dump(elem)
```

Writes an element tree or element structure to `sys.stdout`. This function should be used for debugging only.

The exact output format is implementation dependent. In this version, it’s written as an ordinary XML file.

`elem` is an element tree or an individual element.

```python
xml.etree.ElementTree.fromstring(text)
```

Parses an XML section from a string constant. Same as `XML()`. `text` is a string containing XML data. Returns an `Element` instance.

```python
xml.etree.ElementTree.fromstringlist(sequence, parser=None)
```

Parses an XML document from a sequence of string fragments.
**sequence** is a list or other sequence containing XML data fragments. **parser** is an optional parser instance. If not given, the standard **XMLParser** parser is used. Returns an **Element** instance.

*New in version 3.2.*

**xml.etree.ElementTree.iselement(element)**

Checks if an object appears to be a valid element object. **element** is an element instance. Returns a true value if this is an element object.

**xml.etree.ElementTree.iterparse(source, events=None, parser=None)**

Parses an XML section into an element tree incrementally, and reports what’s going on to the user. **source** is a filename or file object containing XML data. **events** is a sequence of events to report back. The supported events are the strings "start", "end", "start-ns" and "end-ns" (the “ns” events are used to get detailed namespace information). If **events** is omitted, only "end" events are reported. **parser** is an optional parser instance. If not given, the standard **XMLParser** parser is used. **parser** must be a subclass of **XMLParser** and can only use the default **TreeBuilder** as a target. Returns an iterator providing (event, elem) pairs.

Note that while **iterparse()** builds the tree incrementally, it issues blocking reads on **source** (or the file it names). As such, it's unsuitable for applications where blocking reads can’t be made. For fully non-blocking parsing, see **XMLPullParser**.

**Note:** **iterparse()** only guarantees that it has seen the “>”
character of a starting tag when it emits a “start” event, so the attributes are defined, but the contents of the text and tail attributes are undefined at that point. The same applies to the element children; they may or may not be present.
If you need a fully populated element, look for “end” events instead.

*Deprecated since version 3.4:* The `parser` argument.

```python
xml.etree.ElementTree.parse(source, parser=None)
```

Parses an XML section into an element tree. `source` is a filename or file object containing XML data. `parser` is an optional parser instance. If not given, the standard `XMLParser` parser is used. Returns an `ElementTree` instance.

```python
xml.etree.ElementTree.ProcessingInstruction(target, text=None)
```

PI element factory. This factory function creates a special element that will be serialized as an XML processing instruction. `target` is a string containing the PI target. `text` is a string containing the PI contents, if given. Returns an element instance, representing a processing instruction.

Note that `XMLParser` skips over processing instructions in the input instead of creating comment objects for them. An `ElementTree` will only contain processing instruction nodes if they have been inserted into the tree using one of the `Element` methods.

```python
xml.etree.ElementTree.register_namespace(prefix, uri)
```

Registers a namespace prefix. The registry is global, and any existing mapping for either the given prefix or the namespace URI
will be removed. *prefix* is a namespace prefix. *uri* is a namespace uri. Tags and attributes in this namespace will be serialized with the given prefix, if at all possible.

*New in version 3.2.*

```python
xml.etree.ElementTree.SubElement(parent, tag, attrib={}, **extra)
```

Subelement factory. This function creates an element instance, and appends it to an existing element.

The element name, attribute names, and attribute values can be either bytestrings or Unicode strings. *parent* is the parent element. *tag* is the subelement name. *attrib* is an optional dictionary, containing element attributes. *extra* contains additional attributes, given as keyword arguments. Returns an element instance.

```python
xml.etree.ElementTree.tostring(element, encoding="us-ascii", method="xml", *, short_empty_elements=True)
```

Generates a string representation of an XML element, including all subelements. *element* is an *Element* instance. *encoding* [1] is the output encoding (default is US-ASCII). Use encoding="unicode" to generate a Unicode string (otherwise, a bytestring is generated). *method* is either "xml", "html" or "text" (default is "xml"). *short_empty_elements* has the same meaning as in `ElementTree.write()`. Returns an (optionally) encoded string containing the XML data.

*New in version 3.4: The short_empty_elements parameter.*

```python
xml.etree.ElementTree.tostringlist(element, encoding="us-ascii", method="xml", *, short_empty_elements=True)
```

Generates a string representation of an XML element, including all
subelements. *element* is an *Element* instance. *encoding [1]* is the output encoding (default is US-ASCII). Use encoding="unicode" to generate a Unicode string (otherwise, a bytestring is generated). *method* is either "xml", "html" or "text" (default is "xml"). *short_empty_elements* has the same meaning as in ElementTree.write(). Returns a list of (optionally) encoded strings containing the XML data. It does not guarantee any specific sequence, except that \[ b"".join(tostringlist(element)) \] == tostring(element).

*New in version 3.2.*

*New in version 3.4:* The *short_empty_elements* parameter.

```python
xml.etree.ElementTree.XML(text, parser=None)
```

Parses an XML section from a string constant. This function can be used to embed “XML literals” in Python code. *text* is a string containing XML data. *parser* is an optional parser instance. If not given, the standard *XMLParser* parser is used. Returns an *Element* instance.

```python
xml.etree.ElementTree.XMLID(text, parser=None)
```

Parses an XML section from a string constant, and also returns a dictionary which maps from element id:s to elements. *text* is a string containing XML data. *parser* is an optional parser instance. If not given, the standard *XMLParser* parser is used. Returns a tuple containing an *Element* instance and a dictionary.

### 20.5.3.2. Element Objects

```python
class xml.etree.ElementTree.Element(tag, attrib={}, **extra)
```
Element class. This class defines the Element interface, and provides a reference implementation of this interface.

The element name, attribute names, and attribute values can be either bytestrings or Unicode strings. `tag` is the element name. `attrib` is an optional dictionary, containing element attributes. `extra` contains additional attributes, given as keyword arguments.

**tag**

A string identifying what kind of data this element represents (the element type, in other words).

**text**

**tail**

These attributes can be used to hold additional data associated with the element. Their values are usually strings but may be any application-specific object. If the element is created from an XML file, the `text` attribute holds either the text between the element’s start tag and its first child or end tag, or None, and the `tail` attribute holds either the text between the element’s end tag and the next tag, or None. For the XML data

```xml
<a><b>1</c>2<d/></b>3</c></b>4</a>
```

the `a` element has None for both `text` and `tail` attributes, the `b` element has text "1" and tail "4", the `c` element has text "2" and tail None, and the `d` element has text None and tail "3".

To collect the inner text of an element, see `itertext()`, for example "".join(element.itertext()).

Applications may store arbitrary objects in these attributes.
**attrib**

A dictionary containing the element’s attributes. Note that while the *attrib* value is always a real mutable Python dictionary, an ElementTree implementation may choose to use another internal representation, and create the dictionary only if someone asks for it. To take advantage of such implementations, use the dictionary methods below whenever possible.

The following dictionary-like methods work on the element attributes.

**clear()**

Resets an element. This function removes all subelements, clears all attributes, and sets the text and tail attributes to None.

**get(key, default=None)**

Gets the element attribute named *key*.

Returns the attribute value, or *default* if the attribute was not found.

**items()**

Returns the element attributes as a sequence of (name, value) pairs. The attributes are returned in an arbitrary order.

**keys()**

Returns the elements attribute names as a list. The names are returned in an arbitrary order.

**set(key, value)**

Set the attribute *key* on the element to *value*. 
The following methods work on the element’s children (subelements).

**append**(subelement)
Adds the element `subelement` to the end of this element’s internal list of subelements. Raises `TypeError` if `subelement` is not an `Element`.

**extend**(subelements)
Appends `subelements` from a sequence object with zero or more elements. Raises `TypeError` if a subelement is not an `Element`.

*New in version 3.2.*

**find**(match, namespaces=None)
Finds the first subelement matching `match`. `match` may be a tag name or a path. Returns an element instance or None. `namespaces` is an optional mapping from namespace prefix to full name.

**findall**(match, namespaces=None)
Finds all matching subelements, by tag name or path. Returns a list containing all matching elements in document order. `namespaces` is an optional mapping from namespace prefix to full name.

**findtext**(match, default=None, namespaces=None)
Finds text for the first subelement matching `match`. `match` may be a tag name or a path. Returns the text content of the first matching element, or `default` if no element was found. Note that if the matching element has no text content an empty string is
returned. *namespaces* is an optional mapping from namespace prefix to full name.

**getchildren()**

*Deprecated since version 3.2: Use list(elem) or iteration.*

**getiterator**(tag=None)

*Deprecated since version 3.2: Use method `Element.iter()` instead.*

**insert**(index, subelement)

Inserts *subelement* at the given position in this element. Raises *TypeError* if *subelement* is not an *Element*.

**iter**(tag=None)

Creates a tree *iterator* with the current element as the root. The iterator iterates over this element and all elements below it, in document (depth first) order. If *tag* is not None or '*' , only elements whose tag equals *tag* are returned from the iterator. If the tree structure is modified during iteration, the result is undefined.

*New in version 3.2.*

**iterfind**(match, namespaces=None)

Finds all matching subelements, by tag name or *path*. Returns an iterable yielding all matching elements in document order. *namespaces* is an optional mapping from namespace prefix to full name.

*New in version 3.2.*

**itertext()**
Creates a text iterator. The iterator loops over this element and all subelements, in document order, and returns all inner text.

*New in version 3.2.*

**makeelement**(tag, attrib)

Creates a new element object of the same type as this element. Do not call this method, use the `SubElement()` factory function instead.

**remove**(subelement)

Removes `subelement` from the element. Unlike the find* methods this method compares elements based on the instance identity, not on tag value or contents.

Element objects also support the following sequence type methods for working with subelements: `__delitem__()`, `__getitem__()`, `__setitem__()`, `__len__()`. Caution: Elements with no subelements will test as False. This behavior will change in future versions. Use specific `len(elem)` or `elem is None` test instead.

```python
element = root.find('foo')

if not element: # careful!
    print("element not found, or element has no subelements")

if element is None:
    print("element not found")
```

20.5.3.3. ElementTree Objects
class xml.etree.ElementTree.ElementTree(element=None, file=None)

ElementTree wrapper class. This class represents an entire element hierarchy, and adds some extra support for serialization to and from standard XML.

_element_ is the root element. The tree is initialized with the contents of the XML _file_ if given.

_setroot(element)_

Replaces the root element for this tree. This discards the current contents of the tree, and replaces it with the given element. Use with care. _element_ is an element instance.

_find(match, namespaces=None)_

Same as Element.find(), starting at the root of the tree.

_findall(match, namespaces=None)_

Same as Element.findall(), starting at the root of the tree.

_findtext(match, default=None, namespaces=None)_

Same as Element.findtext(), starting at the root of the tree.

_getiterator(tag=None)_

Deprecated since version 3.2: Use method ElementTree.iter() instead.

_getroot()_

Returns the root element for this tree.

_iter(tag=None)_

Creates and returns a tree iterator for the root element. The
iterator loops over all elements in this tree, in section order. tag is the tag to look for (default is to return all elements).

**iterfind**(match, namespaces=None)

Same as `Element.iterfind()`, starting at the root of the tree.

*New in version 3.2.*

**parse**(source, parser=None)

Loads an external XML section into this element tree. source is a file name or file object. parser is an optional parser instance. If not given, the standard `XMLParser` parser is used. Returns the section root element.

**write**(file, encoding="us-ascii", xml_declaration=None, default_namespace=None, method="xml", *, short_empty_elements=True)

Writes the element tree to a file, as XML. file is a file name, or a file object opened for writing. encoding [1] is the output encoding (default is US-ASCII). xml_declaration controls if an XML declaration should be added to the file. Use False for never, True for always, None for only if not US-ASCII or UTF-8 or Unicode (default is None). default_namespace sets the default XML namespace (for “xmlns”). method is either "xml", "html" or "text" (default is "xml"). The keyword-only short_empty_elements parameter controls the formatting of elements that contain no content. If True (the default), they are emitted as a single self-closed tag, otherwise they are emitted as a pair of start/end tags.

The output is either a string (str) or binary (bytes). This is
controlled by the *encoding* argument. If *encoding* is "unicode", the output is a string; otherwise, it's binary. Note that this may conflict with the type of *file* if it's an open *file object*; make sure you do not try to write a string to a binary stream and vice versa.

*New in version 3.4:* The *short_empty_elements* parameter.

This is the XML file that is going to be manipulated:

```xml
<html>
<head>
    <title>Example page</title>
</head>
<body>
    <p>Moved to <a href="http://example.org/">example</a> or <a href="http://example.com/">example.com</a></p>
</body>
</html>
```

Example of changing the attribute “target” of every link in first paragraph:

```python
>>> from xml.etree.ElementTree import ElementTree
>>> tree = ElementTree()
>>> tree.parse("index.xhtml")
<Element 'html' at 0xb77e6fac>
>>> p = tree.find("body/p")  # Finds first occurrence
>>> p
<Element 'p' at 0xb77ec26c>
>>> links = list(p.iter("a"))  # Returns list of all
>>> links
[<Element 'a' at 0xb77ec2ac>, <Element 'a' at 0xb77ed70>]
>>> for i in links:  # Iterates through all
...    i.attrib["target"] = "blank"
```
20.5.3.4. QName Objects

class xml.etree.ElementTree.QName(text_or_uri, tag=None)
    QName wrapper. This can be used to wrap a QName attribute value, in order to get proper namespace handling on output. text_or_uri is a string containing the QName value, in the form {uri}local, or, if the tag argument is given, the URI part of a QName. If tag is given, the first argument is interpreted as an URI, and this argument is interpreted as a local name. QName instances are opaque.

20.5.3.5. TreeBuilder Objects

class xml.etree.ElementTree.TreeBuilder(element_factory=None)
    Generic element structure builder. This builder converts a sequence of start, data, and end method calls to a well-formed element structure. You can use this class to build an element structure using a custom XML parser, or a parser for some other XML-like format. element_factory, when given, must be a callable accepting two positional arguments: a tag and a dict of attributes. It is expected to return a new element instance.

    close()
        Flushes the builder buffers, and returns the toplevel document element. Returns an Element instance.

    data(data)
        Adds text to the current element. data is a string. This should be
either a bytestring, or a Unicode string.

**end**(*tag*)

Closes the current element. *tag* is the element name. Returns the closed element.

**start**(*tag, attrs*)

Opens a new element. *tag* is the element name. *attrs* is a dictionary containing element attributes. Returns the opened element.

In addition, a custom `TreeBuilder` object can provide the following method:

**doctype**(*name, pubid, system*)

Handles a doctype declaration. *name* is the doctype name. *pubid* is the public identifier. *system* is the system identifier. This method does not exist on the default `TreeBuilder` class.

*New in version 3.2.*

### 20.5.3.6. XMLParser Objects

```python
class xml.etree.ElementTree.XMLParser(*html=0, target=None, encoding=None*)
```

This class is the low-level building block of the module. It uses `xml.parsers.expat` for efficient, event-based parsing of XML. It can be fed XML data incrementall with the `feed()` method, and parsing events are translated to a push API - by invoking callbacks on the `target` object. If `target` is omitted, the standard `TreeBuilder` is used. The `html` argument was historically used for backwards compatibility and is now deprecated. If `encoding` [1]
is given, the value overrides the encoding specified in the XML file.

*Deprecated since version 3.4:* The `html` argument. The remaining arguments should be passed via keyword to prepare for the removal of the `html` argument.

**close()**

Finishes feeding data to the parser. Returns the result of calling the `close()` method of the `target` passed during construction; by default, this is the toplevel document element.

**doctype**(name, `pubid`, `system`)

*Deprecated since version 3.2:* Define the `TreeBuilder.doctype()` method on a custom `TreeBuilder` target.

**feed**(data)

Feeds data to the parser. `data` is encoded data.

`XMLParser.feed()` calls `target`'s `start(tag, attrs_dict)` method for each opening tag, its `end(tag)` method for each closing tag, and data is processed by method `data(data)`. `XMLParser.close()` calls `target`'s method `close()`. `XMLParser` can be used not only for building a tree structure. This is an example of counting the maximum depth of an XML file:

```python
>>> from xml.etree.ElementTree import XMLParser

```
20.5.3.7. XMLPullParser Objects

class
xml.etree.ElementTree.XMLPullParser(events=None)

A pull parser suitable for non-blocking applications. Its input-side
API is similar to that of XMLParser, but instead of pushing calls to
a callback target, XMLPullParser collects an internal list of
parsing events and lets the user read from it. events is a sequence
of events to report back. The supported events are the strings
"start", "end", "start-ns" and "end-ns" (the "ns" events are used to get detailed namespace information). If events is omitted, only "end" events are reported.

**feed**(*data*)

Feed the given bytes data to the parser.

**close**()

Signal the parser that the data stream is terminated. Unlike `XMLParser.close()`, this method always returns `None`. Any events not yet retrieved when the parser is closed can still be read with `read_events()`.

**read_events**()

Return an iterator over the events which have been encountered in the data fed to the parser. The iterator yields (event, elem) pairs, where event is a string representing the type of event (e.g. "end") and elem is the encountered `Element` object.

Events provided in a previous call to `read_events()` will not be yielded again. Events are consumed from the internal queue only when they are retrieved from the iterator, so multiple readers iterating in parallel over iterators obtained from `read_events()` will have unpredictable results.

**Note:** `XMLPullParser` only guarantees that it has seen the “>” character of a starting tag when it emits a “start” event, so the attributes are defined, but the contents of the text and tail attributes are undefined at that point. The same applies to the element children; they may or may not be present. If you need a fully populated element, look for “end” events
New in version 3.4.

20.5.3.8. Exceptions

class xml.etree.ElementTree.ParseError
XML parse error, raised by the various parsing methods in this module when parsing fails. The string representation of an instance of this exception will contain a user-friendly error message. In addition, it will have the following attributes available:

**code**
A numeric error code from the expat parser. See the documentation of `xml.parsers.expat` for the list of error codes and their meanings.

**position**
A tuple of `line, column` numbers, specifying where the error occurred.

Footnotes

[1] The encoding string included in XML output should conform to the appropriate standards. For example, “UTF-8” is valid, but “UTF8” is not. See [http://www.w3.org/TR/2006/REC-xml11-20060816/#NT-EncodingDecl](http://www.w3.org/TR/2006/REC-xml11-20060816/#NT-EncodingDecl) and [http://www.iana.org/assignments/character-sets/character-sets.xhtml](http://www.iana.org/assignments/character-sets/character-sets.xhtml).
20.6. `xml.dom` — The Document Object Model API

The Document Object Model, or “DOM,” is a cross-language API from the World Wide Web Consortium (W3C) for accessing and modifying XML documents. A DOM implementation presents an XML document as a tree structure, or allows client code to build such a structure from scratch. It then gives access to the structure through a set of objects which provided well-known interfaces.

The DOM is extremely useful for random-access applications. SAX only allows you a view of one bit of the document at a time. If you are looking at one SAX element, you have no access to another. If you are looking at a text node, you have no access to a containing element. When you write a SAX application, you need to keep track of your program’s position in the document somewhere in your own code. SAX does not do it for you. Also, if you need to look ahead in the XML document, you are just out of luck.

Some applications are simply impossible in an event driven model with no access to a tree. Of course you could build some sort of tree yourself in SAX events, but the DOM allows you to avoid writing that code. The DOM is a standard tree representation for XML data.

The Document Object Model is being defined by the W3C in stages, or “levels” in their terminology. The Python mapping of the API is substantially based on the DOM Level 2 recommendation.

DOM applications typically start by parsing some XML into a DOM. How this is accomplished is not covered at all by DOM Level 1, and Level 2 provides only limited improvements: There is a
DOMImplementation object class which provides access to Document creation methods, but no way to access an XML reader/parser/Document builder in an implementation-independent way. There is also no well-defined way to access these methods without an existing Document object. In Python, each DOM implementation will provide a function `getDOMImplementation()`. DOM Level 3 adds a Load/Store specification, which defines an interface to the reader, but this is not yet available in the Python standard library.

Once you have a DOM document object, you can access the parts of your XML document through its properties and methods. These properties are defined in the DOM specification; this portion of the reference manual describes the interpretation of the specification in Python.

The specification provided by the W3C defines the DOM API for Java, ECMAScript, and OMG IDL. The Python mapping defined here is based in large part on the IDL version of the specification, but strict compliance is not required (though implementations are free to support the strict mapping from IDL). See section Conformance for a detailed discussion of mapping requirements.

See also:

**Document Object Model (DOM) Level 2 Specification**
  The W3C recommendation upon which the Python DOM API is based.

**Document Object Model (DOM) Level 1 Specification**
  The W3C recommendation for the DOM supported by `xml.dom.minidom`.

**Python Language Mapping Specification**
This specifies the mapping from OMG IDL to Python.
The `xml.dom` contains the following functions:

`xml.dom.registerDOMImplementation(name, factory)`

Register the `factory` function with the name `name`. The factory function should return an object which implements the DOMImplementation interface. The factory function can return the same object every time, or a new one for each call, as appropriate for the specific implementation (e.g. if that implementation supports some customization).

`xml.dom.getDOMImplementation(name=None, features=())`  
Return a suitable DOM implementation. The `name` is either well-known, the module name of a DOM implementation, or None. If it is not None, imports the corresponding module and returns a DOMImplementation object if the import succeeds. If no name is given, and if the environment variable PYTHON_DOM is set, this variable is used to find the implementation.

If name is not given, this examines the available implementations to find one with the required feature set. If no implementation can be found, raise an `ImportError`. The features list must be a sequence of (feature, version) pairs which are passed to the hasFeature() method on available DOMImplementation objects.

Some convenience constants are also provided:

`xml.dom.EMPTY_NAMESPACE`

The value used to indicate that no namespace is associated with a
node in the DOM. This is typically found as the namespaceURI of a node, or used as the `namespaceURI` parameter to a namespaces-specific method.

```python
xml.dom.XML_NAMESPACE
```

The namespace URI associated with the reserved prefix `xml`, as defined by *Namespaces in XML* (section 4).

```python
xml.dom.XMLNS_NAMESPACE
```

The namespace URI for namespace declarations, as defined by *Document Object Model (DOM) Level 2 Core Specification* (section 1.1.8).

```python
xml.dom.XHTML_NAMESPACE
```

The URI of the XHTML namespace as defined by *XHTML 1.0: The Extensible HyperText Markup Language* (section 3.1.1).

In addition, `xml.dom` contains a base Node class and the DOM exception classes. The Node class provided by this module does not implement any of the methods or attributes defined by the DOM specification; concrete DOM implementations must provide those. The Node class provided as part of this module does provide the constants used for the `nodeType` attribute on concrete Node objects; they are located within the class rather than at the module level to conform with the DOM specifications.
20.6.2. Objects in the DOM

The definitive documentation for the DOM is the DOM specification from the W3C.

Note that DOM attributes may also be manipulated as nodes instead of as simple strings. It is fairly rare that you must do this, however, so this usage is not yet documented.

<table>
<thead>
<tr>
<th>Interface</th>
<th>Section</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOMImplementation</td>
<td>DOMImplementation Objects</td>
<td>Interface to the underlying implementation</td>
</tr>
<tr>
<td>Node</td>
<td>Node Objects</td>
<td>Base interface for most object in a document.</td>
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</tr>
<tr>
<td>------------</td>
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<td>ProcessingInstruction</td>
<td>ProcessingInstruction Objects</td>
<td>Processing instruction representation</td>
</tr>
</tbody>
</table>

An additional section describes the exceptions defined for working with the DOM in Python.

### 20.6.2.1. DOMImplementation Objects

The DOMImplementation interface provides a way for applications to determine the availability of particular features in the DOM they are using. DOM Level 2 added the ability to create new Document and DocumentType objects using the DOMImplementation as well.

**DOMImplementation**. `hasFeature(feature, version)`

Return true if the feature identified by the pair of strings `feature` and `version` is implemented.

**DOMImplementation**. `createDocument(namespaceUri, qualifiedName, doctype)`
Return a new Document object (the root of the DOM), with a child Element object having the given namespaceUri and qualifiedName. The doctype must be a DocumentType object created by createDocumentType(), or None. In the Python DOM API, the first two arguments can also be None in order to indicate that no Element child is to be created.

DOMImplementation.createDocumentType(qualifiedName, publicId, systemId)

Return a new DocumentType object that encapsulates the given qualifiedName, publicId, and systemId strings, representing the information contained in an XML document type declaration.

20.6.2.2. Node Objects

All of the components of an XML document are subclasses of Node.

Node.nodeType

An integer representing the node type. Symbolic constants for the types are on the Node object: ELEMENT_NODE, ATTRIBUTE_NODE, TEXT_NODE, CDATA_SECTION_NODE, ENTITY_NODE, PROCESSING_INSTRUCTION_NODE, COMMENT_NODE, DOCUMENT_NODE, DOCUMENT_TYPE_NODE, NOTATION_NODE. This is a read-only attribute.

Node.parentNode

The parent of the current node, or None for the document node. The value is always a Node object or None. For Element nodes, this will be the parent element, except for the root element, in which case it will be the Document object. For Attr nodes, this is always None. This is a read-only attribute.
Node. **attributes**
A NamedNodeMap of attribute objects. Only elements have actual values for this; others provide None for this attribute. This is a read-only attribute.

Node. **previousSibling**
The node that immediately precedes this one with the same parent. For instance the element with an end-tag that comes just before the self element’s start-tag. Of course, XML documents are made up of more than just elements so the previous sibling could be text, a comment, or something else. If this node is the first child of the parent, this attribute will be None. This is a read-only attribute.

Node. **nextSibling**
The node that immediately follows this one with the same parent. See also previousSibling. If this is the last child of the parent, this attribute will be None. This is a read-only attribute.

Node. **childNodes**
A list of nodes contained within this node. This is a read-only attribute.

Node. **firstChild**
The first child of the node, if there are any, or None. This is a read-only attribute.

Node. **lastChild**
The last child of the node, if there are any, or None. This is a read-only attribute.

Node. **localName**
The part of the tagName following the colon if there is one, else the
entire tagName. The value is a string.

Node.

**prefix**
The part of the tagName preceding the colon if there is one, else the empty string. The value is a string, or None.

Node.

**namespaceURI**
The namespace associated with the element name. This will be a string or None. This is a read-only attribute.

Node.

**nodeName**
This has a different meaning for each node type; see the DOM specification for details. You can always get the information you would get here from another property such as the tagName property for elements or the name property for attributes. For all node types, the value of this attribute will be either a string or None. This is a read-only attribute.

Node.

**nodeValue**
This has a different meaning for each node type; see the DOM specification for details. The situation is similar to that with nodeName. The value is a string or None.

Node.

**hasAttributes()**
Returns true if the node has any attributes.

Node.

**hasChildNodes()**
Returns true if the node has any child nodes.

Node.

**isSameNode**(other)
Returns true if other refers to the same node as this node. This is especially useful for DOM implementations which use any sort of
proxy architecture (because more than one object can refer to the same node).

**Note:** This is based on a proposed DOM Level 3 API which is still in the “working draft” stage, but this particular interface appears uncontroversial. Changes from the W3C will not necessarily affect this method in the Python DOM interface (though any new W3C API for this would also be supported).

Node `.appendChild(newChild)`

Add a new child node to this node at the end of the list of children, returning `newChild`. If the node was already in the tree, it is removed first.

Node `.insertBefore(newChild, refChild)`

Insert a new child node before an existing child. It must be the case that `refChild` is a child of this node; if not, `ValueError` is raised. `newChild` is returned. If `refChild` is None, it inserts `newChild` at the end of the children's list.

Node `.removeChild(oldChild)`

Remove a child node. `oldChild` must be a child of this node; if not, `ValueError` is raised. `oldChild` is returned on success. If `oldChild` will not be used further, its `unlink()` method should be called.

Node `.replaceChild(newChild, oldChild)`

Replace an existing node with a new node. It must be the case that `oldChild` is a child of this node; if not, `ValueError` is raised.

Node `.normalize()`

Join adjacent text nodes so that all stretches of text are stored as single Text instances. This simplifies processing text from a DOM
tree for many applications.

Node.`cloneNode`(deep)
Clone this node. Setting `deep` means to clone all child nodes as well. This returns the clone.

20.6.2.3. NodeList Objects

A NodeList represents a sequence of nodes. These objects are used in two ways in the DOM Core recommendation: the Element objects provides one as its list of child nodes, and the `getElementsByTagName()` and `getElementsByTagNameNS()` methods of Node return objects with this interface to represent query results.

The DOM Level 2 recommendation defines one method and one attribute for these objects:

NodeList.`item(i)`
Return the `i`th item from the sequence, if there is one, or None. The index `i` is not allowed to be less than zero or greater than or equal to the length of the sequence.

NodeList.`length`
The number of nodes in the sequence.

In addition, the Python DOM interface requires that some additional support is provided to allow NodeList objects to be used as Python sequences. All NodeList implementations must include support for `__len__()` and `__getitem__()`; this allows iteration over the NodeList in `for` statements and proper support for the `len()` built-in function.
If a DOM implementation supports modification of the document, the NodeList implementation must also support the `__setitem__()` and `__delitem__()` methods.

### 20.6.2.4. DocumentType Objects

Information about the notations and entities declared by a document (including the external subset if the parser uses it and can provide the information) is available from a DocumentType object. The DocumentType for a document is available from the Document object's doctype attribute; if there is no DOCTYPE declaration for the document, the document's doctype attribute will be set to None instead of an instance of this interface.

DocumentType is a specialization of Node, and adds the following attributes:

**DocumentType.publicId**

The public identifier for the external subset of the document type definition. This will be a string or None.

**DocumentType.systemId**

The system identifier for the external subset of the document type definition. This will be a URI as a string, or None.

**DocumentType.internalSubset**

A string giving the complete internal subset from the document. This does not include the brackets which enclose the subset. If the document has no internal subset, this should be None.

**DocumentType.name**

The name of the root element as given in the DOCTYPE declaration,
if present.

**DocumentType.entities**
This is a NamedNodeMap giving the definitions of external entities. For entity names defined more than once, only the first definition is provided (others are ignored as required by the XML recommendation). This may be None if the information is not provided by the parser, or if no entities are defined.

**DocumentType.notations**
This is a NamedNodeMap giving the definitions of notations. For notation names defined more than once, only the first definition is provided (others are ignored as required by the XML recommendation). This may be None if the information is not provided by the parser, or if no notations are defined.

### 20.6.2.5. Document Objects

A Document represents an entire XML document, including its constituent elements, attributes, processing instructions, comments etc. Remember that it inherits properties from Node.

**Document.documentElement**
The one and only root element of the document.

**Document.createElement(tagName)**
Create and return a new element node. The element is not inserted into the document when it is created. You need to explicitly insert it with one of the other methods such as insertBefore() or appendChild().

**Document.createElementNS(namespaceURI, tagName)**
Create and return a new element with a namespace. The `tagName` may have a prefix. The element is not inserted into the document when it is created. You need to explicitly insert it with one of the other methods such as `insertBefore()` or `appendChild()`.

**Document.createTextNode(data)**
Create and return a text node containing the data passed as a parameter. As with the other creation methods, this one does not insert the node into the tree.

**Document.createComment(data)**
Create and return a comment node containing the data passed as a parameter. As with the other creation methods, this one does not insert the node into the tree.

**Document.createProcessingInstruction(target, data)**
Create and return a processing instruction node containing the `target` and `data` passed as parameters. As with the other creation methods, this one does not insert the node into the tree.

**Document.createAttribute(name)**
Create and return an attribute node. This method does not associate the attribute node with any particular element. You must use `setAttributeNode()` on the appropriate `Element` object to use the newly created attribute instance.

**Document.createAttributeNS(namespaceURI, qualifiedName)**
Create and return an attribute node with a namespace. The `tagName` may have a prefix. This method does not associate the attribute node with any particular element. You must use `setAttributeNode()` on the appropriate `Element` object to use
the newly created attribute instance.

Document \texttt{getElementsByTagName}(\texttt{tagName})
Search for all descendants (direct children, children’s children, etc.) with a particular element type name.

Document \texttt{getElementsByTagNameNS}(\texttt{namespaceURI}, \texttt{localName})
Search for all descendants (direct children, children’s children, etc.) with a particular namespace URI and localname. The localname is the part of the namespace after the prefix.

**20.6.2.6. Element Objects**

Element is a subclass of Node, so inherits all the attributes of that class.

Element \texttt{.tagName}
The element type name. In a namespace-using document it may have colons in it. The value is a string.

Element \texttt{getElementsByTagName}(\texttt{tagName})
Same as equivalent method in the Document class.

Element \texttt{getElementsByTagNameNS}(\texttt{namespaceURI}, \texttt{localName})
Same as equivalent method in the Document class.

Element \texttt{.hasAttribute}(\texttt{name})
Returns true if the element has an attribute named by \texttt{name}.

Element \texttt{.hasAttributeNS}(\texttt{namespaceURI}, \texttt{localName})
Returns true if the element has an attribute named by \textit{namespaceURI} and \textit{localName}.

**Element.\texttt{getAttribute}(name)**
Return the value of the attribute named by \textit{name} as a string. If no such attribute exists, an empty string is returned, as if the attribute had no value.

**Element.\texttt{getAttributeNode}(attrname)**
Return the \texttt{Attr} node for the attribute named by \textit{attrname}.

**Element.\texttt{getAttributeNS}(namespaceURI, localName)**
Return the value of the attribute named by \textit{namespaceURI} and \textit{localName} as a string. If no such attribute exists, an empty string is returned, as if the attribute had no value.

**Element.\texttt{getAttributeNodeNS}(namespaceURI, localName)**
Return an attribute value as a node, given a \textit{namespaceURI} and \textit{localName}.

**Element.\texttt{removeAttribute}(name)**
Remove an attribute by name. If there is no matching attribute, a \texttt{NotFoundError} is raised.

**Element.\texttt{removeAttributeNode}(oldAttr)**
Remove and return \textit{oldAttr} from the attribute list, if present. If \textit{oldAttr} is not present, \texttt{NotFoundError} is raised.

**Element.\texttt{removeAttributeNS}(namespaceURI, localName)**
Remove an attribute by name. Note that it uses a \textit{localName}, not a qname. No exception is raised if there is no matching attribute.

**Element.\texttt{setAttribute}(name, value)**
Set an attribute value from a string.

**Element**. `setAttributeNode(newAttr)`
Add a new attribute node to the element, replacing an existing attribute if necessary if the name attribute matches. If a replacement occurs, the old attribute node will be returned. If `newAttr` is already in use, `InuseAttributeErr` will be raised.

**Element**. `setAttributeNodeNS(newAttr)`
Add a new attribute node to the element, replacing an existing attribute if necessary if the namespaceURI and `localName` attributes match. If a replacement occurs, the old attribute node will be returned. If `newAttr` is already in use, `InuseAttributeErr` will be raised.

**Element**. `setAttributeNS(namespaceURI, qname, value)`
Set an attribute value from a string, given a `namespaceURI` and a `qname`. Note that a qname is the whole attribute name. This is different than above.

### 20.6.2.7. Attr Objects

Attr inherits from Node, so inherits all its attributes.

**Attr**. `name`
The attribute name. In a namespace-using document it may include a colon.

**Attr**. `localName`
The part of the name following the colon if there is one, else the entire name. This is a read-only attribute.
**Attr. prefix**

The part of the name preceding the colon if there is one, else the empty string.

**Attr. value**

The text value of the attribute. This is a synonym for the `nodeValue` attribute.

### 20.6.2.8. NamedNodeMap Objects

NamedNodeMap does *not* inherit from Node.

**NamedNodeMap.length**

The length of the attribute list.

**NamedNodeMap.item(index)**

Return an attribute with a particular index. The order you get the attributes in is arbitrary but will be consistent for the life of a DOM. Each item is an attribute node. Get its value with the `value` attribute.

There are also experimental methods that give this class more mapping behavior. You can use them or you can use the standardized `getAttribute*()` family of methods on the `Element` objects.

### 20.6.2.9. Comment Objects

Comment represents a comment in the XML document. It is a subclass of Node, but cannot have child nodes.

**Comment.data**

The content of the comment as a string. The attribute contains all
characters between the leading <!-- and trailing -->, but does not include them.

20.6.2.10. Text and CDATASection Objects

The Text interface represents text in the XML document. If the parser and DOM implementation support the DOM's XML extension, portions of the text enclosed in CDATA marked sections are stored in CDATASection objects. These two interfaces are identical, but provide different values for the nodeType attribute.

These interfaces extend the Node interface. They cannot have child nodes.

Text.data

The content of the text node as a string.

**Note:** The use of a CDATASection node does not indicate that the node represents a complete CDATA marked section, only that the content of the node was part of a CDATA section. A single CDATA section may be represented by more than one node in the document tree. There is no way to determine whether two adjacent CDATASection nodes represent different CDATA marked sections.

20.6.2.11. ProcessingInstruction Objects

Represents a processing instruction in the XML document; this inherits from the Node interface and cannot have child nodes.

ProcessingInstruction.target

The content of the processing instruction up to the first whitespace
character. This is a read-only attribute.

**ProcessingInstruction**. **data**

The content of the processing instruction following the first whitespace character.

### 20.6.2.12. Exceptions

The DOM Level 2 recommendation defines a single exception, **DOMException**, and a number of constants that allow applications to determine what sort of error occurred. **DOMException** instances carry a **code** attribute that provides the appropriate value for the specific exception.

The Python DOM interface provides the constants, but also expands the set of exceptions so that a specific exception exists for each of the exception codes defined by the DOM. The implementations must raise the appropriate specific exception, each of which carries the appropriate value for the **code** attribute.

**exception** xml.dom.**DOMException**

Base exception class used for all specific DOM exceptions. This exception class cannot be directly instantiated.

**exception** xml.dom.**DomstringSizeErr**

Raised when a specified range of text does not fit into a string. This is not known to be used in the Python DOM implementations, but may be received from DOM implementations not written in Python.

**exception** xml.dom.**HierarchyRequestErr**

Raised when an attempt is made to insert a node where the node type is not allowed.
exception xml.dom.IndexSizeErr
  Raised when an index or size parameter to a method is negative or exceeds the allowed values.

exception xml.dom.InuseAttributeErr
  Raised when an attempt is made to insert an Attr node that is already present elsewhere in the document.

exception xml.dom.InvalidAccessErr
  Raised if a parameter or an operation is not supported on the underlying object.

exception xml.dom.InvalidCharacterErr
  This exception is raised when a string parameter contains a character that is not permitted in the context it’s being used in by the XML 1.0 recommendation. For example, attempting to create an Element node with a space in the element type name will cause this error to be raised.

exception xml.dom.InvalidModificationErr
  Raised when an attempt is made to modify the type of a node.

exception xml.dom.InvalidStateErr
  Raised when an attempt is made to use an object that is not defined or is no longer usable.

exception xml.dom.NamespaceErr
  If an attempt is made to change any object in a way that is not permitted with regard to the Namespaces in XML recommendation, this exception is raised.

exception xml.dom.NotFoundErr
  Exception when a node does not exist in the referenced context.
For example, `NamedNodeMap.removeNamedItem()` will raise this if the node passed in does not exist in the map.

*exception* `xml.dom.NotSupportedErr`  
Raised when the implementation does not support the requested type of object or operation.

*exception* `xml.dom.NoDataAllowedErr`  
This is raised if data is specified for a node which does not support data.

*exception* `xml.dom.NoModificationAllowedErr`  
Raised on attempts to modify an object where modifications are not allowed (such as for read-only nodes).

*exception* `xml.dom.SyntaxErr`  
Raised when an invalid or illegal string is specified.

*exception* `xml.dom.WrongDocumentErr`  
Raised when a node is inserted in a different document than it currently belongs to, and the implementation does not support migrating the node from one document to the other.

The exception codes defined in the DOM recommendation map to the exceptions described above according to this table:

<table>
<thead>
<tr>
<th>Constant</th>
<th>Exception</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOMSTRING_SIZE_ERR</td>
<td>DomstringSizeErr</td>
</tr>
<tr>
<td>HIERARCHY_REQUEST_ERR</td>
<td>HierarchyRequestErr</td>
</tr>
<tr>
<td>INDEX_SIZE_ERR</td>
<td>IndexSizeErr</td>
</tr>
<tr>
<td>INUSE_ATTRIBUTE_ERR</td>
<td>InuseAttributeErr</td>
</tr>
<tr>
<td>INVALID_ACCESS_ERR</td>
<td>InvalidAccessErr</td>
</tr>
<tr>
<td>Error Code</td>
<td>Error Message</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>INVALID_CHARACTER_ERR</td>
<td>InvalidCharacterErr</td>
</tr>
<tr>
<td>INVALID_MODIFICATION_ERR</td>
<td>InvalidModificationErr</td>
</tr>
<tr>
<td>INVALID_STATE_ERR</td>
<td>InvalidStateErr</td>
</tr>
<tr>
<td>NAMESPACE_ERR</td>
<td>NamespaceErr</td>
</tr>
<tr>
<td>NOT_FOUND_ERR</td>
<td>NotFoundErr</td>
</tr>
<tr>
<td>NOT_SUPPORTED_ERR</td>
<td>NotSupportedErr</td>
</tr>
<tr>
<td>NO_DATA_ALLOWED_ERR</td>
<td>NoDataAllowedErr</td>
</tr>
<tr>
<td>NO_MODIFICATION_ALLOWED_ERR</td>
<td>NoModificationAllowedErr</td>
</tr>
<tr>
<td>SYNTAX_ERR</td>
<td>SyntaxErr</td>
</tr>
<tr>
<td>WRONG_DOCUMENT_ERR</td>
<td>WrongDocumentErr</td>
</tr>
</tbody>
</table>
20.6.3. Conformance

This section describes the conformance requirements and relationships between the Python DOM API, the W3C DOM recommendations, and the OMG IDL mapping for Python.

20.6.3.1. Type Mapping

The IDL types used in the DOM specification are mapped to Python types according to the following table.

<table>
<thead>
<tr>
<th>IDL Type</th>
<th>Python Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>boolean</td>
<td>bool or int</td>
</tr>
<tr>
<td>int</td>
<td>int</td>
</tr>
<tr>
<td>long int</td>
<td>int</td>
</tr>
<tr>
<td>unsigned int</td>
<td>int</td>
</tr>
<tr>
<td>DOMString</td>
<td>str or bytes</td>
</tr>
<tr>
<td>null</td>
<td>None</td>
</tr>
</tbody>
</table>

20.6.3.2. Accessor Methods

The mapping from OMG IDL to Python defines accessor functions for IDL attribute declarations in much the way the Java mapping does. Mapping the IDL declarations

```python
readonly attribute string someValue;
attribute string anotherValue;
```

yields three accessor functions: a “get” method for `someValue`
Callable functions

(_get_someValue()), and “get” and “set” methods for anotherValue (_get_anotherValue()) and _set_anotherValue()). The mapping, in particular, does not require that the IDL attributes are accessible as normal Python attributes: object.someValue is not required to work, and may raise an AttributeError.

The Python DOM API, however, does require that normal attribute access work. This means that the typical surrogates generated by Python IDL compilers are not likely to work, and wrapper objects may be needed on the client if the DOM objects are accessed via CORBA. While this does require some additional consideration for CORBA DOM clients, the implementers with experience using DOM over CORBA from Python do not consider this a problem. Attributes that are declared readonly may not restrict write access in all DOM implementations.

In the Python DOM API, accessor functions are not required. If provided, they should take the form defined by the Python IDL mapping, but these methods are considered unnecessary since the attributes are accessible directly from Python. “Set” accessors should never be provided for readonly attributes.

The IDL definitions do not fully embody the requirements of the W3C DOM API, such as the notion of certain objects, such as the return value of getElementsByTagName(), being “live”. The Python DOM API does not require implementations to enforce such requirements.
20.7. xml.dom.minidom — Minimal DOM implementation

Source code: Lib/xml/dom/minidom.py

xml.dom.minidom is a minimal implementation of the Document Object Model interface, with an API similar to that in other languages. It is intended to be simpler than the full DOM and also significantly smaller. Users who are not already proficient with the DOM should consider using the xml.etree.ElementTree module for their XML processing instead.

**Warning:** The xml.dom.minidom module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see XML vulnerabilities.

DOM applications typically start by parsing some XML into a DOM. With xml.dom.minidom, this is done through the parse functions:

```python
from xml.dom.minidom import parse, parseString

dom1 = parse('c:\temp\mydata.xml')  # parse an XML file

datasource = open('c:\temp\mydata.xml')
dom2 = parse(datasource)  # parse an open file

dom3 = parseString('<myxml>Some data<empty/> some more data</myxml>')
```

The `parse()` function can take either a filename or an open file.
xml.dom.minidom.parse(filename_or_file, parser=None, bufsize=None)

Return a Document from the given input. filename_or_file may be either a file name, or a file-like object. parser, if given, must be a SAX2 parser object. This function will change the document handler of the parser and activate namespace support; other parser configuration (like setting an entity resolver) must have been done in advance.

If you have XML in a string, you can use the parseString() function instead:

xml.dom.minidom.parseString(string, parser=None)

Return a Document that represents the string. This method creates an io.StringIO object for the string and passes that on to parse().

Both functions return a Document object representing the content of the document.

What the parse() and parseString() functions do is connect an XML parser with a “DOM builder” that can accept parse events from any SAX parser and convert them into a DOM tree. The name of the functions are perhaps misleading, but are easy to grasp when learning the interfaces. The parsing of the document will be completed before these functions return; it’s simply that these functions do not provide a parser implementation themselves.

You can also create a Document by calling a method on a “DOM Implementation” object. You can get this object either by calling the
getDOMImplementation() function in the xml.dom package or the xml.dom.minidom module. Once you have a Document, you can add child nodes to it to populate the DOM:

```python
from xml.dom.minidom import getDOMImplementation
impl = getDOMImplementation()
newdoc = impl.createDocument(None, "some_tag", None)
top_element = newdoc.documentElement
text = newdoc.createTextNode('Some textual content.')
top_element.appendChild(text)
```

Once you have a DOM document object, you can access the parts of your XML document through its properties and methods. These properties are defined in the DOM specification. The main property of the document object is the documentElement property. It gives you the main element in the XML document: the one that holds all others. Here is an example program:

```python
dom3 = parseString("<myxml>Some data</myxml>")
assert dom3.documentElement.tagName == "myxml"
```

When you are finished with a DOM tree, you may optionally call the unlink() method to encourage early cleanup of the now-unneeded objects. unlink() is a xml.dom.minidom-specific extension to the DOM API that renders the node and its descendants are essentially useless. Otherwise, Python’s garbage collector will eventually take care of the objects in the tree.

See also:

Document Object Model (DOM) Level 1 Specification
The W3C recommendation for the DOM supported by `xml.dom.minidom`. 
20.7.1. DOM Objects

The definition of the DOM API for Python is given as part of the `xml.dom` module documentation. This section lists the differences between the API and `xml.dom.minidom`.

Node `.unlink()`

Break internal references within the DOM so that it will be garbage collected on versions of Python without cyclic GC. Even when cyclic GC is available, using this can make large amounts of memory available sooner, so calling this on DOM objects as soon as they are no longer needed is good practice. This only needs to be called on the Document object, but may be called on child nodes to discard children of that node.

You can avoid calling this method explicitly by using the `with` statement. The following code will automatically unlink `dom` when the `with` block is exited:

```python
with xml.dom.minidom.parse(datasource) as dom:
    ... # Work with dom.
```

Node `.writexml(writer, indent='', addindent='', newl='')`

Write XML to the writer object. The writer should have a `write()` method which matches that of the file object interface. The `indent` parameter is the indentation of the current node. The `addindent` parameter is the incremental indentation to use for subnodes of the current one. The `newl` parameter specifies the string to use to terminate newlines.

For the Document node, an additional keyword argument `encoding`
can be used to specify the encoding field of the XML header.

Node .\texttt{toxml}(\texttt{encoding=\text{None}})

Return a string or byte string containing the XML represented by the DOM node.

With an explicit \textit{encoding} [1] argument, the result is a byte string in the specified encoding. With no \textit{encoding} argument, the result is a Unicode string, and the XML declaration in the resulting string does not specify an encoding. Encoding this string in an encoding other than UTF-8 is likely incorrect, since UTF-8 is the default encoding of XML.

Node .\texttt{toprettyxml}(\texttt{indent=\text{"\""}, \texttt{newl=\text{"\n"}, \texttt{encoding=\text{"\"}}})

Return a pretty-printed version of the document. \textit{indent} specifies the indentation string and defaults to a tabulator; \textit{newl} specifies the string emitted at the end of each line and defaults to \texttt{\n}.

The \textit{encoding} argument behaves like the corresponding argument of \texttt{toxml()}.  

20.7.2. DOM Example

This example program is a fairly realistic example of a simple program. In this particular case, we do not take much advantage of the flexibility of the DOM.

```python
import xml.dom.minidom

document = """"
<slideshow>
<title>Demo slideshow</title>
<slide><title>Slide title</title>
<point>This is a demo</point>
<point>Of a program for processing slides</point>
</slide>

<slide><title>Another demo slide</title>
<point>It is important</point>
<point>To have more than</point>
<point>one slide</point>
</slide>
"""

dom = xml.dom.minidom.parseString(document)

def getText(nodelist):
    rc = []
    for node in nodelist:
        if node.nodeType == node.TEXT_NODE:
            rc.append(node.data)
    return ''.join(rc)

def handleSlideshow(slideshow):
    print("<html>")
```

handleSlideshowTitle(slideshow.getElementsByTagName("slide"))
slides = slideshow.getElementsByTagName("slide")
handleToc(slides)
handleSlides(slides)
print("</html>")

def handleSlides(slides):
    for slide in slides:
        handleSlide(slide)

def handleSlide(slide):
    handleSlideTitle(slide.getElementsByTagName("title"))
    handlePoints(slide.getElementsByTagName("point"))

def handleSlideshowTitle(title):
    print("<title>%s</title>" % getText(title.childNodes))

def handleSlideTitle(title):
    print("<h2>%s</h2>" % getText(title.childNodes))

def handlePoints(points):
    print("<ul>"
for point in points:
    handlePoint(point)
print("</ul>")

def handlePoint(point):
    print("<li>%s</li>" % getText(point.childNodes))

def handleToc(slides):
    for slide in slides:
        title = slide.getElementsByTagName("title")
        print("<p>%s</p>" % getText(title.childNodes))
handleSlideshow(dom)
20.7.3. minidom and the DOM standard

The `xml.dom.minidom` module is essentially a DOM 1.0-compatible DOM with some DOM 2 features (primarily namespace features).

Usage of the DOM interface in Python is straight-forward. The following mapping rules apply:

- Interfaces are accessed through instance objects. Applications should not instantiate the classes themselves; they should use the creator functions available on the Document object. Derived interfaces support all operations (and attributes) from the base interfaces, plus any new operations.
- Operations are used as methods. Since the DOM uses only `in` parameters, the arguments are passed in normal order (from left to right). There are no optional arguments. void operations return `None`.
- IDL attributes map to instance attributes. For compatibility with the OMG IDL language mapping for Python, an attribute `foo` can also be accessed through accessor methods `_get_foo()` and `_set_foo()`. readonly attributes must not be changed; this is not enforced at runtime.
- The types `short`, `int`, `unsigned int`, `unsigned long`, and `boolean` all map to Python integer objects.
- The type `DOMString` maps to Python strings. `xml.dom.minidom` supports either bytes or strings, but will normally produce strings. Values of type `DOMString` may also be `None` where allowed to have the IDL null value by the DOM specification from the W3C.
- `const` declarations map to variables in their respective scope (e.g. `xml.dom.minidom.Node.PROCESSING_INSTRUCTION_NODE`);
they must not be changed.

- DOMException is currently not supported in `xml.dom.minidom`. Instead, `xml.dom.minidom` uses standard Python exceptions such as `TypeError` and `AttributeError`.
- NodeList objects are implemented using Python's built-in list type. These objects provide the interface defined in the DOM specification, but with earlier versions of Python they do not support the official API. They are, however, much more “Pythonic” than the interface defined in the W3C recommendations.

The following interfaces have no implementation in `xml.dom.minidom`:

- DOMTimeStamp
- DocumentType
- DOMImplementation
- CharacterData
- CDATASection
- Notation
- Entity
- EntityReference
- DocumentFragment

Most of these reflect information in the XML document that is not of general utility to most DOM users.

**Footnotes**

The encoding name included in the XML output should conform to the appropriate standards. For example, “UTF-8” is valid, but “UTF8” is not valid in an XML document’s declaration, even though Python accepts it as an encoding name. See [http://www.w3.org/TR/2006/REC-xml11-20060816/#NT-EncodingDecl](http://www.w3.org/TR/2006/REC-xml11-20060816/#NT-EncodingDecl) and [http://www.iana.org/assignments/character-](http://www.iana.org/assignments/character-
20.8. `xml.dom.pulldom` — Support for building partial DOM trees

Source code: `Lib/xml/dom/pulldom.py`

The `xml.dom.pulldom` module provides a “pull parser” which can also be asked to produce DOM-accessible fragments of the document where necessary. The basic concept involves pulling “events” from a stream of incoming XML and processing them. In contrast to SAX which also employs an event-driven processing model together with callbacks, the user of a pull parser is responsible for explicitly pulling events from the stream, looping over those events until either processing is finished or an error condition occurs.

**Warning:** The `xml.dom.pulldom` module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see [XML vulnerabilities](#).

Example:
```
from xml.dom import pulldom

doc = pulldom.parse('sales_items.xml')
for event, node in doc:
    if event == pulldom.START_ELEMENT and node.tagName:
        if int(node.getAttribute('price')) > 50:
            doc.expandNode(node)
        print(node.toxml())
```
event is a constant and can be one of:

- START_ELEMENT
- END_ELEMENT
- COMMENT
- START_DOCUMENT
- END_DOCUMENT
- CHARACTERS
- PROCESSING_INSTRUCTION
- IGNORABLE_WHITESPACE

Node is an object of type xml.dom.minidom.Document, xml.dom.minidom.Element or xml.dom.minidom.Text.

Since the document is treated as a “flat” stream of events, the document “tree” is implicitly traversed and the desired elements are found regardless of their depth in the tree. In other words, one does not need to consider hierarchical issues such as recursive searching of the document nodes, although if the context of elements were important, one would either need to maintain some context-related state (i.e. remembering where one is in the document at any given point) or to make use of the DOMEventStream.expandNode() method and switch to DOM-related processing.

```
class xml.dom.pulldom.PullDom(documentFactory=None)
    Subclass of xml.sax.handler.ContentHandler.

class xml.dom.pulldom.SAX2DOM(documentFactory=None)
    Subclass of xml.sax.handler.ContentHandler.
```

```
xml.dom.pulldom.parse(stream_or_string, parser=None, bufsize=None)
```
Return a `DOMEventStream` from the given input. `stream_or_string` may be either a file name, or a file-like object. `parser`, if given, must be a `XMLReader` object. This function will change the document handler of the parser and activate namespace support; other parser configuration (like setting an entity resolver) must have been done in advance.

If you have XML in a string, you can use the `parseString()` function instead:

```python
xml.dom.pulldom.parseString(string, parser=None)
```

Return a `DOMEventStream` that represents the (Unicode) `string`.

```python
xml.dom.pulldom.default_bufsize
```

Default value for the `bufsize` parameter to `parse()`.

The value of this variable can be changed before calling `parse()` and the new value will take effect.
20.8.1. DOMEventStream Objects

class xml.dom.pulldom.DOMEventStream(stream, parser, bufsize)

getEvent()
Return a tuple containing event and the current node as xml.dom.minidom.Document if event equals START_DOCUMENT, xml.dom.minidom.Element if event equals START_ELEMENT or END_ELEMENT or xml.dom.minidom.Text if event equals CHARACTERS. The current node does not contain informations about its children, unless expandNode() is called.

expandNode(node)
Expands all children of node into node. Example:

```python
xml = '<html><title>Foo</title> <p>Some text </p><div>and more</div> 
for event, node in doc:
    if event == pulldom.START_ELEMENT and node:
        # Following statement only prints '<p/>
        print(node.toxml())
        doc.expandNode(node)
        # Following statement prints node with children
        print(node.toxml())
```

reset()
20.9. xml.sax — Support for SAX2 parsers

The xml.sax package provides a number of modules which implement the Simple API for XML (SAX) interface for Python. The package itself provides the SAX exceptions and the convenience functions which will be most used by users of the SAX API.

**Warning:** The xml.sax module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see XML vulnerabilities.

The convenience functions are:

```python
xml.sax.make_parser(parser_list=[])  
Create and return a SAX XMLReader object. The first parser found will be used. If parser_list is provided, it must be a sequence of strings which name modules that have a function named create_parser(). Modules listed in parser_list will be used before modules in the default list of parsers.
```

```python
xml.sax.parse(filename_or_stream, handler,  
error_handler=handler.ErrorHandler())  
Create a SAX parser and use it to parse a document. The document, passed in as filename_or_stream, can be a filename or a file object. The handler parameter needs to be a SAX ContentHandler instance. If error_handler is given, it must be a SAX ErrorHandler instance; if omitted, SAXParseException will be raised on all errors. There is no return value; all work must
be done by the handler passed in.

```python
xml.sax.parseString(string, handler,
error_handler=handler.ErrorHandler())
```

Similar to `parse()`, but parses from a buffer `string` received as a parameter. `string` must be a `str` instance or a `bytes-like object`.

*Changed in version 3.5:* Added support of `str` instances.

A typical SAX application uses three kinds of objects: readers, handlers and input sources. “Reader” in this context is another term for parser, i.e. some piece of code that reads the bytes or characters from the input source, and produces a sequence of events. The events then get distributed to the handler objects, i.e. the reader invokes a method on the handler. A SAX application must therefore obtain a reader object, create or open the input sources, create the handlers, and connect these objects all together. As the final step of preparation, the reader is called to parse the input. During parsing, methods on the handler objects are called based on structural and syntactic events from the input data.

For these objects, only the interfaces are relevant; they are normally not instantiated by the application itself. Since Python does not have an explicit notion of interface, they are formally introduced as classes, but applications may use implementations which do not inherit from the provided classes. The `InputSource`, `Locator`, `Attributes`, `AttributesNS`, and `XMLReader` interfaces are defined in the module `xml.sax.xmlreader`. The handler interfaces are defined in `xml.sax.handler`. For convenience, `InputSource` (which is often instantiated directly) and the handler classes are also available from `xml.sax`. These interfaces are described below.
In addition to these classes, `xml.sax` provides the following exception classes.

```
exception xml.sax.SAXException(msg, exception=None)
```

Encapsulate an XML error or warning. This class can contain basic error or warning information from either the XML parser or the application: it can be subclassed to provide additional functionality or to add localization. Note that although the handlers defined in the `ErrorHandler` interface receive instances of this exception, it is not required to actually raise the exception — it is also useful as a container for information.

When instantiated, `msg` should be a human-readable description of the error. The optional `exception` parameter, if given, should be None or an exception that was caught by the parsing code and is being passed along as information.

This is the base class for the other SAX exception classes.

```
exception xml.sax.SAXParseException(msg, exception, locator)
```

Subclass of `SAXException` raised on parse errors. Instances of this class are passed to the methods of the SAX `ErrorHandler` interface to provide information about the parse error. This class supports the SAX `Locator` interface as well as the `SAXException` interface.

```
exception xml.sax.SAXNotRecognizedException(msg, exception=None)
```

Subclass of `SAXException` raised when a SAX `XMLReader` is confronted with an unrecognized feature or property. SAX applications and extensions may use this class for similar
exception xml.sax.SAXNotSupportedException(msg, exception=None)

Subclass of SAXException raised when a SAX XMLReader is asked to enable a feature that is not supported, or to set a property to a value that the implementation does not support. SAX applications and extensions may use this class for similar purposes.

See also:

**SAX: The Simple API for XML**
This site is the focal point for the definition of the SAX API. It provides a Java implementation and online documentation. Links to implementations and historical information are also available.

Module xml.sax.handler
Definitions of the interfaces for application-provided objects.

Module xml.sax.saxutils
Convenience functions for use in SAX applications.

Module xml.sax.xmlreader
Definitions of the interfaces for parser-provided objects.
20.9.1. SAXException Objects

The **SAXException** exception class supports the following methods:

**SAXException**. **getMessage()**

Return a human-readable message describing the error condition.

**SAXException**. **getException()**

Return an encapsulated exception object, or None.
20.10. `xml.sax.handler` —
Base classes for SAX handlers

The SAX API defines four kinds of handlers: content handlers, DTD handlers, error handlers, and entity resolvers. Applications normally only need to implement those interfaces whose events they are interested in; they can implement the interfaces in a single object or in multiple objects. Handler implementations should inherit from the base classes provided in the module `xml.sax.handler`, so that all methods get default implementations.

`class xml.sax.handler.ContentHandler`

This is the main callback interface in SAX, and the one most important to applications. The order of events in this interface mirrors the order of the information in the document.

`class xml.sax.handler.DTDHandler`

Handle DTD events.

This interface specifies only those DTD events required for basic parsing (unparsed entities and attributes).

`class xml.sax.handler.EntityResolver`

Basic interface for resolving entities. If you create an object implementing this interface, then register the object with your Parser, the parser will call the method in your object to resolve all external entities.

`class xml.sax.handler.ErrorHandler`

Interface used by the parser to present error and warning messages to the application. The methods of this object control
whether errors are immediately converted to exceptions or are handled in some other way.

In addition to these classes, \texttt{xml.sax.handler} provides symbolic constants for the feature and property names.

\texttt{xml.sax.handler.feature_namespaces}

value: "http://xml.org/sax/features/namespaces"
true: Perform Namespace processing.
false: Optionally do not perform Namespace processing (implies namespace-prefixes; default).
access: (parsing) read-only; (not parsing) read/write

\texttt{xml.sax.handler.feature_namespace_prefixes}

value: "http://xml.org/sax/features/namespace-prefixes"
true: Report the original prefixed names and attributes used for Namespace declarations.
false: Do not report attributes used for Namespace declarations, and optionally do not report original prefixed names (default).
access: (parsing) read-only; (not parsing) read/write

\texttt{xml.sax.handler.feature_string_interning}

value: "http://xml.org/sax/features/string-interning"
true: All element names, prefixes, attribute names, Namespace URIs, and local names are interned using the built-in intern function.
false: Names are not necessarily interned, although they may be (default).
access: (parsing) read-only; (not parsing) read/write
xml.sax.handler.feature_validation

value: "http://xml.org/sax/features/validation"
true: Report all validation errors (implies external-general-entities and external-parameter-entities).
false: Do not report validation errors.
access: (parsing) read-only; (not parsing) read/write

xml.sax.handler.feature_external_ges

value: "http://xml.org/sax/features/external-general-entities"
true: Include all external general (text) entities.
false: Do not include external general entities.
access: (parsing) read-only; (not parsing) read/write

xml.sax.handler.feature_external_pes

value: "http://xml.org/sax/features/external-parameter-entities"
true: Include all external parameter entities, including the external DTD subset.
false: Do not include any external parameter entities, even the external DTD subset.
access: (parsing) read-only; (not parsing) read/write

xml.sax.handler.all_features

List of all features.

xml.sax.handler.property_lexical_handler

value: "http://xml.org/sax/properties/lexical-handler"
data type: xml.sax.sax2lib.LexicalHandler (not supported in Python 2)
description: An optional extension handler for lexical events like comments.
access: read/write

xml.sax.handler.**property_declaration_handler**

value: "http://xml.org/sax/properties/declaration-handler"
data type: xml.sax.sax2lib.DeclHandler (not supported in Python 2)
description: An optional extension handler for DTD-related events other than notations and unparsed entities.
access: read/write

xml.sax.handler.**property_dom_node**

value: "http://xml.org/sax/properties/dom-node"
data type: org.w3c.dom.Node (not supported in Python 2)
description: When parsing, the current DOM node being visited if this is a DOM iterator; when not parsing, the root DOM node for iteration.
access: (parsing) read-only; (not parsing) read/write

xml.sax.handler.**property_xml_string**

value: "http://xml.org/sax/properties/xml-string"
data type: String
description: The literal string of characters that was the source for the current event.
access: read-only

xml.sax.handler.**all_properties**
List of all known property names.
20.10.1. ContentHandler Objects

Users are expected to subclass `ContentHandler` to support their application. The following methods are called by the parser on the appropriate events in the input document:

**ContentHandler**.`setDocumentLocator(locator)`

Called by the parser to give the application a locator for locating the origin of document events.

SAX parsers are strongly encouraged (though not absolutely required) to supply a locator: if it does so, it must supply the locator to the application by invoking this method before invoking any of the other methods in the DocumentHandler interface.

The locator allows the application to determine the end position of any document-related event, even if the parser is not reporting an error. Typically, the application will use this information for reporting its own errors (such as character content that does not match an application’s business rules). The information returned by the locator is probably not sufficient for use with a search engine.

Note that the locator will return correct information only during the invocation of the events in this interface. The application should not attempt to use it at any other time.

**ContentHandler**.`startDocument()`

Receive notification of the beginning of a document.

The SAX parser will invoke this method only once, before any other methods in this interface or in DTDHandler (except for `setDocumentLocator()`).
ContentHandler.endDocument()
Receive notification of the end of a document.

The SAX parser will invoke this method only once, and it will be the last method invoked during the parse. The parser shall not invoke this method until it has either abandoned parsing (because of an unrecoverable error) or reached the end of input.

ContentHandler.startPrefixMapping(prefix, uri)
Begin the scope of a prefix-URI Namespace mapping.

The information from this event is not necessary for normal Namespace processing: the SAX XML reader will automatically replace prefixes for element and attribute names when the feature_namespaces feature is enabled (the default).

There are cases, however, when applications need to use prefixes in character data or in attribute values, where they cannot safely be expanded automatically; the startPrefixMapping() and endPrefixMapping() events supply the information to the application to expand prefixes in those contexts itself, if necessary.

Note that startPrefixMapping() and endPrefixMapping() events are not guaranteed to be properly nested relative to each other: all startPrefixMapping() events will occur before the corresponding startElement() event, and all endPrefixMapping() events will occur after the corresponding endElement() event, but their order is not guaranteed.

ContentHandler.endPrefixMapping(prefix)
End the scope of a prefix-URI mapping.

See startPrefixMapping() for details. This event will always
occur after the corresponding `endElement()` event, but the order of `endPrefixMapping()` events is not otherwise guaranteed.

`ContentHandler.startElement(name, attrs)`
Signals the start of an element in non-namespace mode.

The `name` parameter contains the raw XML 1.0 name of the element type as a string and the `attrs` parameter holds an object of the `Attributes` interface (see The Attributes Interface) containing the attributes of the element. The object passed as `attrs` may be re-used by the parser; holding on to a reference to it is not a reliable way to keep a copy of the attributes. To keep a copy of the attributes, use the `copy()` method of the `attrs` object.

`ContentHandler.endElement(name)`
Signals the end of an element in non-namespace mode.

The `name` parameter contains the name of the element type, just as with the `startElement()` event.

`ContentHandler.startElementNS(name, qname, attrs)`
Signals the start of an element in namespace mode.

The `name` parameter contains the name of the element type as a `(uri, localname)` tuple, the `qname` parameter contains the raw XML 1.0 name used in the source document, and the `attrs` parameter holds an instance of the `AttributesNS` interface (see The AttributesNS Interface) containing the attributes of the element. If no namespace is associated with the element, the `uri` component of `name` will be None. The object passed as `attrs` may be re-used by the parser; holding on to a reference to it is not a reliable way to keep a copy of the attributes. To keep a copy of the
attributes, use the `copy()` method of the `attrs` object.

Parsers may set the `qname` parameter to `None`, unless the `feature_namespace_prefixes` feature is activated.

`ContentHandler.endElementNS(name, qname)`
Signals the end of an element in namespace mode.

The `name` parameter contains the name of the element type, just as with the `startElementNS()` method, likewise the `qname` parameter.

`ContentHandler.characters(content)`
Receive notification of character data.

The Parser will call this method to report each chunk of character data. SAX parsers may return all contiguous character data in a single chunk, or they may split it into several chunks; however, all of the characters in any single event must come from the same external entity so that the Locator provides useful information.

`content` may be a string or bytes instance; the expat reader module always produces strings.

**Note:** The earlier SAX 1 interface provided by the Python XML Special Interest Group used a more Java-like interface for this method. Since most parsers used from Python did not take advantage of the older interface, the simpler signature was chosen to replace it. To convert old code to the new interface, use `content` instead of slicing content with the old `offset` and `length` parameters.

`ContentHandler.ignorableWhitespace(whitespace)`
Receive notification of ignorable whitespace in element content.

Validating Parsers must use this method to report each chunk of ignorable whitespace (see the W3C XML 1.0 recommendation, section 2.10): non-validating parsers may also use this method if they are capable of parsing and using content models.

SAX parsers may return all contiguous whitespace in a single chunk, or they may split it into several chunks; however, all of the characters in any single event must come from the same external entity, so that the Locator provides useful information.

**ContentHandler.** **processingInstruction**(target, data)

Receive notification of a processing instruction.

The Parser will invoke this method once for each processing instruction found: note that processing instructions may occur before or after the main document element.

A SAX parser should never report an XML declaration (XML 1.0, section 2.8) or a text declaration (XML 1.0, section 4.3.1) using this method.

**ContentHandler.** **skippedEntity**(name)

Receive notification of a skipped entity.

The Parser will invoke this method once for each entity skipped. Non-validating processors may skip entities if they have not seen the declarations (because, for example, the entity was declared in an external DTD subset). All processors may skip external entities, depending on the values of the feature_external_ges and the feature_external_pes properties.
20.10.2. DTDHandler Objects

**DTDHandler** instances provide the following methods:

**DTDHandler**.\texttt{notationDecl}(name, publicId, systemId)
- Handle a notation declaration event.

**DTDHandler**.\texttt{unparsedEntityDecl}(name, publicId, systemId, ndata)
- Handle an unparsed entity declaration event.
20.10.3. EntityResolver Objects

EntityResolver.*resolveEntity*(*publicId*, *systemId*)

Resolve the system identifier of an entity and return either the system identifier to read from as a string, or an InputSource to read from. The default implementation returns *systemId*. 
20.10.4. ErrorHandler Objects

Objects with this interface are used to receive error and warning information from the `XMLReader`. If you create an object that implements this interface, then register the object with your `XMLReader`, the parser will call the methods in your object to report all warnings and errors. There are three levels of errors available: warnings, (possibly) recoverable errors, and unrecoverable errors. All methods take a `SAXParseException` as the only parameter. Errors and warnings may be converted to an exception by raising the passed-in exception object.

`ErrorHandler.error(exception)`

Called when the parser encounters a recoverable error. If this method does not raise an exception, parsing may continue, but further document information should not be expected by the application. Allowing the parser to continue may allow additional errors to be discovered in the input document.

`ErrorHandler.fatalError(exception)`

Called when the parser encounters an error it cannot recover from; parsing is expected to terminate when this method returns.

`ErrorHandler.warning(exception)`

Called when the parser presents minor warning information to the application. Parsing is expected to continue when this method returns, and document information will continue to be passed to the application. Raising an exception in this method will cause parsing to end.
20.11. **xml.sax.saxutils** — SAX Utilities

The module **xml.sax.saxutils** contains a number of classes and functions that are commonly useful when creating SAX applications, either in direct use, or as base classes.

```python
xml.sax.saxutils.escape(data, entities={})
```

Escape '&, '<', and '>' in a string of data.

You can escape other strings of data by passing a dictionary as the optional `entities` parameter. The keys and values must all be strings; each key will be replaced with its corresponding value. The characters '&', '<' and '>' are always escaped, even if `entities` is provided.

```python
xml.sax.saxutils.unescape(data, entities={})
```

Unescape '&amp;', '&lt;', and '&gt;' in a string of data.

You can unescape other strings of data by passing a dictionary as the optional `entities` parameter. The keys and values must all be strings; each key will be replaced with its corresponding value. '&amp;', '&lt;', and '&gt;' are always unescaped, even if `entities` is provided.

```python
xml.sax.saxutils.quoteattr(data, entities={})
```

Similar to `escape()`, but also prepares `data` to be used as an attribute value. The return value is a quoted version of `data` with any additional required replacements. `quoteattr()` will select a quote character based on the content of `data`, attempting to avoid
encoding any quote characters in the string. If both single- and
double-quote characters are already in data, the double-quote
characters will be encoded and data will be wrapped in double-
quotes. The resulting string can be used directly as an attribute
value:

```python
>>> print("<element attr=%s>" % quoteattr("ab ' cd &quot; ef")

This function is useful when generating attribute values for HTML
or any SGML using the reference concrete syntax.

class xml.sax.saxutils.XMLGenerator(out=None,
encoding='iso-8859-1', short_empty_elements=False)

This class implements the ContentHandler interface by writing
SAX events back into an XML document. In other words, using an
XMLGenerator as the content handler will reproduce the original
document being parsed. out should be a file-like object which will
default to sys.stdout. encoding is the encoding of the output stream
which defaults to 'iso-8859-1'. short_empty_elements controls
the formatting of elements that contain no content: if False (the
default) they are emitted as a pair of start/end tags, if set to True
they are emitted as a single self-closed tag.

New in version 3.2: The short_empty_elements parameter.

class xml.sax.saxutils.XMLFilterBase(base)

This class is designed to sit between an XMLReader and the client
application’s event handlers. By default, it does nothing but pass
requests up to the reader and events on to the handlers
unmodified, but subclasses can override specific methods to
modify the event stream or the configuration requests as they pass
`xml.sax.saxutils.prepare_input_source(source, base='')`  
This function takes an input source and an optional base URL and returns a fully resolved `InputSource` object ready for reading. The input source can be given as a string, a file-like object, or an `InputSource` object; parsers will use this function to implement the polymorphic `source` argument to their `parse()` method.
SAX parsers implement the `XMLReader` interface. They are implemented in a Python module, which must provide a function `create_parser()`. This function is invoked by `xml.sax.make_parser()` with no arguments to create a new parser object.

```python
class xml.sax.xmlreader.XMLReader
    Base class which can be inherited by SAX parsers.
```

```python
class xml.sax.xmlreader.IncrementalParser
    In some cases, it is desirable not to parse an input source at once, but to feed chunks of the document as they get available. Note that the reader will normally not read the entire file, but read it in chunks as well; still `parse()` won’t return until the entire document is processed. So these interfaces should be used if the blocking behaviour of `parse()` is not desirable.

    When the parser is instantiated it is ready to begin accepting data from the feed method immediately. After parsing has been finished with a call to close the reset method must be called to make the parser ready to accept new data, either from feed or using the parse method.

    Note that these methods must *not* be called during parsing, that is, after `parse` has been called and before it returns.

    By default, the class also implements the parse method of the
XMLReader interface using the feed, close and reset methods of
the IncrementalParser interface as a convenience to SAX 2.0
driver writers.

class xml.sax.xmlreader.Locator
Interface for associating a SAX event with a document location. A
locator object will return valid results only during calls to
DocumentHandler methods; at any other time, the results are
unpredictable. If information is not available, methods may return
None.

class xml.sax.xmlreader.InputSource(system_id=None)
Encapsulation of the information needed by the XMLReader to
read entities.

This class may include information about the public identifier,
system identifier, byte stream (possibly with character encoding
information) and/or the character stream of an entity.

Applications will create objects of this class for use in the
XMLReader.parse() method and for returning from
EntityResolver.resolveEntity.

An InputSource belongs to the application, the XMLReader is
not allowed to modify InputSource objects passed to it from the
application, although it may make copies and modify those.

class xml.sax.xmlreader.AttributesImpl(attrs)
This is an implementation of the Attributes interface (see
section The Attributes Interface). This is a dictionary-like object
which represents the element attributes in a startElement() call. In addition to the most useful dictionary operations, it supports
a number of other methods as described by the interface. Objects
of this class should be instantiated by readers; attrs must be a dictionary-like object containing a mapping from attribute names to attribute values.

```python
class xml.sax.xmlreader.AttributesNSImpl(attrs, qnames)
```

Namespace-aware variant of `AttributesImpl`, which will be passed to `startElementNS()`. It is derived from `AttributesImpl`, but understands attribute names as two-tuples of `namespaceURI` and `localname`. In addition, it provides a number of methods expecting qualified names as they appear in the original document. This class implements the AttributesNS interface (see section The AttributesNS Interface).
20.12.1. XMLReader Objects

The `XMLReader` interface supports the following methods:

**`XMLReader.parse(source)`**

Process an input source, producing SAX events. The `source` object can be a system identifier (a string identifying the input source – typically a file name or an URL), a file-like object, or an `InputSource` object. When `parse()` returns, the input is completely processed, and the parser object can be discarded or reset.

*Changed in version 3.5: Added support of character streams.*

**`XMLReader.getEntityResolver()`**

Return the current `EntityResolver`.

**`XMLReader.setContentHandler(handler)`**

Set the current `ContentHandler`. If no `ContentHandler` is set, content events will be discarded.

**`XMLReader.getDTDHandler()`**

Return the current `DTDHandler`.

**`XMLReader.setDTDHandler(handler)`**

Set the current `DTDHandler`. If no `DTDHandler` is set, DTD events will be discarded.

**`XMLReader.getEntityResolver()`**

Return the current `EntityResolver`.

**`XMLReader.setEntityResolver(handler)`**
Set the current `EntityResolver`. If no `EntityResolver` is set, attempts to resolve an external entity will result in opening the system identifier for the entity, and fail if it is not available.

**XMLReader**. `getErrorHandler()`  
Return the current `ErrorHandler`.

**XMLReader**. `setErrorHandler(handler)`  
Set the current error handler. If no `ErrorHandler` is set, errors will be raised as exceptions, and warnings will be printed.

**XMLReader**. `setLocale(locale)`  
Allow an application to set the locale for errors and warnings.

SAX parsers are not required to provide localization for errors and warnings; if they cannot support the requested locale, however, they must raise a SAX exception. Applications may request a locale change in the middle of a parse.

**XMLReader**. `getFeature(featurename)`  
Return the current setting for feature `featurename`. If the feature is not recognized, SAXNotRecognizedException is raised. The well-known featurenames are listed in the module `xml.sax.handler`.

**XMLReader**. `setFeature(featurename, value)`  
Set the `featurename` to `value`. If the feature is not recognized, SAXNotRecognizedException is raised. If the feature or its setting is not supported by the parser, SAXNotSupportedException is raised.

**XMLReader**. `getProperty(propertyname)`
Return the current setting for property \textit{propertynane}. If the property is not recognized, a \texttt{SAXNotRecognizedException} is raised. The well-known properties are listed in the module \texttt{xml.sax.handler}.

\texttt{XMLReader.setProperty(propertynane, value)}

Set the \textit{propertynane} to \textit{value}. If the property is not recognized, \texttt{SAXNotRecognizedException} is raised. If the property or its setting is not supported by the parser, \texttt{SAXNotSupportedException} is raised.
20.12.2. IncrementalParser Objects

Instances of IncrementalParser offer the following additional methods:

IncrementalParser.\texttt{feed}(data)

Process a chunk of \texttt{data}.

IncrementalParser.\texttt{close}()

Assume the end of the document. That will check well-formedness conditions that can be checked only at the end, invoke handlers, and may clean up resources allocated during parsing.

IncrementalParser.\texttt{reset}()

This method is called after close has been called to reset the parser so that it is ready to parse new documents. The results of calling parse or feed after close without calling reset are undefined.
Instances of `Locator` provide these methods:

- `Locator.getColumnNumber()`
  Return the column number where the current event ends.

- `Locator.getLineNumber()`
  Return the line number where the current event ends.

- `Locator.getPublicId()`
  Return the public identifier for the current event.

- `Locator.getSystemId()`
  Return the system identifier for the current event.
20.12.4. InputSource Objects

InputSource.setPublicId(id)
Sets the public identifier of this InputSource.

InputSource.getPublicId()
Returns the public identifier of this InputSource.

InputSource.setSystemId(id)
Sets the system identifier of this InputSource.

InputSource.getSystemId()
Returns the system identifier of this InputSource.

InputSource.setEncoding(encoding)
Sets the character encoding of this InputSource.

The encoding must be a string acceptable for an XML encoding declaration (see section 4.3.3 of the XML recommendation).

The encoding attribute of the InputSource is ignored if the InputSource also contains a character stream.

InputSource.getEncoding()
Get the character encoding of this InputSource.

InputSource.setByteStream(bytefile)
Set the byte stream (a binary file) for this input source.

The SAX parser will ignore this if there is also a character stream specified, but it will use a byte stream in preference to opening a URI connection itself.
If the application knows the character encoding of the byte stream, it should set it with the `setEncoding` method.

**InputSource**. `getBytesStream()`  
Get the byte stream for this input source.

The `getEncoding` method will return the character encoding for this byte stream, or None if unknown.

**InputSource**. `setCharacterStream(charfile)`  
Set the character stream (a text file) for this input source.

If there is a character stream specified, the SAX parser will ignore any byte stream and will not attempt to open a URI connection to the system identifier.

**InputSource**. `getCharacterStream()`  
Get the character stream for this input source.
20.12.5. The Attributes Interface

Attributes objects implement a portion of the mapping protocol, including the methods copy(), get(), __contains__(), items(), keys(), and values(). The following methods are also provided:

Attributes.getLength()
Return the number of attributes.

Attributes.getNames()
Return the names of the attributes.

Attributes.getType(name)
Returns the type of the attribute name, which is normally 'CDATA'.

Attributes.getValue(name)
Return the value of attribute name.
20.12.6. The AttributesNS Interface

This interface is a subtype of the Attributes interface (see section The Attributes Interface). All methods supported by that interface are also available on AttributesNS objects.

The following methods are also available:

AttributesNS.getValueByQName(name)
   Return the value for a qualified name.

AttributesNS.getNameByQName(name)
   Return the (namespace, localname) pair for a qualified name.

AttributesNS.getQNameByName(name)
   Return the qualified name for a (namespace, localname) pair.

AttributesNS.getQNames()
   Return the qualified names of all attributes.
20.13. `xml.parsers.expat` — Fast XML parsing using Expat

**Warning:** The `pyexpat` module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see XML vulnerabilities.

The `xml.parsers.expat` module is a Python interface to the Expat non-validating XML parser. The module provides a single extension type, `xmlparser`, that represents the current state of an XML parser. After an `xmlparser` object has been created, various attributes of the object can be set to handler functions. When an XML document is then fed to the parser, the handler functions are called for the character data and markup in the XML document.

This module uses the `pyexpat` module to provide access to the Expat parser. Direct use of the `pyexpat` module is deprecated.

This module provides one exception and one type object:

* `exception xml.parsers.expat.ExpatError`  
  The exception raised when Expat reports an error. See section `ExpatError Exceptions` for more information on interpreting Expat errors.

* `exception xml.parsers.expat.error`  
  Alias for `ExpatError`.

* `xml.parsers.expat.XMLParserType`  
  The type of the return values from the `ParserCreate()` function.
The `xml.parsers.expat` module contains two functions:

```python
xml.parsers.expat.ErrorString(errno)
```

Returns an explanatory string for a given error number `errno`.

```python
xml.parsers.expat.ParserCreate(encoding=None, namespace_separator=None)
```

Creates and returns a new `xmlparser` object. `encoding`, if specified, must be a string naming the encoding used by the XML data. Expat doesn't support as many encodings as Python does, and its repertoire of encodings can't be extended; it supports UTF-8, UTF-16, ISO-8859-1 (Latin1), and ASCII. If `encoding` [1] is given it will override the implicit or explicit encoding of the document.

Expat can optionally do XML namespace processing for you, enabled by providing a value for `namespace_separator`. The value must be a one-character string; a `ValueError` will be raised if the string has an illegal length (None is considered the same as omission). When namespace processing is enabled, element type names and attribute names that belong to a namespace will be expanded. The element name passed to the element handlers `StartElementHandler` and `EndElementHandler` will be the concatenation of the namespace URI, the namespace separator character, and the local part of the name. If the namespace separator is a zero byte (`chr(0)`) then the namespace URI and the local part will be concatenated without any separator.

For example, if `namespace_separator` is set to a space character (`' '`) and the following document is parsed:

```xml
<?xml version="1.0"?>
<root xmlns = "http://default-namespace.org/
     xmlns:py = "http://www.python.org/ns/"/>
```
StartElementHandler will receive the following strings for each element:

```
http://default-namespace.org/ root
http://www.python.org/ns/ elem1
elem2
```

Due to limitations in the Expat library used by pyexpat, the xmlparser instance returned can only be used to parse a single XML document. Call ParserCreate for each document to provide unique parser instances.

See also:

**The Expat XML Parser**

Home page of the Expat project.
20.13.1. XMLParser Objects

xmlparser objects have the following methods:

**xmlparser.Parse(data[, isfinal])**

Parses the contents of the string *data*, calling the appropriate handler functions to process the parsed data. *isfinal* must be true on the final call to this method; it allows the parsing of a single file in fragments, not the submission of multiple files. *data* can be the empty string at any time.

**xmlparser.ParseFile(file)**

Parse XML data reading from the object *file*. *file* only needs to provide the `read(nbytes)` method, returning the empty string when there's no more data.

**xmlparser.SetBase(base)**

Sets the base to be used for resolving relative URIs in system identifiers in declarations. Resolving relative identifiers is left to the application: this value will be passed through as the *base* argument to the `ExternalEntityRefHandler()`, `NotationDeclHandler()`, and `UnparsedEntityDeclHandler()` functions.

**xmlparser.GetBase()**

Returns a string containing the base set by a previous call to `SetBase()`, or None if `SetBase()` hasn't been called.

**xmlparser.GetInputContext()**

Returns the input data that generated the current event as a string. The data is in the encoding of the entity which contains the text.
When called while an event handler is not active, the return value is None.

```
xmlparser.ExternalEntityParserCreate(context[, encoding])
```

Create a “child” parser which can be used to parse an external parsed entity referred to by content parsed by the parent parser. The `context` parameter should be the string passed to the `ExternalEntityRefHandler()` handler function, described below. The child parser is created with the `ordered_attributes` and `specified_attributes` set to the values of this parser.

```
xmlparser.SetParamEntityParsing(flag)
```

Control parsing of parameter entities (including the external DTD subset). Possible `flag` values are `XML_PARAM_ENTITY_PARSING_NEVER`, `XML_PARAM_ENTITY_PARSING_UNLESS_STANDALONE` and `XML_PARAM_ENTITY_PARSING_ALWAYS`. Return true if setting the flag was successful.

```
xmlparser.UseForeignDTD([flag])
```

Calling this with a true value for `flag` (the default) will cause Expat to call the `ExternalEntityRefHandler` with `None` for all arguments to allow an alternate DTD to be loaded. If the document does not contain a document type declaration, the `ExternalEntityRefHandler` will still be called, but the `StartDoctypeDeclHandler` and `EndDoctypeDeclHandler` will not be called.

Passing a false value for `flag` will cancel a previous call that passed a true value, but otherwise has no effect.
This method can only be called before the `Parse()` or `ParseFile()` methods are called; calling it after either of those have been called causes `ExpatError` to be raised with the `code` attribute set to `errors.codes[errors.XML_ERROR_CANT_CHANGE_FEATURE_`

`xmlparser` objects have the following attributes:

**xmlparser.buffer_size**

The size of the buffer used when `buffer_text` is true. A new buffer size can be set by assigning a new integer value to this attribute. When the size is changed, the buffer will be flushed.

**xmlparser.buffer_text**

Setting this to true causes the `xmlparser` object to buffer textual content returned by Expat to avoid multiple calls to the `CharacterDataHandler()` callback whenever possible. This can improve performance substantially since Expat normally breaks character data into chunks at every line ending. This attribute is false by default, and may be changed at any time.

**xmlparser.buffer_used**

If `buffer_text` is enabled, the number of bytes stored in the buffer. These bytes represent UTF-8 encoded text. This attribute has no meaningful interpretation when `buffer_text` is false.

**xmlparser.ordered_attributes**

Setting this attribute to a non-zero integer causes the attributes to be reported as a list rather than a dictionary. The attributes are presented in the order found in the document text. For each attribute, two list entries are presented: the attribute name and the attribute value. (Older versions of this module also used this
format.) By default, this attribute is false; it may be changed at any time.

xmlparser.specified_attributes
If set to a non-zero integer, the parser will report only those attributes which were specified in the document instance and not those which were derived from attribute declarations. Applications which set this need to be especially careful to use what additional information is available from the declarations as needed to comply with the standards for the behavior of XML processors. By default, this attribute is false; it may be changed at any time.

The following attributes contain values relating to the most recent error encountered by an xmlparser object, and will only have correct values once a call to Parse() or ParseFile() has raised a xml.parsers.expat.ExpatError exception.

xmlparser.ErrorByteIndex
Byte index at which an error occurred.

xmlparser.ErrorCode
Numeric code specifying the problem. This value can be passed to the ErrorString() function, or compared to one of the constants defined in the errors object.

xmlparser.ErrorColumnNumber
Column number at which an error occurred.

xmlparser.ErrorLineNumber
Line number at which an error occurred.

The following attributes contain values relating to the current parse location in an xmlparser object. During a callback reporting a parse
event they indicate the location of the first of the sequence of characters that generated the event. When called outside of a callback, the position indicated will be just past the last parse event (regardless of whether there was an associated callback).

`xmlparser.CurrentByteIndex`  
Current byte index in the parser input.

`xmlparser.CurrentColumnNumber`  
Current column number in the parser input.

`xmlparser.CurrentLineNumber`  
Current line number in the parser input.

Here is the list of handlers that can be set. To set a handler on an `xmlparser` object `o`, use `o.handlername = func`. `handlername` must be taken from the following list, and `func` must be a callable object accepting the correct number of arguments. The arguments are all strings, unless otherwise stated.

`xmlparser.XmlDeclHandler(version, encoding, standalone)`  
Called when the XML declaration is parsed. The XML declaration is the (optional) declaration of the applicable version of the XML recommendation, the encoding of the document text, and an optional “standalone” declaration. `version` and `encoding` will be strings, and `standalone` will be 1 if the document is declared standalone, 0 if it is declared not to be standalone, or -1 if the standalone clause was omitted. This is only available with Expat version 1.95.0 or newer.

`xmlparser.StartDoctypeDeclHandler(doctypeName, systemId, publicId, has_internal_subset)`  
Called when Expat begins parsing the document type declaration
(<!DOCTYPE ...). The `doctypeName` is provided exactly as presented. The `systemId` and `publicId` parameters give the system and public identifiers if specified, or None if omitted. `has_internal_subset` will be true if the document contains and internal document declaration subset. This requires Expat version 1.2 or newer.

`xmlparser.EndDoctypeDeclHandler()`
Called when Expat is done parsing the document type declaration. This requires Expat version 1.2 or newer.

`xmlparser.ElementDeclHandler(name, model)`
Called once for each element type declaration. `name` is the name of the element type, and `model` is a representation of the content model.

`xmlparser.AttlistDeclHandler(elname, attname, type, default, required)`
Called for each declared attribute for an element type. If an attribute list declaration declares three attributes, this handler is called three times, once for each attribute. `elname` is the name of the element to which the declaration applies and `attname` is the name of the attribute declared. The attribute type is a string passed as `type`; the possible values are 'CDATA', 'ID', 'IDREF', ... `default` gives the default value for the attribute used when the attribute is not specified by the document instance, or None if there is no default value (#IMPLIED values). If the attribute is required to be given in the document instance, `required` will be true. This requires Expat version 1.95.0 or newer.

`xmlparser.StartElementHandler(name, attributes)`
Called for the start of every element. `name` is a string containing
the element name, and *attributes* is the element attributes. If *ordered_attributes* is true, this is a list (see *ordered_attributes* for a full description). Otherwise it's a dictionary mapping names to values.

```python
xmlparser.EndElementHandler(name)
```
Called for the end of every element.

```python
xmlparser.ProcessingInstructionHandler(target, data)
```
Called for every processing instruction.

```python
xmlparser.CharacterDataHandler(data)
```
Called for character data. This will be called for normal character data, CDATA marked content, and ignorable whitespace. Applications which must distinguish these cases can use the *StartCdataSectionHandler*, *EndCdataSectionHandler*, and *ElementDeclHandler* callbacks to collect the required information.

```python
xmlparser.UnparsedEntityDeclHandler(entityName, base, systemId, publicId, notationName)
```
Called for unparsed (NDATA) entity declarations. This is only present for version 1.2 of the Expat library; for more recent versions, use *EntityDeclHandler* instead. (The underlying function in the Expat library has been declared obsolete.)

```python
xmlparser.EntityDeclHandler(entityName, is_parameter_entity, value, base, systemId, publicId, notationName)
```
Called for all entity declarations. For parameter and internal entities, *value* will be a string giving the declared contents of the entity; this will be None for external entities. The *notationName* parameter will be None for parsed entities, and the name of the
notation for unparsed entities. \texttt{is\_parameter\_entity} will be true if the entity is a parameter entity or false for general entities (most applications only need to be concerned with general entities). This is only available starting with version 1.95.0 of the Expat library.

\texttt{xmlparser.\texttt{NotationDeclHandler}(notationName, base, systemId, publicId)}

Called for notation declarations. \texttt{notationName}, \texttt{base}, and \texttt{systemId}, and \texttt{publicId} are strings if given. If the public identifier is omitted, \texttt{publicId} will be \texttt{None}.

\texttt{xmlparser.\texttt{StartNamespaceDeclHandler}(prefix, uri)}

Called when an element contains a namespace declaration. Namespace declarations are processed before the \texttt{StartElementHandler} is called for the element on which declarations are placed.

\texttt{xmlparser.\texttt{EndNamespaceDeclHandler}(prefix)}

Called when the closing tag is reached for an element that contained a namespace declaration. This is called once for each namespace declaration on the element in the reverse of the order for which the \texttt{StartNamespaceDeclHandler} was called to indicate the start of each namespace declaration’s scope. Calls to this handler are made after the corresponding \texttt{EndElementHandler} for the end of the element.

\texttt{xmlparser.\texttt{CommentHandler}(data)}

Called for comments. \texttt{data} is the text of the comment, excluding the leading '\texttt{<!--} and trailing '\texttt{-->}'.

\texttt{xmlparser.\texttt{StartCdataSectionHandler}()} 

Called at the start of a CDATA section. This and
**EndCdataSectionHandler** are needed to be able to identify the syntactical start and end for CDATA sections.

**xmlparser.** **EndCdataSectionHandler()**
Called at the end of a CDATA section.

**xmlparser.** **DefaultHandler**(data)
Called for any characters in the XML document for which no applicable handler has been specified. This means characters that are part of a construct which could be reported, but for which no handler has been supplied.

**xmlparser.** **DefaultHandlerExpand**(data)
This is the same as the **DefaultHandler()**, but doesn't inhibit expansion of internal entities. The entity reference will not be passed to the default handler.

**xmlparser.** **NotStandaloneHandler()**
Called if the XML document hasn't been declared as being a standalone document. This happens when there is an external subset or a reference to a parameter entity, but the XML declaration does not set standalone to yes in an XML declaration. If this handler returns 0, then the parser will raise an XML_ERROR_NOT_STANDALONE error. If this handler is not set, no exception is raised by the parser for this condition.

**xmlparser.** **ExternalEntityRefHandler**(context, base, systemId, publicId)
Called for references to external entities. *base* is the current base, as set by a previous call to **SetBase()**. The public and system identifiers, *systemId* and *publicId*, are strings if given; if the public identifier is not given, *publicId* will be None. The *context* value is
opaque and should only be used as described below.

For external entities to be parsed, this handler must be implemented. It is responsible for creating the sub-parser using `ExternalEntityParserCreate(context)`, initializing it with the appropriate callbacks, and parsing the entity. This handler should return an integer; if it returns 0, the parser will raise an `XML_ERROR_EXTERNAL_ENTITY_HANDLING` error, otherwise parsing will continue.

If this handler is not provided, external entities are reported by the `DefaultHandler` callback, if provided.
20.13.2. ExpatError Exceptions

*ExpatError* exceptions have a number of interesting attributes:

**ExpatError.**`code`

Expat's internal error number for the specific error. The `errors.messages` dictionary maps these error numbers to Expat's error messages. For example:

```python
from xml.parsers.expat import ParserCreate, ExpatError

p = ParserCreate()
try:
    p.Parse(some_xml_document)
except ExpatError as err:
    print("Error:", errors.messages[err.code])
```

The `errors` module also provides error message constants and a dictionary `codes` mapping these messages back to the error codes, see below.

**ExpatError.**`lineno`

Line number on which the error was detected. The first line is numbered 1.

**ExpatError.**`offset`

Character offset into the line where the error occurred. The first column is numbered 0.
20.13.3. Example

The following program defines three handlers that just print out their arguments.

```python
import xml.parsers.expat

# 3 handler functions
def start_element(name, attrs):
    print('Start element:', name, attrs)

def end_element(name):
    print('End element:', name)

def char_data(data):
    print('Character data:', repr(data))

p = xml.parsers.expat.ParserCreate()

p.StartElementHandler = start_element
p.EndElementHandler = end_element
p.CharacterDataHandler = char_data

p.Parse("""<?xml version='1.0'?><parent id='top'><child1 name='paul'>Text goes here</child1><child2 name='fred'>More text</child2></parent>""", 1)
```

The output from this program is:

```
Start element: parent {'id': 'top'}
Start element: child1 {'name': 'paul'}
Character data: 'Text goes here'
End element: child1
Character data: '\n'
Start element: child2 {'name': 'fred'}
```
Character data: 'More text'
End element: child2
Character data: '\n'
End element: parent
20.13.4. Content Model Descriptions

Content modules are described using nested tuples. Each tuple contains four values: the type, the quantifier, the name, and a tuple of children. Children are simply additional content module descriptions.

The values of the first two fields are constants defined in the `xml.parsers.expat.model` module. These constants can be collected in two groups: the model type group and the quantifier group.

The constants in the model type group are:

- `xml.parsers.expat.model.XML_CTYPE_ANY`
  The element named by the model name was declared to have a content model of ANY.

- `xml.parsers.expat.model.XML_CTYPE_CHOICE`
  The named element allows a choice from a number of options; this is used for content models such as `(A | B | C)`.

- `xml.parsers.expat.model.XML_CTYPE_EMPTY`
  Elements which are declared to be EMPTY have this model type.

- `xml.parsers.expat.model.XML_CTYPE_MIXED`

- `xml.parsers.expat.model.XML_CTYPE_NAME`

- `xml.parsers.expat.model.XML_CTYPE_SEQ`
  Models which represent a series of models which follow one after the other are indicated with this model type. This is used for models such as `(A, B, C)`.

The constants in the quantifier group are:
xml.parsers.expat.model.XML_CQUANT_NONE
No modifier is given, so it can appear exactly once, as for A.

xml.parsers.expat.model.XML_CQUANT_OPT
The model is optional: it can appear once or not at all, as for A?.

xml.parsers.expat.model.XML_CQUANT_PLUS
The model must occur one or more times (like A+).

xml.parsers.expat.model.XML_CQUANT_REP
The model must occur zero or more times, as for A*.
20.13.5. Expat error constants

The following constants are provided in the `xml.parsers.expat.errors` module. These constants are useful in interpreting some of the attributes of the ExpatError exception objects raised when an error has occurred. Since for backwards compatibility reasons, the constants' value is the error message and not the numeric error code, you do this by comparing its code attribute with `errors.codes[errors.XML_ERROR_CONSTANT_NAME]`.

The `errors` module has the following attributes:

- `xml.parsers.expat.errors.codes`  
  A dictionary mapping numeric error codes to their string descriptions.  
  
  *New in version 3.2.*

- `xml.parsers.expat.errors.messages`  
  A dictionary mapping string descriptions to their error codes.  
  
  *New in version 3.2.*

- `xml.parsers.expat.errors.XML_ERROR_ASYNC_ENTITY`
- `xml.parsers.expat.errors.XML_ERROR_ATTRIBUTE_EXTERNAL_ENTITY_REF`  
  An entity reference in an attribute value referred to an external entity instead of an internal entity.

- `xml.parsers.expat.errors.XML_ERROR_BAD_CHAR_REF`  
  A character reference referred to a character which is illegal in XML (for example, character θ, or `&#0;`).
xml.parsers.expat.errors.XML_ERROR_BINARY_ENTITY
An entity reference referred to an entity which was declared with a notation, so cannot be parsed.

xml.parsers.expat.errors.XML_ERROR_DUPLICATE_ATTRIBUTE
An attribute was used more than once in a start tag.

xml.parsers.expat.errors.XML_ERROR_INCORRECT_ENCODING
xml.parsers.expat.errors.XML_ERROR_INVALID_TOKEN
Raised when an input byte could not properly be assigned to a character; for example, a NUL byte (value 0) in a UTF-8 input stream.

xml.parsers.expat.errors.XML_ERROR_JUNK_AFTER_DOC
Something other than whitespace occurred after the document element.

xml.parsers.expat.errors.XML_ERROR_MISPLACED_XML_PI
An XML declaration was found somewhere other than the start of the input data.

xml.parsers.expat.errors.XML_ERROR_NO_ELEMENTS
The document contains no elements (XML requires all documents to contain exactly one top-level element).

xml.parsers.expat.errors.XML_ERROR_NO_MEMORY
Expat was not able to allocate memory internally.

xml.parsers.expat.errors.XML_ERROR_PARAM_ENTITY_REF
A parameter entity reference was found where it was not allowed.

xml.parsers.expat.errors.XML_ERROR_PARTIAL_CHAR
An incomplete character was found in the input.
xml.parsers.expat.errors.XML_ERROR_RECURSIVE_ENTITY
An entity reference contained another reference to the same entity; possibly via a different name, and possibly indirectly.

xml.parsers.expat.errors.XML_ERROR_SYNTAX
Some unspecified syntax error was encountered.

xml.parsers.expat.errors.XML_ERROR_TAG_MISMATCH
An end tag did not match the innermost open start tag.

xml.parsers.expat.errors.XML_ERROR_UNCLOSED_TOKEN
Some token (such as a start tag) was not closed before the end of the stream or the next token was encountered.

xml.parsers.expat.errors.XML_ERROR_UNDEFINED_ENTITY
A reference was made to an entity which was not defined.

xml.parsers.expat.errors.XML_ERROR_UNKNOWN_ENCODING
The document encoding is not supported by Expat.

xml.parsers.expat.errors.XML_ERROR_UNCLOSED_CDATA
A CDATA marked section was not closed.

xml.parsers.expat.errors.XML_ERROR_EXTERNAL_ENTITY_HANDLING
xml.parsers.expat.errors.XML_ERROR_NOT_STANDALONE
The parser determined that the document was not “standalone” though it declared itself to be in the XML declaration, and the NotStandaloneHandler was set and returned 0.

xml.parsers.expat.errors.XML_ERROR_UNEXPECTED_STATE
xml.parsers.expat.errors.XML_ERROR_ENTITY_DECLARED_IN_PIE
An operation was requested that requires DTD support to be compiled in, but Expat was configured without DTD support. This should never be reported by a standard build of the xml.parsers.expat module.

A behavioral change was requested after parsing started that can only be changed before parsing has started. This is (currently) only raised by UseForeignDTD().

An undeclared prefix was found when namespace processing was enabled.

The document attempted to remove the namespace declaration associated with a prefix.

A parameter entity contained incomplete markup.

The document contained no document element at all.

There was an error parsing a text declaration in an external entity.

Characters were found in the public id that are not allowed.

The requested operation was made on a suspended parser, but
isn’t allowed. This includes attempts to provide additional input or to stop the parser.

xml.parsers.expat.errors.XML_ERROR_NOT_SUSPENDED
An attempt to resume the parser was made when the parser had not been suspended.

xml.parsers.expat.errors.XML_ERROR_ABORTED
This should not be reported to Python applications.

xml.parsers.expat.errors.XML_ERROR_FINISHED
The requested operation was made on a parser which was finished parsing input, but isn’t allowed. This includes attempts to provide additional input or to stop the parser.

xml.parsers.expat.errors.XML_ERROR_SUSPEND_PE

Footnotes

[1] The encoding string included in XML output should conform to the appropriate standards. For example, “UTF-8” is valid, but “UTF8” is not. See http://www.w3.org/TR/2006/REC-xml11-20060816/#NT-EncodingDecl and http://www.iana.org/assignments/character-sets/character-sets.xhtml.
21. Internet Protocols and Support

The modules described in this chapter implement Internet protocols and support for related technology. They are all implemented in Python. Most of these modules require the presence of the system-dependent module `socket`, which is currently supported on most popular platforms. Here is an overview:

- **21.1. webbrowser** — Convenient Web-browser controller
  - 21.1.1. Browser Controller Objects
- **21.2. cgi** — Common Gateway Interface support
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- **21.3. cgitb** — Traceback manager for CGI scripts
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- 21.7. urllib.response — Response classes used by urllib
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  - 21.8.1. URL Parsing
  - 21.8.2. Parsing ASCII Encoded Bytes
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- 21.9. urllib.error — Exception classes raised by urllib.request
- 21.10. urllib.robotparser — Parser for robots.txt
- 21.11. http — HTTP modules
• 21.11.1. HTTP status codes

• 21.12. `http.client` — HTTP protocol client
  • 21.12.1. `HTTPConnection` Objects
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• 21.13. `ftplib` — FTP protocol client
  • 21.13.1. `FTP` Objects
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• 21.14. `poplib` — POP3 protocol client
  • 21.14.1. `POP3` Objects
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• 21.15. `imaplib` — IMAP4 protocol client
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    • 21.16.1.1. Attributes
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• 21.19. `telnetlib` — Telnet client
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21.1. **webbrowser** — Convenient Web-browser controller

**Source code:** Lib/webbrowser.py

The `webbrowser` module provides a high-level interface to allow displaying Web-based documents to users. Under most circumstances, simply calling the `open()` function from this module will do the right thing.

Under Unix, graphical browsers are preferred under X11, but text-mode browsers will be used if graphical browsers are not available or an X11 display isn’t available. If text-mode browsers are used, the calling process will block until the user exits the browser.

If the environment variable `BROWSER` exists, it is interpreted as the `os.pathsep`-separated list of browsers to try ahead of the platform defaults. When the value of a list part contains the string `%s`, then it is interpreted as a literal browser command line to be used with the argument URL substituted for `%s`; if the part does not contain `%s`, it is simply interpreted as the name of the browser to launch. [1]

For non-Unix platforms, or when a remote browser is available on Unix, the controlling process will not wait for the user to finish with the browser, but allow the remote browser to maintain its own windows on the display. If remote browsers are not available on Unix, the controlling process will launch a new browser and wait.

The script `webbrowser` can be used as a command-line interface for the module. It accepts an URL as the argument. It accepts the
following optional parameters: -n opens the URL in a new browser window, if possible; -t opens the URL in a new browser page ("tab"). The options are, naturally, mutually exclusive. Usage example:

```
python -m webbrowser -t "http://www.python.org"
```

The following exception is defined:

```
exception webbrowser.Error
    Exception raised when a browser control error occurs.
```

The following functions are defined:

```
webbrowser.open(url, new=0, autoraise=True)
    Display url using the default browser. If new is 0, the url is opened in the same browser window if possible. If new is 1, a new browser window is opened if possible. If new is 2, a new browser page ("tab") is opened if possible. If autoraise is True, the window is raised if possible (note that under many window managers this will occur regardless of the setting of this variable).

    Note that on some platforms, trying to open a filename using this function, may work and start the operating system's associated program. However, this is neither supported nor portable.

webbrowser.open_new(url)
    Open url in a new window of the default browser, if possible, otherwise, open url in the only browser window.

webbrowser.open_new_tab(url)
    Open url in a new page ("tab") of the default browser, if possible, otherwise equivalent to open_new().```
webbrowser.get(using=None)

Return a controller object for the browser type using. If using is None, return a controller for a default browser appropriate to the caller's environment.

webbrowser.register(name, constructor, instance=None)

Register the browser type name. Once a browser type is registered, the get() function can return a controller for that browser type. If instance is not provided, or is None, constructor will be called without parameters to create an instance when needed. If instance is provided, constructor will never be called, and may be None.

This entry point is only useful if you plan to either set the BROWSER variable or call get() with a nonempty argument matching the name of a handler you declare.

A number of browser types are predefined. This table gives the type names that may be passed to the get() function and the corresponding instantiations for the controller classes, all defined in this module.

<table>
<thead>
<tr>
<th>Type Name</th>
<th>Class Name</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>'mozilla'</td>
<td>Mozilla('mozilla')</td>
<td></td>
</tr>
<tr>
<td>'firefox'</td>
<td>Mozilla('mozilla')</td>
<td></td>
</tr>
<tr>
<td>'netscape'</td>
<td>Mozilla('netscape')</td>
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</tr>
<tr>
<td>'galeon'</td>
<td>Galeon('galeon')</td>
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</tr>
<tr>
<td>'epiphany'</td>
<td>Galeon('epiphany')</td>
<td></td>
</tr>
<tr>
<td>'skipstone'</td>
<td>BackgroundBrowser('skipstone')</td>
<td>(1)</td>
</tr>
<tr>
<td>'kfmclient'</td>
<td>Konqueror()</td>
<td></td>
</tr>
<tr>
<td>'konqueror'</td>
<td>Konqueror()</td>
<td>(1)</td>
</tr>
<tr>
<td>'kfm'</td>
<td>Konqueror()</td>
<td>(1)</td>
</tr>
<tr>
<td>'mosaic'</td>
<td>BackgroundBrowser('mosaic')</td>
<td></td>
</tr>
<tr>
<td>'opera'</td>
<td>Opera()</td>
<td></td>
</tr>
<tr>
<td>'grail'</td>
<td>Grail()</td>
<td></td>
</tr>
<tr>
<td>'links'</td>
<td>GenericBrowser('links')</td>
<td></td>
</tr>
<tr>
<td>'elinks'</td>
<td>Elinks('elinks')</td>
<td></td>
</tr>
<tr>
<td>'lynx'</td>
<td>GenericBrowser('lynx')</td>
<td></td>
</tr>
<tr>
<td>'w3m'</td>
<td>GenericBrowser('w3m')</td>
<td></td>
</tr>
<tr>
<td>'windows-default'</td>
<td>WindowsDefault</td>
<td>(2)</td>
</tr>
<tr>
<td>'macosx'</td>
<td>MacOSX('default')</td>
<td>(3)</td>
</tr>
<tr>
<td>'safari'</td>
<td>MacOSX('safari')</td>
<td>(3)</td>
</tr>
<tr>
<td>'google-chrome'</td>
<td>Chrome('google-chrome')</td>
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<td>'chrome'</td>
<td>Chrome('chrome')</td>
<td></td>
</tr>
<tr>
<td>'chromium'</td>
<td>Chromium('chromium')</td>
<td></td>
</tr>
<tr>
<td>'chromium-browser'</td>
<td>Chromium('chromium-browser')</td>
<td></td>
</tr>
</tbody>
</table>

Notes:

1. “Konqueror” is the file manager for the KDE desktop environment for Unix, and only makes sense to use if KDE is running. Some way of reliably detecting KDE would be nice; the KDEDIR variable is not sufficient. Note also that the name “kfm” is used even when using the konqueror command with KDE 2 — the implementation selects the best strategy for running Konqueror.
2. Only on Windows platforms.
3. Only on Mac OS X platform.

*New in version 3.3:* Support for Chrome/Chromium has been added.

Here are some simple examples:

```python
url = 'http://docs.python.org/'

# Open URL in a new tab, if a browser window is already open.
webbrowser.open_new_tab(url)

# Open URL in new window, raising the window if possible.
webbrowser.open_new(url)
```
21.1.1. Browser Controller Objects

Browser controllers provide these methods which parallel three of the module-level convenience functions:

controller. `open(url, new=0, autoraise=True)`

Display `url` using the browser handled by this controller. If `new` is 1, a new browser window is opened if possible. If `new` is 2, a new browser page ("tab") is opened if possible.

controller. `open_new(url)`

Open `url` in a new window of the browser handled by this controller, if possible, otherwise, open `url` in the only browser window. Alias `open_new()`.

controller. `open_new_tab(url)`

Open `url` in a new page ("tab") of the browser handled by this controller, if possible, otherwise equivalent to `open_new()`.

Footnotes

[1] Executables named here without a full path will be searched in the directories given in the PATH environment variable.
21.2. **cgi** — Common Gateway Interface support

**Source code:** Lib/cgi.py

Support module for Common Gateway Interface (CGI) scripts.

This module defines a number of utilities for use by CGI scripts written in Python.
21.2.1. Introduction

A CGI script is invoked by an HTTP server, usually to process user input submitted through an HTML `<FORM>` or `<ISINDEX>` element.

Most often, CGI scripts live in the server’s special cgi-bin directory. The HTTP server places all sorts of information about the request (such as the client’s hostname, the requested URL, the query string, and lots of other goodies) in the script’s shell environment, executes the script, and sends the script’s output back to the client.

The script's input is connected to the client too, and sometimes the form data is read this way; at other times the form data is passed via the “query string” part of the URL. This module is intended to take care of the different cases and provide a simpler interface to the Python script. It also provides a number of utilities that help in debugging scripts, and the latest addition is support for file uploads from a form (if your browser supports it).

The output of a CGI script should consist of two sections, separated by a blank line. The first section contains a number of headers, telling the client what kind of data is following. Python code to generate a minimal header section looks like this:

```python
print("Content-Type: text/html")  # HTML is followed by blank line, end of headers
print()
```

The second section is usually HTML, which allows the client software to display nicely formatted text with header, in-line images, etc. Here’s Python code that prints a simple piece of HTML:

```python
print("<TITLE>CGI script output</TITLE>")
```
print("<H1>This is my first CGI script</H1>")
print("Hello, world!")
21.2.2. Using the cgi module

Begin by writing `import cgi`.

When you write a new script, consider adding these lines:

```python
import cgitb
cgitb.enable()
```

This activates a special exception handler that will display detailed reports in the Web browser if any errors occur. If you’d rather not show the guts of your program to users of your script, you can have the reports saved to files instead, with code like this:

```python
import cgitb
cgitb.enable(display=0, logdir="/path/to/logdir")
```

It’s very helpful to use this feature during script development. The reports produced by `cgitb` provide information that can save you a lot of time in tracking down bugs. You can always remove the `cgitb` line later when you have tested your script and are confident that it works correctly.

To get at submitted form data, use the `FieldStorage` class. If the form contains non-ASCII characters, use the `encoding` keyword parameter set to the value of the encoding defined for the document. It is usually contained in the META tag in the HEAD section of the HTML document or by the `Content-Type` header). This reads the form contents from the standard input or the environment (depending on the value of various environment variables set according to the CGI standard). Since it may consume standard input, it should be instantiated only once.
The FieldStorage instance can be indexed like a Python dictionary. It allows membership testing with the `in` operator, and also supports the standard dictionary method `keys()` and the built-in function `len()`. Form fields containing empty strings are ignored and do not appear in the dictionary; to keep such values, provide a true value for the optional `keep_blank_values` keyword parameter when creating the FieldStorage instance.

For instance, the following code (which assumes that the `Content-Type` header and blank line have already been printed) checks that the fields `name` and `addr` are both set to a non-empty string:

```python
form = cgi.FieldStorage()
if "name" not in form or "addr" not in form:
    print("<H1>Error</H1>")
    print("Please fill in the name and addr fields.
return
print("<p>name:", form["name"].value)
print("<p>addr:", form["addr"].value)
...further form processing here...
```

Here the fields, accessed through `form[key]`, are themselves instances of FieldStorage (or MiniFieldStorage, depending on the form encoding). The value attribute of the instance yields the string value of the field. The `getvalue()` method returns this string value directly; it also accepts an optional second argument as a default to return if the requested key is not present.

If the submitted form data contains more than one field with the same name, the object retrieved by `form[key]` is not a FieldStorage or MiniFieldStorage instance but a list of such instances. Similarly, in this situation, `form.getvalue(key)` would return a list of strings. If
you expect this possibility (when your HTML form contains multiple fields with the same name), use the `getlist()` method, which always returns a list of values (so that you do not need to special-case the single item case). For example, this code concatenates any number of username fields, separated by commas:

```python
value = form.getlist("username")
usernames = ",".join(value)
```

If a field represents an uploaded file, accessing the value via the `value` attribute or the `getvalue()` method reads the entire file in memory as bytes. This may not be what you want. You can test for an uploaded file by testing either the `filename` attribute or the `file` attribute. You can then read the data from the `file` attribute before it is automatically closed as part of the garbage collection of the `FieldStorage` instance (the `read()` and `readline()` methods will return bytes):

```python
fileitem = form["userfile"]
if fileitem.file:
    # It's an uploaded file; count lines
    linecount = 0
    while True:
        line = fileitem.file.readline()
        if not line: break
    linecount = linecount + 1
```

FieldStorage objects also support being used in a `with` statement, which will automatically close them when done.

If an error is encountered when obtaining the contents of an uploaded file (for example, when the user interrupts the form submission by clicking on a Back or Cancel button) the `done` attribute of the object
for the field will be set to the value -1.

The file upload draft standard entertains the possibility of uploading multiple files from one field (using a recursive multipart/* encoding). When this occurs, the item will be a dictionary-like FieldStorage item. This can be determined by testing its type attribute, which should be multipart/form-data (or perhaps another MIME type matching multipart/*). In this case, it can be iterated over recursively just like the top-level form object.

When a form is submitted in the “old” format (as the query string or as a single data part of type application/x-www-form-urlencoded), the items will actually be instances of the class MiniFieldStorage. In this case, the list, file, and filename attributes are always None.

A form submitted via POST that also has a query string will contain both FieldStorage and MiniFieldStorage items.

*Changed in version 3.4:* The file attribute is automatically closed upon the garbage collection of the creating FieldStorage instance.

*Changed in version 3.5:* Added support for the context management protocol to the FieldStorage class.
21.2.3. Higher Level Interface

The previous section explains how to read CGI form data using the FieldStorage class. This section describes a higher level interface which was added to this class to allow one to do it in a more readable and intuitive way. The interface doesn't make the techniques described in previous sections obsolete — they are still useful to process file uploads efficiently, for example.

The interface consists of two simple methods. Using the methods you can process form data in a generic way, without the need to worry whether only one or more values were posted under one name.

In the previous section, you learned to write following code anytime you expected a user to post more than one value under one name:

```python
item = form.getvalue("item")
if isinstance(item, list):
    # The user is requesting more than one item.
else:
    # The user is requesting only one item.
```

This situation is common for example when a form contains a group of multiple checkboxes with the same name:

```html
<input type="checkbox" name="item" value="1" />
<input type="checkbox" name="item" value="2" />
```

In most situations, however, there's only one form control with a particular name in a form and then you expect and need only one value associated with this name. So you write a script containing for example this code:
The problem with the code is that you should never expect that a client will provide valid input to your scripts. For example, if a curious user appends another user=foo pair to the query string, then the script would crash, because in this situation the `getvalue("user")` method call returns a list instead of a string. Calling the `upper()` method on a list is not valid (since lists do not have a method of this name) and results in an `AttributeError` exception.

Therefore, the appropriate way to read form data values was to always use the code which checks whether the obtained value is a single value or a list of values. That's annoying and leads to less readable scripts.

A more convenient approach is to use the methods `getfirst()` and `getlist()` provided by this higher level interface.

**FieldStorage.getfirst(name, default=None)**

This method always returns only one value associated with form field `name`. The method returns only the first value in case that more values were posted under such name. Please note that the order in which the values are received may vary from browser to browser and should not be counted on. If no such form field or value exists then the method returns the value specified by the optional parameter `default`. This parameter defaults to None if not specified.

**FieldStorage.getlist(name)**

This method always returns a list of values associated with form field `name`. The method returns an empty list if no such form field or value exists for `name`. It returns a list consisting of one item if
only one such value exists.

Using these methods you can write nice compact code:

```python
import cgi
form = cgi.FieldStorage()
user = form.getfirst("user", "").upper()  # This way it's safe.
for item in form.getlist("item"):
    do_something(item)
```
21.2.4. Functions

These are useful if you want more control, or if you want to employ some of the algorithms implemented in this module in other circumstances.

cgi.\texttt{parse}(fp=None, environ=os.environ, keep_blank_values=False, strict_parsing=False)

Parse a query in the environment or from a file (the file defaults to \texttt{sys.stdin}). The \texttt{keep_blank_values} and \texttt{strict_parsing} parameters are passed to \texttt{urllib.parse.parse_qs()} unchanged.

cgi.\texttt{parse_qs}(qs, keep_blank_values=False, strict_parsing=False)

This function is deprecated in this module. Use \texttt{urllib.parse.parse_qs()} instead. It is maintained here only for backward compatibility.

cgi.\texttt{parse_qsl}(qs, keep_blank_values=False, strict_parsing=False)

This function is deprecated in this module. Use \texttt{urllib.parse.parse_qsl()} instead. It is maintained here only for backward compatibility.

cgi.\texttt{parse_multipart}(fp, pdict)

Parse input of type \texttt{multipart/form-data} (for file uploads). Arguments are \texttt{fp} for the input file and \texttt{pdict} for a dictionary containing other parameters in the \texttt{Content-Type} header.

Returns a dictionary just like \texttt{urllib.parse.parse_qs()} keys
are the field names, each value is a list of values for that field. This is easy to use but not much good if you are expecting megabytes to be uploaded — in that case, use the FieldStorage class instead which is much more flexible.

Note that this does not parse nested multipart parts — use FieldStorage for that.

cgi.parse_header(string)
Parse a MIME header (such as Content-Type) into a main value and a dictionary of parameters.

cgi.test()
Robust test CGI script, usable as main program. Writes minimal HTTP headers and formats all information provided to the script in HTML form.

cgi.print_environ()
Format the shell environment in HTML.

cgi.print_form(form)
Format a form in HTML.

cgi.print_directory()
Format the current directory in HTML.

cgi.print_environ_usage()
Print a list of useful (used by CGI) environment variables in HTML.

cgi.escape(s, quote=False)
Convert the characters '&', '<' and '>' in string s to HTML-safe sequences. Use this if you need to display text that might contain such characters in HTML. If the optional flag quote is true, the
quotation mark character (") is also translated; this helps for inclusion in an HTML attribute value delimited by double quotes, as in `<a href="...">. Note that single quotes are never translated.

*Deprecated since version 3.2:* This function is unsafe because `quote` is false by default, and therefore deprecated. Use `html.escape()` instead.
21.2.5. Caring about security

There’s one important rule: if you invoke an external program (via the `os.system()` or `os.popen()` functions, or others with similar functionality), make very sure you don’t pass arbitrary strings received from the client to the shell. This is a well-known security hole whereby clever hackers anywhere on the Web can exploit a gullible CGI script to invoke arbitrary shell commands. Even parts of the URL or field names cannot be trusted, since the request doesn’t have to come from your form!

To be on the safe side, if you must pass a string gotten from a form to a shell command, you should make sure the string contains only alphanumeric characters, dashes, underscores, and periods.
21.2.6. Installing your CGI script on a Unix system

Read the documentation for your HTTP server and check with your local system administrator to find the directory where CGI scripts should be installed; usually this is in a directory cgi-bin in the server tree.

Make sure that your script is readable and executable by “others”; the Unix file mode should be 0o755 octal (use chmod 0755 filename). Make sure that the first line of the script contains #! starting in column 1 followed by the pathname of the Python interpreter, for instance:

```bash
#!/usr/local/bin/python
```

Make sure the Python interpreter exists and is executable by “others”.

Make sure that any files your script needs to read or write are readable or writable, respectively, by “others” — their mode should be 0o644 for readable and 0o666 for writable. This is because, for security reasons, the HTTP server executes your script as user “nobody”, without any special privileges. It can only read (write, execute) files that everybody can read (write, execute). The current directory at execution time is also different (it is usually the server’s cgi-bin directory) and the set of environment variables is also different from what you get when you log in. In particular, don’t count on the shell’s search path for executables (PATH) or the Python module search path (PYTHONPATH) to be set to anything interesting.

If you need to load modules from a directory which is not on Python’s default module search path, you can change the path in your script,
before importing other modules. For example:

```python
import sys
sys.path.insert(0, "/usr/home/joe/lib/python")
sys.path.insert(0, "/usr/local/lib/python")
```

(This way, the directory inserted last will be searched first!)

Instructions for non-Unix systems will vary; check your HTTP server’s documentation (it will usually have a section on CGI scripts).
21.2.7. Testing your CGI script

Unfortunately, a CGI script will generally not run when you try it from the command line, and a script that works perfectly from the command line may fail mysteriously when run from the server. There's one reason why you should still test your script from the command line: if it contains a syntax error, the Python interpreter won't execute it at all, and the HTTP server will most likely send a cryptic error to the client.

Assuming your script has no syntax errors, yet it does not work, you have no choice but to read the next section.
21.2.8. Debugging CGI scripts

First of all, check for trivial installation errors — reading the section above on installing your CGI script carefully can save you a lot of time. If you wonder whether you have understood the installation procedure correctly, try installing a copy of this module file (cgi.py) as a CGI script. When invoked as a script, the file will dump its environment and the contents of the form in HTML form. Give it the right mode etc, and send it a request. If it’s installed in the standard cgi-bin directory, it should be possible to send it a request by entering a URL into your browser of the form:

```
http://yourhostname/cgi-bin/cgi.py?name=Joe+Blow&addr=At+Home
```

If this gives an error of type 404, the server cannot find the script — perhaps you need to install it in a different directory. If it gives another error, there’s an installation problem that you should fix before trying to go any further. If you get a nicely formatted listing of the environment and form content (in this example, the fields should be listed as “addr” with value “At Home” and “name” with value “Joe Blow”), the cgi.py script has been installed correctly. If you follow the same procedure for your own script, you should now be able to debug it.

The next step could be to call the `cgi` module’s `test()` function from your script: replace its main code with the single statement

```
cgi.test()
```

This should produce the same results as those gotten from installing the `cgi.py` file itself.
When an ordinary Python script raises an unhandled exception (for whatever reason: of a typo in a module name, a file that can’t be opened, etc.), the Python interpreter prints a nice traceback and exits. While the Python interpreter will still do this when your CGI script raises an exception, most likely the traceback will end up in one of the HTTP server’s log files, or be discarded altogether.

Fortunately, once you have managed to get your script to execute some code, you can easily send tracebacks to the Web browser using the `cgitb` module. If you haven’t done so already, just add the lines:

```python
import cgitb
cgitb.enable()
```

to the top of your script. Then try running it again; when a problem occurs, you should see a detailed report that will likely make apparent the cause of the crash.

If you suspect that there may be a problem in importing the `cgitb` module, you can use an even more robust approach (which only uses built-in modules):

```python
import sys
sys.stderr = sys.stdout
print("Content-Type: text/plain")
print()
...your code here...
```

This relies on the Python interpreter to print the traceback. The content type of the output is set to plain text, which disables all HTML processing. If your script works, the raw HTML will be displayed by your client. If it raises an exception, most likely after the first two lines have been printed, a traceback will be displayed. Because no HTML
interpretation is going on, the traceback will be readable.
21.2.9. Common problems and solutions

- Most HTTP servers buffer the output from CGI scripts until the script is completed. This means that it is not possible to display a progress report on the client's display while the script is running.
- Check the installation instructions above.
- Check the HTTP server’s log files. (`tail -f logfile` in a separate window may be useful!)
- Always check a script for syntax errors first, by doing something like `python script.py`.
- If your script does not have any syntax errors, try adding `import cgitb; cgitb.enable()` to the top of the script.
- When invoking external programs, make sure they can be found. Usually, this means using absolute path names — PATH is usually not set to a very useful value in a CGI script.
- When reading or writing external files, make sure they can be read or written by the userid under which your CGI script will be running: this is typically the userid under which the web server is running, or some explicitly specified userid for a web server’s suexec feature.
- Don’t try to give a CGI script a set-uid mode. This doesn’t work on most systems, and is a security liability as well.

Footnotes

Note that some recent versions of the HTML specification do state what order the field values should be supplied in, but knowing whether a request was received from a conforming browser, or even from a browser at all, is tedious and error-prone.

[1]
21.3. **cgitb — Traceback manager for CGI scripts**

The `cgitb` module provides a special exception handler for Python scripts. (Its name is a bit misleading. It was originally designed to display extensive traceback information in HTML for CGI scripts. It was later generalized to also display this information in plain text.) After this module is activated, if an uncaught exception occurs, a detailed, formatted report will be displayed. The report includes a traceback showing excerpts of the source code for each level, as well as the values of the arguments and local variables to currently running functions, to help you debug the problem. Optionally, you can save this information to a file instead of sending it to the browser.

To enable this feature, simply add this to the top of your CGI script:

```python
import cgitb
cgitb.enable()
```

The options to the `enable()` function control whether the report is displayed in the browser and whether the report is logged to a file for later analysis.

```python
cgitb.enable(display=1, logdir=None, context=5, format="html")
```

This function causes the `cgitb` module to take over the interpreter’s default handling for exceptions by setting the value of `sys.excepthook`.

The optional argument `display` defaults to 1 and can be set to 0 to suppress sending the traceback to the browser. If the argument
logdir is present, the traceback reports are written to files. The value of logdir should be a directory where these files will be placed. The optional argument context is the number of lines of context to display around the current line of source code in the traceback; this defaults to 5. If the optional argument format is "html", the output is formatted as HTML. Any other value forces plain text output. The default value is "html".

```
cgitb.handler(info=None)
```

This function handles an exception using the default settings (that is, show a report in the browser, but don’t log to a file). This can be used when you’ve caught an exception and want to report it using cgitb. The optional info argument should be a 3-tuple containing an exception type, exception value, and traceback object, exactly like the tuple returned by `sys.exc_info()`. If the info argument is not supplied, the current exception is obtained from `sys.exc_info()`.
21.4. **wsgiref** — WSGI Utilities and Reference Implementation

The Web Server Gateway Interface (WSGI) is a standard interface between web server software and web applications written in Python. Having a standard interface makes it easy to use an application that supports WSGI with a number of different web servers.

Only authors of web servers and programming frameworks need to know every detail and corner case of the WSGI design. You don’t need to understand every detail of WSGI just to install a WSGI application or to write a web application using an existing framework.

**wsgiref** is a reference implementation of the WSGI specification that can be used to add WSGI support to a web server or framework. It provides utilities for manipulating WSGI environment variables and response headers, base classes for implementing WSGI servers, a demo HTTP server that serves WSGI applications, and a validation tool that checks WSGI servers and applications for conformance to the WSGI specification (**PEP 3333**).

See [http://www.wsgi.org](http://www.wsgi.org) for more information about WSGI, and links to tutorials and other resources.
21.4.1. **wsgiref.util** – WSGI environment utilities

This module provides a variety of utility functions for working with WSGI environments. A WSGI environment is a dictionary containing HTTP request variables as described in **PEP 3333**. All of the functions taking an `environ` parameter expect a WSGI-compliant dictionary to be supplied; please see **PEP 3333** for a detailed specification.

```python
wsgiref.util.guess_scheme(environ)
```

Return a guess for whether `wsgi.url_scheme` should be “http” or “https”, by checking for a HTTPS environment variable in the `environ` dictionary. The return value is a string.

This function is useful when creating a gateway that wraps CGI or a CGI-like protocol such as FastCGI. Typically, servers providing such protocols will include a HTTPS variable with a value of “1” “yes”, or “on” when a request is received via SSL. So, this function returns “https” if such a value is found, and “http” otherwise.

```python
wsgiref.util.request_uri(environ, include_query=True)
```

Return the full request URI, optionally including the query string, using the algorithm found in the “URL Reconstruction” section of **PEP 3333**. If `include_query` is false, the query string is not included in the resulting URI.

```python
wsgiref.util.application_uri(environ)
```

Similar to `request_uri()`, except that the PATH_INFO and QUERY_STRING variables are ignored. The result is the base URI of the application object addressed by the request.
wsgiref.util.shift_path_info(environ)

Shift a single name from PATH_INFO0 to SCRIPT_NAME and return the name. The environ dictionary is modified in-place; use a copy if you need to keep the original PATH_INFO0 or SCRIPT_NAME intact.

If there are no remaining path segments in PATH_INFO0, None is returned.

Typically, this routine is used to process each portion of a request URI path, for example to treat the path as a series of dictionary keys. This routine modifies the passed-in environment to make it suitable for invoking another WSGI application that is located at the target URI. For example, if there is a WSGI application at /foo, and the request URI path is /foo/bar/baz, and the WSGI application at /foo calls shift_path_info(), it will receive the string “bar”, and the environment will be updated to be suitable for passing to a WSGI application at /foo/bar. That is, SCRIPT_NAME will change from /foo to /foo/bar, and PATH_INFO0 will change from /bar/baz to /baz.

When PATH_INFO0 is just a “/”, this routine returns an empty string and appends a trailing slash to SCRIPT_NAME, even though empty path segments are normally ignored, and SCRIPT_NAME doesn’t normally end in a slash. This is intentional behavior, to ensure that an application can tell the difference between URIs ending in /x from ones ending in /x/ when using this routine to do object traversal.

wsgiref.util.setup_testing_defaults(environ)

Update environ with trivial defaults for testing purposes.

This routine adds various parameters required for WSGI, including
HTTP_HOST, SERVER_NAME, SERVER_PORT, REQUEST_METHOD, SCRIPT_NAME, PATH_INFO, and all of the PEP 3333-defined wsgi.* variables. It only supplies default values, and does not replace any existing settings for these variables.

This routine is intended to make it easier for unit tests of WSGI servers and applications to set up dummy environments. It should NOT be used by actual WSGI servers or applications, since the data is fake!

Example usage:

```python
from wsgiref.util import setup_testing_defaults
from wsgiref.simple_server import make_server

# A relatively simple WSGI application. It's going to print out the
# environment dictionary after being updated by setup_testing_defaults

def simple_app(environ, start_response):
    setup_testing_defaults(environ)

    status = '200 OK'
    headers = [('Content-type', 'text/plain; charset=utf-8')]

    start_response(status, headers)

    ret = ['%s: %s
' % (key, value).encode('utf-8')
        for key, value in environ.items()]
    return ret

httpd = make_server('', 8000, simple_app)
print("Serving on port 8000...")
httpd.serve_forever()
```

In addition to the environment functions above, the wsgiref.util
module also provides these miscellaneous utilities:

\texttt{wsgiref.util.is\_hop\_by\_hop(header\_name)}

Return true if ‘header\_name’ is an HTTP/1.1 “Hop-by-Hop” header, as defined by \texttt{RFC 2616}.

\texttt{class wsgiref.util.FileWrapper(filelike, blksize=8192)}

A wrapper to convert a file-like object to an \texttt{iterator}. The resulting objects support both \texttt{\_getitem()} and \texttt{\_iter()} iteration styles, for compatibility with Python 2.1 and Jython. As the object is iterated over, the optional \texttt{blksize} parameter will be repeatedly passed to the \texttt{filelike} object’s \texttt{read()} method to obtain bytestrings to yield. When \texttt{read()} returns an empty bytestring, iteration is ended and is not resumable.

If \texttt{filelike} has a \texttt{close()} method, the returned object will also have a \texttt{close()} method, and it will invoke the \texttt{filelike} object’s \texttt{close()} method when called.

Example usage:

\begin{verbatim}
from io import StringIO
from wsgiref.util import FileWrapper

# We're using a StringIO-buffer for as the file-like
filelike = StringIO("This is an example file-like
wrapper = FileWrapper(filelike, blksize=5)

for chunk in wrapper:
    print(chunk)
\end{verbatim}
This module provides a single class, `Headers`, for convenient manipulation of WSGI response headers using a mapping-like interface.

```python
class wsgiref.headers.Headers([headers])

Create a mapping-like object wrapping `headers`, which must be a list of header name/value tuples as described in PEP 3333. The default value of `headers` is an empty list.

`Headers` objects support typical mapping operations including `__getitem__()`, `get()`, `__setitem__()`, `setdefault()`, `__delitem__()` and `__contains__()`. For each of these methods, the key is the header name (treated case-insensitively), and the value is the first value associated with that header name. Setting a header deletes any existing values for that header, then adds a new value at the end of the wrapped header list. Headers’ existing order is generally maintained, with new headers added to the end of the wrapped list.

Unlike a dictionary, `Headers` objects do not raise an error when you try to get or delete a key that isn’t in the wrapped header list. Getting a nonexistent header just returns `None`, and deleting a nonexistent header does nothing.

`Headers` objects also support `keys()`, `values()`, and `items()` methods. The lists returned by `keys()` and `items()` can include the same key more than once if there is a multi-valued header. The `len()` of a `Headers` object is the same as the length of its
items(), which is the same as the length of the wrapped header list. In fact, the items() method just returns a copy of the wrapped header list.

Calling bytes() on a Headers object returns a formatted bytestring suitable for transmission as HTTP response headers. Each header is placed on a line with its value, separated by a colon and a space. Each line is terminated by a carriage return and line feed, and the bytestring is terminated with a blank line.

In addition to their mapping interface and formatting features, Headers objects also have the following methods for querying and adding multi-valued headers, and for adding headers with MIME parameters:

**get_all(name)**

Return a list of all the values for the named header.

The returned list will be sorted in the order they appeared in the original header list or were added to this instance, and may contain duplicates. Any fields deleted and re-inserted are always appended to the header list. If no fields exist with the given name, returns an empty list.

**add_header(name, value, **_params)**

Add a (possibly multi-valued) header, with optional MIME parameters specified via keyword arguments.

name is the header field to add. Keyword arguments can be used to set MIME parameters for the header field. Each parameter must be a string or None. Underscores in parameter names are converted to dashes, since dashes are illegal in Python identifiers, but many MIME parameter names include
dashes. If the parameter value is a string, it is added to the header value parameters in the form name="value". If it is None, only the parameter name is added. (This is used for MIME parameters without a value.) Example usage:

```python
h.add_header('content-disposition', 'attachment')
```

The above will add a header that looks like this:

```text
Content-Disposition: attachment; filename="bud.
```

*Changed in version 3.5: headers parameter is optional.*
21.4.3. **wsgiref.simple_server** — a simple WSGI HTTP server

This module implements a simple HTTP server (based on `http.server`) that serves WSGI applications. Each server instance serves a single WSGI application on a given host and port. If you want to serve multiple applications on a single host and port, you should create a WSGI application that parses `PATH_INFO` to select which application to invoke for each request. (E.g., using the `shift_path_info()` function from `wsgiref.util`.)

```python
wsgiref.simple_server.make_server(host, port, app,
server_class=WSGIServer, handler_class=WSGIRequestHandler)
```

Create a new WSGI server listening on `host` and `port`, accepting connections for `app`. The return value is an instance of the supplied `server_class`, and will process requests using the specified `handler_class`. `app` must be a WSGI application object, as defined by **PEP 3333**.

Example usage:

```python
from wsgiref.simple_server import make_server, demo_app

httpd = make_server('', 8000, demo_app)
print("Serving HTTP on port 8000...")

# Respond to requests until process is killed
httpd.serve_forever()

# Alternative: serve one request, then exit
httpd.handle_request()
```
wsgiref.simple_server.demo_app(environ, start_response)

This function is a small but complete WSGI application that returns a text page containing the message “Hello world!” and a list of the key/value pairs provided in the `environ` parameter. It's useful for verifying that a WSGI server (such as `wsgiref.simple_server`) is able to run a simple WSGI application correctly.

class wsgiref.simple_server.WSGIServer(server_address, RequestHandlerClass)

Create a `WSGIServer` instance. `server_address` should be a (host, port) tuple, and `RequestHandlerClass` should be the subclass of `http.server.BaseHTTPRequestHandler` that will be used to process requests.

You do not normally need to call this constructor, as the `make_server()` function can handle all the details for you.

`WSGIServer` is a subclass of `http.server.HTTPServer`, so all of its methods (such as `serve_forever()` and `handle_request()`) are available. `WSGIServer` also provides these WSGI-specific methods:

set_app(application)

Sets the callable `application` as the WSGI application that will receive requests.

get_app()

Returns the currently-set application callable.

Normally, however, you do not need to use these additional methods, as `set_app()` is normally called by `make_server()`, and the `get_app()` exists mainly for the benefit of request handler
instances.

class wsgiref.simple_server.WSGIRequestHandler(request, client_address, server)

Create an HTTP handler for the given request (i.e. a socket), client_address (a (host, port) tuple), and server (WSGIServer instance).

You do not need to create instances of this class directly; they are automatically created as needed by WSGIServer objects. You can, however, subclass this class and supply it as a handler_class to the make_server() function. Some possibly relevant methods for overriding in subclasses:

get_environ()

Returns a dictionary containing the WSGI environment for a request. The default implementation copies the contents of the WSGIServer object's base_environ dictionary attribute and then adds various headers derived from the HTTP request. Each call to this method should return a new dictionary containing all of the relevant CGI environment variables as specified in PEP 3333.

get_stderr()

Return the object that should be used as the wsgi.errors stream. The default implementation just returns sys.stderr.

handle()

Process the HTTP request. The default implementation creates a handler instance using a wsgiref.handlers class to implement the actual WSGI application interface.
21.4.4. **wsgiref.validate** — WSGI conformance checker

When creating new WSGI application objects, frameworks, servers, or middleware, it can be useful to validate the new code's conformance using `wsgiref.validate`. This module provides a function that creates WSGI application objects that validate communications between a WSGI server or gateway and a WSGI application object, to check both sides for protocol conformance.

Note that this utility does not guarantee complete PEP 3333 compliance; an absence of errors from this module does not necessarily mean that errors do not exist. However, if this module does produce an error, then it is virtually certain that either the server or application is not 100% compliant.

This module is based on the `paste.lint` module from Ian Bicking's "Python Paste" library.

**wsgiref.validate.validator(application)**

Wrap `application` and return a new WSGI application object. The returned application will forward all requests to the original `application`, and will check that both the `application` and the server invoking it are conforming to the WSGI specification and to RFC 2616.

Any detected nonconformance results in an `AssertionError` being raised; note, however, that how these errors are handled is server-dependent. For example, `wsgiref.simple_server` and other servers based on `wsgiref.handlers` (that don't override the error handling methods to do something else) will simply output
a message that an error has occurred, and dump the traceback to sys.stderr or some other error stream.

This wrapper may also generate output using the warnings module to indicate behaviors that are questionable but which may not actually be prohibited by PEP 3333. Unless they are suppressed using Python command-line options or the warnings API, any such warnings will be written to sys.stderr (not wsgi.errors, unless they happen to be the same object).

Example usage:

```python
from wsgiref.validate import validator
from wsgiref.simple_server import make_server

# Our callable object which is intentionally not a standard, so the validator is going to break
def simple_app(env, start_response):
    status = '200 OK' # HTTP Status
    headers = [('Content-type', 'text/plain')] # HTTP Headers
    start_response(status, headers)

    # This is going to break because we need to return a list, and the validator is going to inform us
    return b"Hello World"

# This is the application wrapped in a validator
validator_app = validator(simple_app)

httpd = make_server('', 8000, validator_app)
print("Listening on port 8000....")
httpd.serve_forever()
```
21.4.5. **wsgiref.handlers** – server/gateway base classes

This module provides base handler classes for implementing WSGI servers and gateways. These base classes handle most of the work of communicating with a WSGI application, as long as they are given a CGI-like environment, along with input, output, and error streams.

**class wsgiref.handlers.CGIHandler**

CGI-based invocation via sys.stdin, sys.stdout, sys.stderr and os.environ. This is useful when you have a WSGI application and want to run it as a CGI script. Simply invoke CGIHandler().run(app), where app is the WSGI application object you wish to invoke.

This class is a subclass of BaseCGIHandler that sets wsgi.run_once to true, wsgi.multithread to false, and wsgi.multiprocess to true, and always uses sys and os to obtain the necessary CGI streams and environment.

**class wsgiref.handlers.IISCGIHandler**

A specialized alternative to CGIHandler, for use when deploying on Microsoft’s IIS web server, without having set the config allowPathInfo option (IIS>=7) or metabase allowPathInfoForScriptMappings (IIS<7).

By default, IIS gives a PATH_INFO that duplicates the SCRIPT_NAME at the front, causing problems for WSGI applications that wish to implement routing. This handler strips any such duplicated path.
IIS can be configured to pass the correct PATH_INFO, but this causes another bug where PATH_TRANSLATED is wrong. Luckily this variable is rarely used and is not guaranteed by WSGI. On IIS<7, though, the setting can only be made on a vhost level, affecting all other script mappings, many of which break when exposed to the PATH_TRANSLATED bug. For this reason IIS<7 is almost never deployed with the fix. (Even IIS7 rarely uses it because there is still no UI for it.)

There is no way for CGI code to tell whether the option was set, so a separate handler class is provided. It is used in the same way as CGIHandler, i.e., by calling IISCGIHandler().run(app), where app is the WSGI application object you wish to invoke.

*New in version 3.2.*

```python
class wsgiref.handlers.BaseCGIHandler(stdin, stdout, stderr, environ, multithread=True, multiprocess=False)
```

Similar to CGIHandler, but instead of using the sys and os modules, the CGI environment and I/O streams are specified explicitly. The multithread and multiprocess values are used to set the wsgi.multithread and wsgi.multiprocess flags for any applications run by the handler instance.

This class is a subclass of SimpleHandler intended for use with software other than HTTP "origin servers". If you are writing a gateway protocol implementation (such as CGI, FastCGI, SCGI, etc.) that uses a Status: header to send an HTTP status, you probably want to subclass this instead of SimpleHandler.

```python
class wsgiref.handlers.SimpleHandler(stdin, stdout, stderr, environ, multithread=True, multiprocess=False)
```
Similar to `BaseCGIHandler`, but designed for use with HTTP origin servers. If you are writing an HTTP server implementation, you will probably want to subclass this instead of `BaseCGIHandler`.

This class is a subclass of `BaseHandler`. It overrides the `__init__()`, `get_stdin()`, `get_stderr()`, `add_cgi_vars()`, `__write()`, and `__flush()` methods to support explicitly setting the environment and streams via the constructor. The supplied environment and streams are stored in the `stdin`, `stdout`, `stderr`, and `environ` attributes.

```python
class wsgiref.handlers.BaseHandler
This is an abstract base class for running WSGI applications. Each instance will handle a single HTTP request, although in principle you could create a subclass that was reusable for multiple requests.

BaseHandler instances have only one method intended for external use:

```python
run(app)
```
Run the specified WSGI application, `app`.

All of the other `BaseHandler` methods are invoked by this method in the process of running the application, and thus exist primarily to allow customizing the process.

The following methods MUST be overridden in a subclass:

```python
__write(data)
```
Buffer the bytes `data` for transmission to the client. It’s okay if this method actually transmits the data; `BaseHandler` just
separates write and flush operations for greater efficiency when the underlying system actually has such a distinction.

_flush()
Force buffered data to be transmitted to the client. It's okay if this method is a no-op (i.e., if _write() actually sends the data).

get_stdin()
Return an input stream object suitable for use as the wsgi.input of the request currently being processed.

get_stderr()
Return an output stream object suitable for use as the wsgi.errors of the request currently being processed.

add_cgi_vars()
Insert CGI variables for the current request into the environ attribute.

Here are some other methods and attributes you may wish to override. This list is only a summary, however, and does not include every method that can be overridden. You should consult the docstrings and source code for additional information before attempting to create a customized BaseHandler subclass.

Attributes and methods for customizing the WSGI environment:

wsgi_multithread
The value to be used for the wsgi.multithread environment variable. It defaults to true in BaseHandler, but may have a different default (or be set by the constructor) in the other subclasses.
**wsgi_multiprocess**

The value to be used for the wsgi.multiprocess environment variable. It defaults to true in `BaseHandler`, but may have a different default (or be set by the constructor) in the other subclasses.

**wsgi_run_once**

The value to be used for the wsgi.run_once environment variable. It defaults to false in `BaseHandler`, but `CGIHandler` sets it to true by default.

**os_environ**

The default environment variables to be included in every request's WSGI environment. By default, this is a copy of `os.environ` at the time that `wsgiref.handlers` was imported, but subclasses can either create their own at the class or instance level. Note that the dictionary should be considered read-only, since the default value is shared between multiple classes and instances.

**server_software**

If the `origin_server` attribute is set, this attribute's value is used to set the default SERVER_SOFTWARE WSGI environment variable, and also to set a default Server: header in HTTP responses. It is ignored for handlers (such as `BaseCGIHandler` and `CGIHandler`) that are not HTTP origin servers.

*Changed in version 3.3:* The term “Python” is replaced with implementation specific term like “CPython”, “Jython” etc.
get_scheme()
Return the URL scheme being used for the current request. The default implementation uses the guess_scheme() function from wsgiref.util to guess whether the scheme should be “http” or “https”, based on the current request's environ variables.

setup_environ()
Set the environ attribute to a fully-populated WSGI environment. The default implementation uses all of the above methods and attributes, plus the get_stdin(), get_stderr(), and add_cgi_vars() methods and the wsgi_file_wrapper attribute. It also inserts a SERVER_SOFTWARE key if not present, as long as the origin_server attribute is a true value and the server_software attribute is set.

Methods and attributes for customizing exception handling:

log_exception(exc_info)
Log the exc_info tuple in the server log. exc_info is a (type, value, traceback) tuple. The default implementation simply writes the traceback to the request's wsgi.errors stream and flushes it. Subclasses can override this method to change the format or retarget the output, mail the traceback to an administrator, or whatever other action may be deemed suitable.

traceback_limit
The maximum number of frames to include in tracebacks output by the default log_exception() method. If None, all frames
are included.

**error_output**(*environ, start_response*)

This method is a WSGI application to generate an error page for the user. It is only invoked if an error occurs before headers are sent to the client.

This method can access the current error information using `sys.exc_info()`, and should pass that information to `start_response` when calling it (as described in the “Error Handling” section of [PEP 3333](https://www.python.org/dev/peps/pep-0333/)).

The default implementation just uses the `error_status`, `error_headers`, and `error_body` attributes to generate an output page. Subclasses can override this to produce more dynamic error output.

Note, however, that it’s not recommended from a security perspective to spit out diagnostics to any old user; ideally, you should have to do something special to enable diagnostic output, which is why the default implementation doesn’t include any.

**error_status**

The HTTP status used for error responses. This should be a status string as defined in [PEP 3333](https://www.python.org/dev/peps/pep-0333/); it defaults to a 500 code and message.

**error_headers**

The HTTP headers used for error responses. This should be a list of WSGI response headers ([(name, value) tuples], as described in [PEP 3333](https://www.python.org/dev/peps/pep-0333/). The default list just sets the content type to text/plain.
**error_body**

The error response body. This should be an HTTP response body bytestring. It defaults to the plain text, “A server error occurred. Please contact the administrator.”

Methods and attributes for **PEP 3333**'s “Optional Platform-Specific File Handling” feature:

**wsgi_file_wrapper**

A `wsgi.file_wrapper` factory, or None. The default value of this attribute is the `wsgiref.util.FileWrapper` class.

**sendfile()**

Override to implement platform-specific file transmission. This method is called only if the application's return value is an instance of the class specified by the `wsgi_file_wrapper` attribute. It should return a true value if it was able to successfully transmit the file, so that the default transmission code will not be executed. The default implementation of this method just returns a false value.

Miscellaneous methods and attributes:

**origin_server**

This attribute should be set to a true value if the handler's `_write()` and `_flush()` are being used to communicate directly to the client, rather than via a CGI-like gateway protocol that wants the HTTP status in a special `Status:` header.

This attribute's default value is true in `BaseHandler`, but false in `BaseCGIHandler` and `CGIHandler`.

**http_version**
If `origin_server` is true, this string attribute is used to set the HTTP version of the response set to the client. It defaults to "1.0".

`wsgiref.handlers.read_environ()`

Transcode CGI variables from `os.environ` to PEP 3333 “bytes in unicode” strings, returning a new dictionary. This function is used by `CGIHandler` and `IISCGIHandler` in place of directly using `os.environ`, which is not necessarily WSGI-compliant on all platforms and web servers using Python 3 – specifically, ones where the OS's actual environment is Unicode (i.e. Windows), or ones where the environment is bytes, but the system encoding used by Python to decode it is anything other than ISO-8859-1 (e.g. Unix systems using UTF-8).

If you are implementing a CGI-based handler of your own, you probably want to use this routine instead of just copying values out of `os.environ` directly.

*New in version 3.2.*
21.4.6. Examples

This is a working “Hello World” WSGI application:

```python
from wsgiref.simple_server import make_server

# Every WSGI application must have an application object that accepts two arguments. For that purpose use a function (note that you're not limited to a class for example). The first argument passed is a dictionary containing CGI-style environment variables and the second variable is the callable object (see PEP 333).

def hello_world_app(environ, start_response):
    status = '200 OK' # HTTP Status
    headers = [('Content-type', 'text/plain; charset=utf-8')]
    start_response(status, headers)
    # The returned object is going to be printed
    return [b"Hello World"]

httpd = make_server('', 8000, hello_world_app)
print("Serving on port 8000...")

# Serve until process is killed
httpd.serve_forever()
```
21.5. **urllib** — URL handling modules

urllib is a package that collects several modules for working with URLs:

- **urllib.request** for opening and reading URLs
- **urllib.error** containing the exceptions raised by **urllib.request**
- **urllib.parse** for parsing URLs
- **urllib.robotparser** for parsing robots.txt files
21.6. `urllib.request` — Extensible library for opening URLs

The `urllib.request` module defines functions and classes which help in opening URLs (mostly HTTP) in a complex world — basic and digest authentication, redirections, cookies and more.

**See also:** The Requests package is recommended for a higher-level http client interface.

The `urllib.request` module defines the following functions:

```python
urllib.request.urlopen(url, data=None, [timeout, ], *
cafile=None, capath=None, cadefault=False, context=None)
```

Open the URL `url`, which can be either a string or a `Request` object.

`data` must be a bytes object specifying additional data to be sent to the server, or None if no such data is needed. `data` may also be an iterable object and in that case Content-Length value must be specified in the headers. Currently HTTP requests are the only ones that use `data`; the HTTP request will be a POST instead of a GET when the `data` parameter is provided.

`data` should be a buffer in the standard `application/x-www-form-urlencoded` format. The `urllib.parse.urlencode()` function takes a mapping or sequence of 2-tuples and returns a string in this format. It should be encoded to bytes before being used as the
data parameter. The charset parameter in Content-Type header may be used to specify the encoding. If charset parameter is not sent with the Content-Type header, the server following the HTTP 1.1 recommendation may assume that the data is encoded in ISO-8859-1 encoding. It is advisable to use charset parameter with encoding used in Content-Type header with the Request.

urllib.request module uses HTTP/1.1 and includes Connection:close header in its HTTP requests.

The optional timeout parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used). This actually only works for HTTP, HTTPS and FTP connections.

If context is specified, it must be a ssl.SSLContext instance describing the various SSL options. See HTTPSConnection for more details.

The optional cafile and capath parameters specify a set of trusted CA certificates for HTTPS requests. cafile should point to a single file containing a bundle of CA certificates, whereas capath should point to a directory of hashed certificate files. More information can be found in ssl.SSLContext.load_verify_locations().

The cadefault parameter is ignored.

For http and https urls, this function returns a http.client.HTTPResponse object which has the following HTTPResponse Objects methods.

For ftp, file, and data urls and requests explicitly handled by legacy URLopener and FancyURLopener classes, this function returns a
urllib.response.addinfourl object which can work as context manager and has methods such as

- `geturl()` — return the URL of the resource retrieved, commonly used to determine if a redirect was followed
- `info()` — return the meta-information of the page, such as headers, in the form of an `email.message_from_string()` instance (see Quick Reference to HTTP Headers)
- `getcode()` – return the HTTP status code of the response.

Raises `URLError` on errors.

Note that None may be returned if no handler handles the request (though the default installed global `OpenerDirector` uses `UnknownHandler` to ensure this never happens).

In addition, if proxy settings are detected (for example, when a `*_proxy` environment variable like `http_proxy` is set), `ProxyHandler` is default installed and makes sure the requests are handled through the proxy.

The legacy `urllib.urlopen` function from Python 2.6 and earlier has been discontinued; `urllib.request.urlopen()` corresponds to the old `urllib2.urlopen`. Proxy handling, which was done by passing a dictionary parameter to `urllib.urlopen`, can be obtained by using `ProxyHandler` objects.

*Changed in version 3.2:* `cafile` and `capath` were added.

*Changed in version 3.2:* HTTPS virtual hosts are now supported if possible (that is, if `ssl.HAS_SNI` is true).

*New in version 3.2:* `data` can be an iterable object.
Changed in version 3.3: cadefault was added.

Changed in version 3.4.3: context was added.

urllib.request.\texttt{install\_opener}(opener)

Install an OpenerDirector instance as the default global opener. Installing an opener is only necessary if you want urlopen to use that opener; otherwise, simply call \texttt{OpenerDirector.open()} instead of \texttt{urlopen()}. The code does not check for a real OpenerDirector, and any class with the appropriate interface will work.

urllib.request.\texttt{build\_opener}([\texttt{handler}, ...])

Return an OpenerDirector instance, which chains the handlers in the order given. handlers can be either instances of BaseHandler, or subclasses of BaseHandler (in which case it must be possible to call the constructor without any parameters). Instances of the following classes will be in front of the handlers, unless the handlers contain them, instances of them or subclasses of them: ProxyHandler (if proxy settings are detected), UnknownHandler, HTTPDefaultErrorHandler, HTTPRedirectHandler, FTPHandler, FileHandler, HTTPErrorProcessor.

If the Python installation has SSL support (i.e., if the ssl module can be imported), HTTPSHandler will also be added.

A BaseHandler subclass may also change its handler_order attribute to modify its position in the handlers list.

urllib.request.\texttt{pathname2url}(path)

Convert the pathname path from the local syntax for a path to the
form used in the path component of a URL. This does not produce a complete URL. The return value will already be quoted using the \texttt{quote()} function.

\texttt{urllib.request.url2pathname(path)}  
Convert the path component \textit{path} from a percent-encoded URL to the local syntax for a path. This does not accept a complete URL. This function uses \texttt{unquote()} to decode \textit{path}.

\texttt{urllib.request.getproxies()}  
This helper function returns a dictionary of scheme to proxy server URL mappings. It scans the environment for variables named \texttt{<scheme>_proxy}, in a case insensitive approach, for all operating systems first, and when it cannot find it, looks for proxy information from Mac OS X System Configuration for Mac OS X and Windows Systems Registry for Windows.

The following classes are provided:

\texttt{class urllib.request.Request(url, data=None, headers={}, origin_req_host=None, unverifiable=False, method=None)}  
This class is an abstraction of a URL request.

\texttt{url} should be a string containing a valid URL.

\texttt{data} must be a bytes object specifying additional data to send to the server, or None if no such data is needed. Currently HTTP requests are the only ones that use \texttt{data}; the HTTP request will be a POST instead of a GET when the \texttt{data} parameter is provided. \texttt{data} should be a buffer in the standard \texttt{application/x-www-form-urlencoded} format.

The \texttt{urllib.parse.urlencode()} function takes a mapping or
sequence of 2-tuples and returns a string in this format. It should be encoded to bytes before being used as the data parameter. The charset parameter in Content-Type header may be used to specify the encoding. If charset parameter is not sent with the Content-Type header, the server following the HTTP 1.1 recommendation may assume that the data is encoded in ISO-8859-1 encoding. It is advisable to use charset parameter with encoding used in Content-Type header with the Request.

headers should be a dictionary, and will be treated as if add_header() was called with each key and value as arguments. This is often used to “spoon” the User-Agent header, which is used by a browser to identify itself – some HTTP servers only allow requests coming from common browsers as opposed to scripts. For example, Mozilla Firefox may identify itself as "Mozilla/5.0 (X11; U; Linux i686) Gecko/20071127 Firefox/2.0.0.11", while urllib's default user agent string is "Python-urllib/2.6" (on Python 2.6).

An example of using Content-Type header with data argument would be sending a dictionary like {"Content-Type": "application/x-www-form-urlencoded; charset=utf-8"}.

The final two arguments are only of interest for correct handling of third-party HTTP cookies:

origin_req_host should be the request-host of the origin transaction, as defined by RFC 2965. It defaults to http.cookiejar.request_host(self). This is the host name or IP address of the original request that was initiated by the user. For example, if the request is for an image in an HTML document, this should be the request-host of the request for the
page containing the image.

unverifiable should indicate whether the request is unverifiable, as defined by RFC 2965. It defaults to False. An unverifiable request is one whose URL the user did not have the option to approve. For example, if the request is for an image in an HTML document, and the user had no option to approve the automatic fetching of the image, this should be true.

method should be a string that indicates the HTTP request method that will be used (e.g. 'HEAD'). If provided, its value is stored in the method attribute and is used by get_method(). Subclasses may indicate a default method by setting the method attribute in the class itself.

Changed in version 3.3: Request.method argument is added to the Request class.

Changed in version 3.4: Default Request.method may be indicated at the class level.

class urllib.request.OpenerDirector

The OpenerDirector class opens URLs via BaseHandlers chained together. It manages the chaining of handlers, and recovery from errors.

class urllib.request.BaseHandler

This is the base class for all registered handlers — and handles only the simple mechanics of registration.

class urllib.request.HTTPDefaultErrorHandler

A class which defines a default handler for HTTP error responses; all responses are turned into HTTPError exceptions.
class urllib.request.HTTPRedirectHandler
    A class to handle redirections.

class urllib.request.HTTPCookieProcessor(cookiejar=None)
    A class to handle HTTP Cookies.

class urllib.request.ProxyHandler(proxies=None)
    Cause requests to go through a proxy. If proxies is given, it must be
    a dictionary mapping protocol names to URLs of proxies. The
default is to read the list of proxies from the environment variables
<protocol>_proxy. If no proxy environment variables are set,
then in a Windows environment proxy settings are obtained from
the registry's Internet Settings section, and in a Mac OS X
environment proxy information is retrieved from the OS X System
Configuration Framework.

    To disable autodetected proxy pass an empty dictionary.

class urllib.request.HTTPPasswordMgr
    Keep a database of (realm, uri) -> (user, password)
mappings.

class urllib.request.HTTPPasswordMgrWithDefaultRealm
    Keep a database of (realm, uri) -> (user, password)
mappings. A realm of None is considered a catch-all realm, which
is searched if no other realm fits.

class urllib.request.HTTPPasswordMgrWithPriorAuth
    A variant of HTTPPasswordMgrWithDefaultRealm that also
has a database of uri -> is_authenticated mappings. Can
be used by a BasicAuth handler to determine when to send
authentication credentials immediately instead of waiting for a 401 response first.

*New in version 3.5.*

class urllib.request.AbstractBasicAuthHandler(password_mngr=None)

This is a mixin class that helps with HTTP authentication, both to the remote host and to a proxy. `password_mngr`, if given, should be something that is compatible with `HTTPPasswordMgr`; refer to section `HTTPPasswordMgr Objects` for information on the interface that must be supported. If `passwd_mgr` also provides `is_authenticated` and `update_authenticated` methods (see `HTTPPasswordMgrWithPriorAuth Objects`), then the handler will use the `is_authenticated` result for a given URI to determine whether or not to send authentication credentials with the request. If `is_authenticated` returns `True` for the URI, credentials are sent. If `is_authenticated` is `False`, credentials are not sent, and then if a 401 response is received the request is re-sent with the authentication credentials. If authentication succeeds, `update_authenticated` is called to set `is_authenticated` `True` for the URI, so that subsequent requests to the URI or any of its super-URIs will automatically include the authentication credentials.

*New in version 3.5: Added `is_authenticated` support.*

class urllib.request.HTTPBasicAuthHandler(password_mngr=None)

Handle authentication with the remote host. `password_mngr`, if given, should be something that is compatible with `HTTPPasswordMgr`; refer to section `HTTPPasswordMgr Objects`
for information on the interface that must be supported. HTTPBasicAuthHandler will raise a `ValueError` when presented with a wrong Authentication scheme.

class urllib.request.ProxyBasicAuthHandler(password_mgr=None)
    Handle authentication with the proxy. `password_mgr`, if given, should be something that is compatible with `HTTPPasswordMgr`; refer to section `HTTPPasswordMgr Objects` for information on the interface that must be supported.

class urllib.request.AbstractDigestAuthHandler(password_mgr=None)
    This is a mixin class that helps with HTTP authentication, both to the remote host and to a proxy. `password_mgr`, if given, should be something that is compatible with `HTTPPasswordMgr`; refer to section `HTTPPasswordMgr Objects` for information on the interface that must be supported.

class urllib.request.HTTPDigestAuthHandler(password_mgr=None)
    Handle authentication with the remote host. `password_mgr`, if given, should be something that is compatible with `HTTPPasswordMgr`; refer to section `HTTPPasswordMgr Objects` for information on the interface that must be supported. When both Digest Authentication Handler and Basic Authentication Handler are both added, Digest Authentication is always tried first. If the Digest Authentication returns a 40x response again, it is sent to Basic Authentication handler to Handle. This Handler method will raise a `ValueError` when presented with an authentication scheme other than Digest or Basic.
Changed in version 3.3: Raise `ValueError` on unsupported Authentication Scheme.

class urllib.request.ProxyDigestAuthHandler(password_mgr):
    Handle authentication with the proxy. `password_mgr`, if given, should be something that is compatible with `HTTPPasswordMgr`; refer to section `HTTPPasswordMgr Objects` for information on the interface that must be supported.

class urllib.request.HTTPHandler
    A class to handle opening of HTTP URLs.

class urllib.request.HTTPSHandler(debuglevel=0, context=None, check_hostname=None)
    A class to handle opening of HTTPS URLs. `context` and `check_hostname` have the same meaning as in `http.client.HTTPSConnection`.

    Changed in version 3.2: `context` and `check_hostname` were added.

class urllib.request.FileHandler
    Open local files.

class urllib.request.DataHandler
    Open data URLs.

    New in version 3.4.

class urllib.request.FTPHandler
    Open FTP URLs.

class urllib.request.CacheFTPHandler
    Open FTP URLs, keeping a cache of open FTP connections to
minimize delays.

`class urllib.request.UnknownHandler`
A catch-all class to handle unknown URLs.

`class urllib.request.HTTPErrorProcessor`
Process HTTP error responses.
21.6.1. Request Objects

The following methods describe `Request`'s public interface, and so all may be overridden in subclasses. It also defines several public attributes that can be used by clients to inspect the parsed request.

Request.**full_url**

The original URL passed to the constructor.

*Changed in version 3.4.*

Request.full_url is a property with setter, getter and a deleter. Getting **full_url** returns the original request URL with the fragment, if it was present.

Request.**type**

The URI scheme.

Request.**host**

The URI authority, typically a host, but may also contain a port separated by a colon.

Request.**origin_req_host**

The original host for the request, without port.

Request.**selector**

The URI path. If the `Request` uses a proxy, then selector will be the full url that is passed to the proxy.

Request.**data**

The entity body for the request, or None if not specified.

*Changed in version 3.4:* Changing value of `Request.data` now
deletes “Content-Length” header if it was previously set or calculated.

Request.unverifiable

boolean, indicates whether the request is unverifiable as defined by RFC 2965.

Request.method

The HTTP request method to use. By default its value is None, which means that get_method() will do its normal computation of the method to be used. Its value can be set (thus overriding the default computation in get_method()) either by providing a default value by setting it at the class level in a Request subclass, or by passing a value in to the Request constructor via the method argument.

New in version 3.3.

Changed in version 3.4: A default value can now be set in subclasses; previously it could only be set via the constructor argument.

Request.get_method()

Return a string indicating the HTTP request method. If Request.method is not None, return its value, otherwise return 'GET' if Request.data is None, or 'POST' if it's not. This is only meaningful for HTTP requests.

Changed in version 3.3: get_method now looks at the value of Request.method.

Request.add_header(key, val)

Add another header to the request. Headers are currently ignored
by all handlers except HTTP handlers, where they are added to the list of headers sent to the server. Note that there cannot be more than one header with the same name, and later calls will overwrite previous calls in case the `key` collides. Currently, this is no loss of HTTP functionality, since all headers which have meaning when used more than once have a (header-specific) way of gaining the same functionality using only one header.

Request `.add_unredirected_header(key, header)`
Add a header that will not be added to a redirected request.

Request `.has_header(header)`
Return whether the instance has the named header (checks both regular and unredirected).

Request `.remove_header(header)`
Remove named header from the request instance (both from regular and unredirected headers).

*New in version 3.4.*

Request `.get_full_url()`
Return the URL given in the constructor.

*Changed in version 3.4.*

Returns `Request.full_url`

Request `.set_proxy(host, type)`
Prepare the request by connecting to a proxy server. The `host` and `type` will replace those of the instance, and the instance's selector will be the original URL given in the constructor.
Request.\texttt{get\_header}(header\_name, default=\texttt{None})

Return the value of the given header. If the header is not present, return the default value.

Request.\texttt{header\_items}()

Return a list of tuples (header\_name, header\_value) of the Request headers.

\textit{Changed in version 3.4:} The request methods \texttt{add\_data}, \texttt{has\_data}, \texttt{get\_data}, \texttt{get\_type}, \texttt{get\_host}, \texttt{get\_selector}, \texttt{get\_origin\_req\_host} and \texttt{is\_unverifiable} that were deprecated since 3.3 have been removed.
21.6.2. OpenerDirector Objects

**OpenerDirector** instances have the following methods:

**OpenerDirector.**`add_handler(handler)`

*handler* should be an instance of **BaseHandler**. The following methods are searched, and added to the possible chains (note that HTTP errors are a special case).

- **protocol_open()** — signal that the handler knows how to open protocol URLs.
- **http_error_type()** — signal that the handler knows how to handle HTTP errors with HTTP error code *type*.
- **protocol_error()** — signal that the handler knows how to handle errors from (non-http) protocol.
- **protocol_request()** — signal that the handler knows how to pre-process protocol requests.
- **protocol_response()** — signal that the handler knows how to post-process protocol responses.

**OpenerDirector.**`open(url, data=None[, timeout])`

Open the given *url* (which can be a request object or a string), optionally passing the given *data*. Arguments, return values and exceptions raised are the same as those of `urlopen()` (which simply calls the `open()` method on the currently installed global **OpenerDirector**). The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used). The timeout feature actually works only for HTTP, HTTPS and FTP connections).
OpenerDirector.error(proto, *args)

Handle an error of the given protocol. This will call the registered error handlers for the given protocol with the given arguments (which are protocol specific). The HTTP protocol is a special case which uses the HTTP response code to determine the specific error handler; refer to the http_error_*() methods of the handler classes.

Return values and exceptions raised are the same as those of urlopen().

OpenerDirector objects open URLs in three stages:

The order in which these methods are called within each stage is determined by sorting the handler instances.

1. Every handler with a method named like protocol_request() has that method called to pre-process the request.

2. Handlers with a method named like protocol_open() are called to handle the request. This stage ends when a handler either returns a non-None value (ie. a response), or raises an exception (usually URLError). Exceptions are allowed to propagate.

In fact, the above algorithm is first tried for methods named default_open(). If all such methods return None, the algorithm is repeated for methods named like protocol_open(). If all such methods return None, the algorithm is repeated for methods named unknown_open().

Note that the implementation of these methods may involve calls of the parent OpenerDirector instance's open() and error()
methods.

3. Every handler with a method named like `protocol_response()` has that method called to post-process the response.
21.6.3. BaseHandler Objects

BaseHandler objects provide a couple of methods that are directly useful, and others that are meant to be used by derived classes. These are intended for direct use:

BaseHandler .add_parent(director)

Add a director as parent.

BaseHandler .close()

Remove any parents.

The following attribute and methods should only be used by classes derived from BaseHandler.

Note: The convention has been adopted that subclasses defining protocol_request() or protocol_response() methods are named *Processor; all others are named *Handler.

BaseHandler .parent

A valid OpenerDirector, which can be used to open using a different protocol, or handle errors.

BaseHandler .default_open(req)

This method is not defined in BaseHandler, but subclasses should define it if they want to catch all URLs.

This method, if implemented, will be called by the parent OpenerDirector. It should return a file-like object as described in the return value of the open() of OpenerDirector, or None. It should raise URLError, unless a truly exceptional thing happens
(for example, MemoryError should not be mapped to URLError).

This method will be called before any protocol-specific open method.

BaseHandler.\texttt{protocol\_open}(\textit{req})
This method is \textit{not} defined in BaseHandler, but subclasses should define it if they want to handle URLs with the given protocol.

This method, if defined, will be called by the parent OpenerDirector. Return values should be the same as for \texttt{default\_open}().

BaseHandler.\texttt{unknown\_open}(\textit{req})
This method is \textit{not} defined in BaseHandler, but subclasses should define it if they want to catch all URLs with no specific registered handler to open it.

This method, if implemented, will be called by the parent OpenerDirector. Return values should be the same as for \texttt{default\_open}().

BaseHandler.\texttt{http\_error\_default}(\textit{req}, \textit{fp}, \textit{code}, \textit{msg}, \textit{hdrs})
This method is \textit{not} defined in BaseHandler, but subclasses should override it if they intend to provide a catch-all for otherwise unhandled HTTP errors. It will be called automatically by the OpenerDirector getting the error, and should not normally be called in other circumstances.

\textit{req} will be a Request object, \textit{fp} will be a file-like object with the HTTP error body, \textit{code} will be the three-digit code of the error, \textit{msg} will be the user-visible explanation of the code and \textit{hdrs} will be a
mapping object with the headers of the error.

Return values and exceptions raised should be the same as those of `urlopen()`.

`BaseHandler.http_error_nnn(req, fp, code, msg, hdrs)`

`nnn` should be a three-digit HTTP error code. This method is also not defined in `BaseHandler`, but will be called, if it exists, on an instance of a subclass, when an HTTP error with code `nnn` occurs.

Subclasses should override this method to handle specific HTTP errors.

Arguments, return values and exceptions raised should be the same as for `http_error_default()`.

`BaseHandler.protocol_request(req)`

This method is `not` defined in `BaseHandler`, but subclasses should define it if they want to pre-process requests of the given protocol.

This method, if defined, will be called by the parent `OpenerDirector`. `req` will be a `Request` object. The return value should be a `Request` object.

`BaseHandler.protocol_response(req, response)`

This method is `not` defined in `BaseHandler`, but subclasses should define it if they want to post-process responses of the given protocol.

This method, if defined, will be called by the parent `OpenerDirector`. `req` will be a `Request` object. `response` will be an object implementing the same interface as the return value of
urlopen(). The return value should implement the same interface as the return value of urlopen().
21.6.4. HTTPRedirectHandler Objects

Note: Some HTTP redirecions require action from this module's client code. If this is the case, HTTPError is raised. See RFC 2616 for details of the precise meanings of the various redirection codes.

An HTTPError exception raised as a security consideration if the HTTPRedirectHandler is presented with a redirected url which is not an HTTP, HTTPS or FTP url.

HTTPRedirectHandler. redirect_request(req, fp, code, msg, hdrs, newurl)

Return a Request or None in response to a redirect. This is called by the default implementations of the http_error_30*() methods when a redirection is received from the server. If a redirection should take place, return a new Request to allow http_error_30*() to perform the redirect to newurl. Otherwise, raise HTTPError if no other handler should try to handle this URL, or return None if you can’t but another handler might.

Note: The default implementation of this method does not strictly follow RFC 2616, which says that 301 and 302 responses to POST requests must not be automatically redirected without confirmation by the user. In reality, browsers do allow automatic redirection of these responses, changing the POST to a GET, and the default implementation reproduces this behavior.

HTTPRedirectHandler. http_error_301(req, fp, code, msg, hdrs)

Redirect to the Location: or URI: URL. This method is called by
the parent **OpenerDirector** when getting an HTTP 'moved permanently' response.

HTTPRedirectHandler.**http_error_302**(req, fp, code, msg, hdrs)

The same as **http_error_301()**, but called for the ‘found’ response.

HTTPRedirectHandler.**http_error_303**(req, fp, code, msg, hdrs)

The same as **http_error_301()**, but called for the ‘see other’ response.

HTTPRedirectHandler.**http_error_307**(req, fp, code, msg, hdrs)

The same as **http_error_301()**, but called for the ‘temporary redirect’ response.
21.6.5. HTTPCookieProcessor Objects

HTTPCookieProcessor instances have one attribute:

HTTPCookieProcessor.**cookiejar**

The http.cookiejar.CookieJar in which cookies are stored.
21.6.6. ProxyHandler Objects

ProxyHandler.\texttt{protocol\_open}(\textit{request})

The \texttt{ProxyHandler} will have a method \texttt{protocol\_open()} for every \texttt{protocol} which has a proxy in the \texttt{proxies} dictionary given in the constructor. The method will modify requests to go through the proxy, by calling \texttt{request.set\_proxy()}, and call the next handler in the chain to actually execute the protocol.
21.6.7. HTTPPasswordMgr Objects

These methods are available on HTTPPasswordMgr and HTTPPasswordMgrWithDefaultRealm objects.

HTTPPasswordMgr.add_password(realm, uri, user, passwd)

uri can be either a single URI, or a sequence of URIs. realm, user and passwd must be strings. This causes (user, passwd) to be used as authentication tokens when authentication for realm and a super-URI of any of the given URIs is given.

HTTPPasswordMgr.find_user_password(realm, authuri)

Get user/password for given realm and URI, if any. This method will return (None, None) if there is no matching user/password.

For HTTPPasswordMgrWithDefaultRealm objects, the realm None will be searched if the given realm has no matching user/password.
21.6.8. HTTPPasswordMgrWithPriorAuth Objects

This password manager extends HTTPPasswordMgrWithDefaultRealm to support tracking URIs for which authentication credentials should always be sent.

HTTPPasswordMgrWithPriorAuth.add_password(realm, uri, user, passwd, is_authenticated=False)

realm, uri, user, passwd are as for HTTPPasswordMgr.add_password(). is_authenticated sets the initial value of the is_authenticated flag for the given URI or list of URIs. If is_authenticated is specified as True, realm is ignored.

HTTPPasswordMgr.find_user_password(realm, authuri)

Same as for HTTPPasswordMgrWithDefaultRealm objects

HTTPPasswordMgrWithPriorAuth.update_authenticated(uri, is_authenticated=False)

Update the is_authenticated flag for the given uri or list of URIs.

HTTPPasswordMgrWithPriorAuth.is_authenticated(self, authuri)

Returns the current state of the is_authenticated flag for the given URI.
21.6.9. AbstractBasicAuthHandler Objects

AbstractBasicAuthHandler.http_error_auth_reqed(authreq, host, req, headers)

Handle an authentication request by getting a user/password pair, and re-trying the request. authreq should be the name of the header where the information about the realm is included in the request, host specifies the URL and path to authenticate for, req should be the (failed) Request object, and headers should be the error headers.

host is either an authority (e.g. "python.org") or a URL containing an authority component (e.g. "http://python.org/"). In either case, the authority must not contain a userinfo component (so, "python.org" and "python.org:80" are fine, "joe:password@python.org" is not).
21.6.10. HTTPBasicAuthHandler Objects

HTTPBasicAuthHandler.\texttt{http\_error\_401}(req, \textit{fp}, \textit{code}, \textit{msg}, \textit{hdrs})

Retry the request with authentication information, if available.
21.6.11. ProxyBasicAuthHandler Objects

ProxyBasicAuthHandler.\texttt{http\_error\_407}(req, fp, code, msg, hdrs)

Retry the request with authentication information, if available.
21.6.12. AbstractDigestAuthHandler

Objects

AbstractDigestAuthHandler.\texttt{http_error_auth_required}(\texttt{authreq}, \texttt{host}, \texttt{req}, \texttt{headers})

\texttt{authreq} should be the name of the header where the information about the realm is included in the request, \texttt{host} should be the host to authenticate to, \texttt{req} should be the (failed) \texttt{Request} object, and \texttt{headers} should be the error headers.
21.6.13. HTTPDigestAuthHandler Objects

HTTPDigestAuthHandler.\texttt{http\_error\_401}(req, fp, code, msg, hdrs)

Retry the request with authentication information, if available.

ProxyDigestAuthHandler.http_error_407(req, fp, code, msg, hdrs)

Retry the request with authentication information, if available.
21.6.15. HTTPHandler Objects

HTTPHandler.\texttt{http\_open}(\texttt{req})
Send an HTTP request, which can be either GET or POST, depending on \texttt{req.has\_data}().
21.6.16. HTTPSHandler Objects

HTTPSHandler.\texttt{https\_open}(\textit{req})

Send an HTTPS request, which can be either GET or POST, depending on \textit{req}.\texttt{has\_data}().
21.6.17. FileHandler Objects

FileHandler.\texttt{\textbf{file\_open}}(\texttt{req})

Open the file locally, if there is no host name, or the host name is 'localhost'.

\textit{Changed in version 3.2:} This method is applicable only for local hostnames. When a remote hostname is given, an \texttt{URLError} is raised.
21.6.18. DataHandler Objects

DataHandler\texttt{.data\_open}(req)
Read a data URL. This kind of URL contains the content encoded in the URL itself. The data URL syntax is specified in \texttt{RFC 2397}. This implementation ignores white spaces in base64 encoded data URLs so the URL may be wrapped in whatever source file it comes from. But even though some browsers don’t mind about a missing padding at the end of a base64 encoded data URL, this implementation will raise an \texttt{ValueError} in that case.
21.6.19. FTPHandler Objects

FTPHandler.\texttt{ftp\_open}(\textit{req})

Open the FTP file indicated by \textit{req}. The login is always done with empty username and password.
21.6.20. CacheFTPHandler Objects

CacheFTPHandler objects are FTPHandler objects with the following additional methods:

CacheFTPHandler.\texttt{setTimeout}(t)

Set timeout of connections to $t$ seconds.

CacheFTPHandler.\texttt{setMaxConns}(m)

Set maximum number of cached connections to $m$. 
21.6.21. UnknownHandler Objects

UnknownHandler.\texttt{unknown\_open()}

Raise a \texttt{URLError} exception.
HTTPErrorProcessor Objects

HTTPErrorProcessor. `http_response()`
Process HTTP error responses.

For 200 error codes, the response object is returned immediately.

For non-200 error codes, this simply passes the job on to the `protocol_error_code()` handler methods, via `OpenerDirector.error()`. Eventually, `HTTPDefaultErrorHandler` will raise an `HTTPError` if no other handler handles the error.

HTTPErrorProcessor. `https_response()`
Process HTTPS error responses.

The behavior is same as `http_response()`.
This example gets the python.org main page and displays the first 300 bytes of it.

```python
>>> import urllib.request

>>> with urllib.request.urlopen('http://www.python.org/') as f:
    print(f.read(300))
```

Note that urlopen returns a bytes object. This is because there is no way for urlopen to automatically determine the encoding of the byte stream it receives from the http server. In general, a program will decode the returned bytes object to string once it determines or guesses the appropriate encoding.

The following W3C document, [http://www.w3.org/International/O-charset](http://www.w3.org/International/O-charset), lists the various ways in which a (X)HTML or a XML document could have specified its encoding information.

As the python.org website uses utf-8 encoding as specified in its meta tag, we will use the same for decoding the bytes object.

```python
>>> with urllib.request.urlopen('http://www.python.org/') as f:
    print(f.read(100).decode('utf-8'))
```
It is also possible to achieve the same result without using the context manager approach.

```python
>>> import urllib.request
>>> f = urllib.request.urlopen('http://www.python.org/)
>>> print(f.read(100).decode('utf-8'))
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" http://www.w3.org/TR/xhtml1/DTD/xhtml1-1.dtd>
...
```

In the following example, we are sending a data-stream to the stdin of a CGI and reading the data it returns to us. Note that this example will only work when the Python installation supports SSL.

```python
>>> import urllib.request
>>> req = urllib.request.Request(url='https://localhost/cgi-bin/test.cgi'
... data=b'This data is passed to stdin of the CGI'
>>> with urllib.request.urlopen(req) as f:
... print(f.read().decode('utf-8'))
... Got Data: "This data is passed to stdin of the CGI"
```

The code for the sample CGI used in the above example is:

```python
#!/usr/bin/env python
import sys
data = sys.stdin.read()
print('Content-type: text/plain

Got Data: "%s"
```
Use of Basic HTTP Authentication:

```python
import urllib.request
# Create an OpenerDirector with support for Basic HTTP Authentication...
auth_handler = urllib.request.HTTPBasicAuthHandler()
auth_handler.add_password(realm='PDQ Application',
                           uri='https://mahler:8092/site-updates.py',
                           user='klem',
                           passwd='kadidd!ehopper')
operator = urllib.request.build_opener(auth_handler)
# ...and install it globally so it can be used with urllib.request.urlopen(opener)
urllib.request.urlopen('http://www.example.com/login.html')
```

`build_opener()` provides many handlers by default, including a `ProxyHandler`. By default, `ProxyHandler` uses the environment variables named `<scheme>_proxy`, where `<scheme>` is the URL scheme involved. For example, the `http_proxy` environment variable is read to obtain the HTTP proxy's URL.

This example replaces the default `ProxyHandler` with one that uses programmatically-supplied proxy URLs, and adds proxy authorization support with `ProxyBasicAuthHandler`.

```python
proxy_handler = urllib.request.ProxyHandler({'http':
                                           'https':
                                           proxy_auth_handler = urllib.request.ProxyBasicAuthHandler()
proxy_auth_handler.add_password('realm', 'host', 'user'
```
Adding HTTP headers:

Use the `headers` argument to the `Request` constructor, or:

```python
import urllib.request
req = urllib.request.Request('http://www.example.com')
req.add_header('Referer', 'http://www.python.org/')
r = urllib.request.urlopen(req)
```

`OpenerDirector` automatically adds a `User-Agent` header to every `Request`. To change this:

```python
import urllib.request
opener = urllib.request.build_opener()
opener.addheaders = [('User-agent', 'Mozilla/5.0')]
opener.open('http://www.example.com/')
```

Also, remember that a few standard headers (`Content-Length`, `Content-Type` without charset parameter and `Host`) are added when the `Request` is passed to `urlopen()` (or `OpenerDirector.open()`).

Here is an example session that uses the GET method to retrieve a URL containing parameters:

```python
>>> import urllib.request
>>> import urllib.parse
>>> params = urllib.parse.urlencode({'spam': 1, 'egg': 2})
>>> url = "http://www.musical.com/cgi-bin/query?%s"
```
The following example uses the POST method instead. Note that params output from urlencode is encoded to bytes before it is sent to urlopen as data:

```python
>>> import urllib.request
>>> import urllib.parse
>>> data = urllib.parse.urlencode({'spam': 1, 'eggs': 2})
>>> data = data.encode('utf-8')
>>> request = urllib.request.Request("http://requestb.in/xrbl82xr"
>>> # adding charset parameter to the Content-Type header.
>>> request.add_header("Content-Type","application/x-www-form-urlencoded; charset=utf-8")
>>> with urllib.request.urlopen(request, data) as f:
...    print(f.read().decode('utf-8'))
```

The following example uses an explicitly specified HTTP proxy, overriding environment settings:

```python
>>> import urllib.request
>>> proxies = {'http': 'http://proxy.example.com:8080/'}
>>> opener = urllib.request.FancyURLopener(proxies)
>>> with opener.open("http://www.python.org") as f:
...    f.read().decode('utf-8')
```

The following example uses no proxies at all, overriding environment settings:

```python
>>> import urllib.request
```
>>> opener = urllib.request.FancyURLopener({})
>>> with opener.open("http://www.python.org/") as f:
...    f.read().decode('utf-8')
...
21.6.24. Legacy interface

The following functions and classes are ported from the Python 2 module urllib (as opposed to urllib2). They might become deprecated at some point in the future.

urllib.request.urlretrieve(url, filename=None, reporthook=None, data=None)

Copy a network object denoted by a URL to a local file. If the URL points to a local file, the object will not be copied unless filename is supplied. Return a tuple (filename, headers) where filename is the local file name under which the object can be found, and headers is whatever the info() method of the object returned by urlopen() returned (for a remote object). Exceptions are the same as for urlopen().

The second argument, if present, specifies the file location to copy to (if absent, the location will be a tempfile with a generated name). The third argument, if present, is a hook function that will be called once on establishment of the network connection and once after each block read thereafter. The hook will be passed three arguments; a count of blocks transferred so far, a block size in bytes, and the total size of the file. The third argument may be -1 on older FTP servers which do not return a file size in response to a retrieval request.

The following example illustrates the most common usage scenario:

```python
>>> import urllib.request
>>> local_filename, headers = urllib.request.urlretrieve
>>> html = open(local_filename)
```
If the url uses the http: scheme identifier, the optional data argument may be given to specify a POST request (normally the request type is GET). The data argument must be a bytes object in standard application/x-www-form-urlencoded format; see the urllib.parse.urlencode() function.

urlretrieve() will raise ContentTooShortError when it detects that the amount of data available was less than the expected amount (which is the size reported by a Content-Length header). This can occur, for example, when the download is interrupted.

The Content-Length is treated as a lower bound: if there's more data to read, urlretrieve reads more data, but if less data is available, it raises the exception.

You can still retrieve the downloaded data in this case, it is stored in the content attribute of the exception instance.

If no Content-Length header was supplied, urlretrieve can not check the size of the data it has downloaded, and just returns it. In this case you just have to assume that the download was successful.

urllib.request.urlopen()

Cleans up temporary files that may have been left behind by previous calls to urlretrieve().

class urllib.request.URLopener(proxies=None, **x509)

Deprecated since version 3.3.
Base class for opening and reading URLs. Unless you need to support opening objects using schemes other than http:, ftp:, or file:, you probably want to use FancyURLopener.

By default, the URLopener class sends a User-Agent header of urllib/VVV, where VVV is the urllib version number. Applications can define their own User-Agent header by subclassing URLopener or FancyURLopener and setting the class attribute version to an appropriate string value in the subclass definition.

The optional proxies parameter should be a dictionary mapping scheme names to proxy URLs, where an empty dictionary turns proxies off completely. Its default value is None, in which case environmental proxy settings will be used if present, as discussed in the definition of urlopen(), above.

Additional keyword parameters, collected in x509, may be used for authentication of the client when using the https: scheme. The keywords key_file and cert_file are supported to provide an SSL key and certificate; both are needed to support client authentication.

URLopener objects will raise an OSError exception if the server returns an error code.

**open**(fullurl, data=None)

Open fullurl using the appropriate protocol. This method sets up cache and proxy information, then calls the appropriate open method with its input arguments. If the scheme is not recognized, open_unknown() is called. The data argument has the same meaning as the data
argument of `urlopen()`.

**open_unknown**(`fullurl`, `data=None`)

Overridable interface to open unknown URL types.

**retrieve**(`url`, `filename=None`, `reporthook=None`, `data=None`)

Retrieves the contents of `url` and places it in `filename`. The return value is a tuple consisting of a local filename and either an `email.message.Message` object containing the response headers (for remote URLs) or None (for local URLs). The caller must then open and read the contents of `filename`. If `filename` is not given and the URL refers to a local file, the input filename is returned. If the URL is non-local and `filename` is not given, the filename is the output of `tempfile.mktemp()` with a suffix that matches the suffix of the last path component of the input URL. If `reporthook` is given, it must be a function accepting three numeric parameters: A chunk number, the maximum size chunks are read in and the total size of the download (-1 if unknown). It will be called once at the start and after each chunk of data is read from the network. `reporthook` is ignored for local URLs.

If the `url` uses the `http:` scheme identifier, the optional `data` argument may be given to specify a POST request (normally the request type is GET). The `data` argument must in standard `application/x-www-form-urlencoded` format; see the `urllib.parse.urlencode()` function.

**version**

Variable that specifies the user agent of the opener object.
To get `urllib` to tell servers that it is a particular user agent, set this in a subclass as a class variable or in the constructor before calling the base constructor.

```python
class urllib.request.FancyURLopener(...)
```

*Deprecated since version 3.3.*

`FancyURLopener` subclasses `URLopener` providing default handling for the following HTTP response codes: 301, 302, 303, 307 and 401. For the 30x response codes listed above, the `Location` header is used to fetch the actual URL. For 401 response codes (authentication required), basic HTTP authentication is performed. For the 30x response codes, recursion is bounded by the value of the `maxtries` attribute, which defaults to 10.

For all other response codes, the method `http_error_default()` is called which you can override in subclasses to handle the error appropriately.

**Note:** According to the letter of [RFC 2616](https://tools.ietf.org/html/rfc2616), 301 and 302 responses to POST requests must not be automatically redirected without confirmation by the user. In reality, browsers do allow automatic redirection of these responses, changing the POST to a GET, and `urllib` reproduces this behaviour.

The parameters to the constructor are the same as those for `URLopener`.

**Note:** When performing basic authentication, a `FancyURLopener` instance calls its `prompt_user_passwd()` method. The default implementation asks the users for the required information on the controlling terminal. A subclass may
override this method to support more appropriate behavior if needed.

The FancyURLopener class offers one additional method that should be overloaded to provide the appropriate behavior:

**prompt_user_passwd**(host, realm)

Return information needed to authenticate the user at the given host in the specified security realm. The return value should be a tuple, (user, password), which can be used for basic authentication.

The implementation prompts for this information on the terminal; an application should override this method to use an appropriate interaction model in the local environment.
21.6.25. `urllib.request` Restrictions

- Currently, only the following protocols are supported: HTTP (versions 0.9 and 1.0), FTP, local files, and data URLs.

  *Changed in version 3.4:* Added support for data URLs.

- The caching feature of `urllibretrieve()` has been disabled until someone finds the time to hack proper processing of Expiration time headers.

- There should be a function to query whether a particular URL is in the cache.

- For backward compatibility, if a URL appears to point to a local file but the file can't be opened, the URL is re-interpreted using the FTP protocol. This can sometimes cause confusing error messages.

- The `urlopen()` and `urllibretrieve()` functions can cause arbitrarily long delays while waiting for a network connection to be set up. This means that it is difficult to build an interactive Web client using these functions without using threads.

- The data returned by `urlopen()` or `urllibretrieve()` is the raw data returned by the server. This may be binary data (such as an image), plain text or (for example) HTML. The HTTP protocol provides type information in the reply header, which can be inspected by looking at the `Content-Type` header. If the returned data is HTML, you can use the module `html.parser` to parse it.

- The code handling the FTP protocol cannot differentiate between
a file and a directory. This can lead to unexpected behavior when attempting to read a URL that points to a file that is not accessible. If the URL ends in a /, it is assumed to refer to a directory and will be handled accordingly. But if an attempt to read a file leads to a 550 error (meaning the URL cannot be found or is not accessible, often for permission reasons), then the path is treated as a directory in order to handle the case when a directory is specified by a URL but the trailing / has been left off. This can cause misleading results when you try to fetch a file whose read permissions make it inaccessible; the FTP code will try to read it, fail with a 550 error, and then perform a directory listing for the unreadable file. If fine-grained control is needed, consider using the `ftplib` module, subclassing `FancyURLopener`, or changing `_urloper` to meet your needs.
21.7. `urllib.response` — Response classes used by `urllib`

The `urllib.response` module defines functions and classes which define a minimal file like interface, including `read()` and `readline()`. The typical response object is an `addinfourl` instance, which defines an `info()` method and that returns headers and a `geturl()` method that returns the url. Functions defined by this module are used internally by the `urllib.request` module.
This module defines a standard interface to break Uniform Resource Locator (URL) strings up in components (addressing scheme, network location, path etc.), to combine the components back into a URL string, and to convert a “relative URL” to an absolute URL given a “base URL.”

The module has been designed to match the Internet RFC on Relative Uniform Resource Locators. It supports the following URL schemes: file, ftp, gopher, hdl, http, https, imap, mailto, mms, news, nntp, prospero, rsync, rtsp, rtspu, sftp, shttp, sip, sips, snews, svn, svn+ssh, telnet, wais.

The urllib.parse module defines functions that fall into two broad categories: URL parsing and URL quoting. These are covered in detail in the following sections.
21.8.1. URL Parsing

The URL parsing functions focus on splitting a URL string into its components, or on combining URL components into a URL string.

```
urllib.parse.urlparse(urlstring, scheme='', allow_fragments=True)
```

Parse a URL into six components, returning a 6-tuple. This corresponds to the general structure of a URL: `scheme://netloc/path;parameters?query#fragment`. Each tuple item is a string, possibly empty. The components are not broken up in smaller parts (for example, the network location is a single string), and % escapes are not expanded. The delimiters as shown above are not part of the result, except for a leading slash in the `path` component, which is retained if present. For example:

```
>>> from urllib.parse import urlparse
>>> o = urlparse('http://www.cwi.nl:80/%7Eguido/Python.html')
>>> o
ParseResult(scheme='http', netloc='www.cwi.nl:80', path='/%7Eguido/Python.html', params='', query='', fragment='')

>>> o.scheme
'http'

>>> o.port
80

>>> o.geturl()
'http://www.cwi.nl:80/%7Eguido/Python.html'
```

Following the syntax specifications in RFC 1808, urlparse recognizes a netloc only if it is properly introduced by '//'. Otherwise the input is presumed to be a relative URL and thus to start with a
from urllib.parse import urlparse

>>> urlparse('//www.cwi.nl:80/%7Eguido/Python.html')
ParseResult(scheme='', netloc='www.cwi.nl:80', path='/%7Eguido/Python.html', params='', query='', fragment='')

>>> urlparse('www.cwi.nl/%7Eguido/Python.html')
ParseResult(scheme='', netloc='', path='www.cwi.nl/%7Eguido/Python.html', params='', query='', fragment='')

>>> urlparse('help/Python.html')
ParseResult(scheme='', netloc='', path='help/Python.html', params='', query='', fragment='')

The `scheme` argument gives the default addressing scheme, to be used only if the URL does not specify one. It should be the same type (text or bytes) as `urlstring`, except that the default value '' is always allowed, and is automatically converted to b'' if appropriate.

If the `allow_fragments` argument is false, fragment identifiers are not recognized. Instead, they are parsed as part of the path, parameters or query component, and `fragment` is set to the empty string in the return value.

The return value is actually an instance of a subclass of `tuple`. This class has the following additional read-only convenience attributes:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Index</th>
<th>Value</th>
<th>Value if not present</th>
</tr>
</thead>
<tbody>
<tr>
<td>scheme</td>
<td>0</td>
<td>URL scheme specifier</td>
<td><code>scheme parameter</code></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Network location</td>
<td></td>
</tr>
<tr>
<td>netloc</td>
<td>1</td>
<td>part</td>
<td>empty string</td>
</tr>
<tr>
<td>--------</td>
<td>---</td>
<td>------</td>
<td>--------------</td>
</tr>
<tr>
<td>path</td>
<td>2</td>
<td>Hierarchical path</td>
<td>empty string</td>
</tr>
<tr>
<td>params</td>
<td>3</td>
<td>Parameters for last path element</td>
<td>empty string</td>
</tr>
<tr>
<td>query</td>
<td>4</td>
<td>Query component</td>
<td>empty string</td>
</tr>
<tr>
<td>fragment</td>
<td>5</td>
<td>Fragment identifier</td>
<td>empty string</td>
</tr>
<tr>
<td>username</td>
<td></td>
<td>User name</td>
<td>None</td>
</tr>
<tr>
<td>password</td>
<td></td>
<td>Password</td>
<td>None</td>
</tr>
<tr>
<td>hostname</td>
<td></td>
<td>Host name (lower case)</td>
<td>None</td>
</tr>
<tr>
<td>port</td>
<td></td>
<td>Port number as integer, if present</td>
<td>None</td>
</tr>
</tbody>
</table>

See section [Structured Parse Results](#) for more information on the result object.

*Changed in version 3.2:* Added IPv6 URL parsing capabilities.

*Changed in version 3.3:* The fragment is now parsed for all URL schemes (unless allow_fragment is false), in accordance with [RFC 3986](https://tools.ietf.org/html/rfc3986). Previously, a whitelist of schemes that support fragments existed.

```python
urllib.parse.parse_qs(qs, keep_blank_values=False, strict_parsing=False, encoding='utf-8', errors='replace')
```

Parse a query string given as a string argument (data of type `application/x-www-form-urlencoded`). Data are returned as a dictionary. The dictionary keys are the unique query variable names and the values are lists of values for each name.

The optional argument `keep_blank_values` is a flag indicating
whether blank values in percent-encoded queries should be treated as blank strings. A true value indicates that blanks should be retained as blank strings. The default false value indicates that blank values are to be ignored and treated as if they were not included.

The optional argument `strict_parsing` is a flag indicating what to do with parsing errors. If false (the default), errors are silently ignored. If true, errors raise a `ValueError` exception.

The optional `encoding` and `errors` parameters specify how to decode percent-encoded sequences into Unicode characters, as accepted by the `bytes.decode()` method.

Use the `urllib.parse.urlencode()` function (with the `doseq` parameter set to `True`) to convert such dictionaries into query strings.

`Changed in version 3.2: Add encoding and errors parameters.`

`urllib.parse.parse_qsl(qs, keep_blank_values=False, strict_parsing=False, encoding='utf-8', errors='replace')`

Parse a query string given as a string argument (data of type `application/x-www-form-urlencoded`). Data are returned as a list of name, value pairs.

The optional argument `keep_blank_values` is a flag indicating whether blank values in percent-encoded queries should be treated as blank strings. A true value indicates that blanks should be retained as blank strings. The default false value indicates that blank values are to be ignored and treated as if they were not included.
The optional argument `strict_parsing` is a flag indicating what to do with parsing errors. If false (the default), errors are silently ignored. If true, errors raise a `ValueError` exception.

The optional `encoding` and `errors` parameters specify how to decode percent-encoded sequences into Unicode characters, as accepted by the `bytes.decode()` method.

Use the `urllib.parse.urlenconde()` function to convert such lists of pairs into query strings.

*Changed in version 3.2:* Add `encoding` and `errors` parameters.

`urllib.parse.urlunparse(parts)`

Construct a URL from a tuple as returned by `urlparse()`. The `parts` argument can be any six-item iterable. This may result in a slightly different, but equivalent URL, if the URL that was parsed originally had unnecessary delimiters (for example, a ? with an empty query; the RFC states that these are equivalent).

`urllib.parse.urlsplit(urlstring, scheme='', allow_fragments=True)`

This is similar to `urlparse()`, but does not split the params from the URL. This should generally be used instead of `urlparse()` if the more recent URL syntax allowing parameters to be applied to each segment of the path portion of the URL (see RFC 2396) is wanted. A separate function is needed to separate the path segments and parameters. This function returns a 5-tuple: (addressing scheme, network location, path, query, fragment identifier).

The return value is actually an instance of a subclass of `tuple`. This class has the following additional read-only convenience
attributes:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Index</th>
<th>Value</th>
<th>Value if not present</th>
</tr>
</thead>
<tbody>
<tr>
<td>scheme</td>
<td>0</td>
<td>URL scheme specifier</td>
<td>scheme parameter</td>
</tr>
<tr>
<td>netloc</td>
<td>1</td>
<td>Network location part</td>
<td>empty string</td>
</tr>
<tr>
<td>path</td>
<td>2</td>
<td>Hierarchical path</td>
<td>empty string</td>
</tr>
<tr>
<td>query</td>
<td>3</td>
<td>Query component</td>
<td>empty string</td>
</tr>
<tr>
<td>fragment</td>
<td>4</td>
<td>Fragment identifier</td>
<td>empty string</td>
</tr>
<tr>
<td>username</td>
<td></td>
<td>User name</td>
<td>None</td>
</tr>
<tr>
<td>password</td>
<td></td>
<td>Password</td>
<td>None</td>
</tr>
<tr>
<td>hostname</td>
<td></td>
<td>Host name (lower case)</td>
<td>None</td>
</tr>
<tr>
<td>port</td>
<td></td>
<td>Port number as integer, if present</td>
<td>None</td>
</tr>
</tbody>
</table>

See section Structured Parse Results for more information on the result object.

urllib.parse.urlunsplit(parts)

Combine the elements of a tuple as returned by urlsplit() into a complete URL as a string. The parts argument can be any five-item iterable. This may result in a slightly different, but equivalent URL, if the URL that was parsed originally had unnecessary delimiters (for example, a ? with an empty query; the RFC states that these are equivalent).

urllib.parse.urljoin(base, url, allow_fragments=True)

Construct a full (“absolute”) URL by combining a “base URL” (base)
with another URL (url). Informally, this uses components of the base URL, in particular the addressing scheme, the network location and (part of) the path, to provide missing components in the relative URL. For example:

```python
>>> from urllib.parse import urljoin
>>> urljoin('http://www.cwi.nl/%7Eguido/Python.html', 'http://www.cwi.nl/%7Eguido/FAQ.html')
'http://www.cwi.nl/%7Eguido/FAQ.html'
```

The allow_fragments argument has the same meaning and default as for urlparse().

**Note:** If url is an absolute URL (that is, starting with // or scheme://), the url's host name and/or scheme will be present in the result. For example:

```python
>>> urljoin('http://www.cwi.nl/%7Eguido/Python.html', '//www.python.org/%7Eguido')
'http://www.python.org/%7Eguido'
```

If you do not want that behavior, preprocess the url with urlsplit() and urlunsplit(), removing possible scheme and netloc parts.

*Changed in version 3.5:* Behaviour updated to match the semantics defined in RFC 3986.

**urlib.parse.urldefrag(url)**

If url contains a fragment identifier, return a modified version of url with no fragment identifier, and the fragment identifier as a separate string. If there is no fragment identifier in url, return url unmodified and an empty string.
The return value is actually an instance of a subclass of `tuple`. This class has the following additional read-only convenience attributes:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Index</th>
<th>Value</th>
<th>Value if not present</th>
</tr>
</thead>
<tbody>
<tr>
<td>url</td>
<td>0</td>
<td>URL with no fragment</td>
<td>empty string</td>
</tr>
<tr>
<td>fragment</td>
<td>1</td>
<td>Fragment identifier</td>
<td>empty string</td>
</tr>
</tbody>
</table>

See section [Structured Parse Results](#) for more information on the result object.

*Changed in version 3.2:* Result is a structured object rather than a simple 2-tuple.
21.8.2. Parsing ASCII Encoded Bytes

The URL parsing functions were originally designed to operate on character strings only. In practice, it is useful to be able to manipulate properly quoted and encoded URLs as sequences of ASCII bytes. Accordingly, the URL parsing functions in this module all operate on bytes and bytearray objects in addition to str objects.

If str data is passed in, the result will also contain only str data. If bytes or bytearray data is passed in, the result will contain only bytes data.

Attempting to mix str data with bytes or bytearray in a single function call will result in a TypeError being raised, while attempting to pass in non-ASCII byte values will trigger UnicodeDecodeError.

To support easier conversion of result objects between str and bytes, all return values from URL parsing functions provide either an encode() method (when the result contains str data) or a decode() method (when the result contains bytes data). The signatures of these methods match those of the corresponding str and bytes methods (except that the default encoding is 'ascii' rather than 'utf-8'). Each produces a value of a corresponding type that contains either bytes data (for encode() methods) or str data (for decode() methods).

Applications that need to operate on potentially improperly quoted URLs that may contain non-ASCII data will need to do their own decoding from bytes to characters before invoking the URL parsing methods.
The behaviour described in this section applies only to the URL parsing functions. The URL quoting functions use their own rules when producing or consuming byte sequences as detailed in the documentation of the individual URL quoting functions.

*Changed in version 3.2:* URL parsing functions now accept ASCII encoded byte sequences
21.8.3. Structured Parse Results

The result objects from the `urlparse()`, `urlsplit()` and `urldefrag()` functions are subclasses of the `tuple` type. These subclasses add the attributes listed in the documentation for those functions, the encoding and decoding support described in the previous section, as well as an additional method:

`urllib.parse.SplitResult.geturl()`

Return the re-combined version of the original URL as a string. This may differ from the original URL in that the scheme may be normalized to lower case and empty components may be dropped. Specifically, empty parameters, queries, and fragment identifiers will be removed.

For `urldefrag()` results, only empty fragment identifiers will be removed. For `urlsplit()` and `urlparse()` results, all noted changes will be made to the URL returned by this method.

The result of this method remains unchanged if passed back through the original parsing function:

```python
>>> from urllib.parse import urlsplit
>>> url = 'HTTP://www.Python.org/doc/#'
>>> r1 = urlsplit(url)
>>> r1.geturl()
'http://www.Python.org/doc/
>>> r2 = urlsplit(r1.geturl())
>>> r2.geturl()
'http://www.Python.org/doc/'
```

The following classes provide the implementations of the structured
parse results when operating on `str` objects:

```python
class urllib.parse.DefragResult(url, fragment)
    Concrete class for urldefrag() results containing `str` data. The encode() method returns a DefragResultBytes instance.

    New in version 3.2.
```

```python
class urllib.parse.ParseResult(scheme, netloc, path, params, query, fragment)
    Concrete class for urlparse() results containing `str` data. The encode() method returns a ParseResultBytes instance.

    New in version 3.2.
```

```python
class urllib.parse.SplitResult(scheme, netloc, path, query, fragment)
    Concrete class for urlsplit() results containing `str` data. The encode() method returns a SplitResultBytes instance.
```

The following classes provide the implementations of the parse results when operating on `bytes` or `bytearray` objects:

```python
class urllib.parse.DefragResultBytes(url, fragment)
    Concrete class for urldefrag() results containing `bytes` data. The decode() method returns a DefragResult instance.

    New in version 3.2.
```

```python
class urllib.parse.ParseResultBytes(scheme, netloc, path, params, query, fragment)
    Concrete class for urlparse() results containing `bytes` data. The decode() method returns a ParseResult instance.

    New in version 3.2.
```
class urllib.parse.SplitResultBytes(scheme, netloc, path, query, fragment)

Concrete class for urlsplit() results containing bytes data. The decode() method returns a SplitResult instance.

New in version 3.2.
21.8.4. URL Quoting

The URL quoting functions focus on taking program data and making it safe for use as URL components by quoting special characters and appropriately encoding non-ASCII text. They also support reversing these operations to recreate the original data from the contents of a URL component if that task isn't already covered by the URL parsing functions above.

```
urllib.parse.quote(string, safe='/', encoding=None, errors=None)
```

Replace special characters in `string` using the `%xx` escape. Letters, digits, and the characters '_.-' are never quoted. By default, this function is intended for quoting the path section of URL. The optional `safe` parameter specifies additional ASCII characters that should not be quoted — its default value is '/'.

`string` may be either a `str` or a `bytes`.

The optional `encoding` and `errors` parameters specify how to deal with non-ASCII characters, as accepted by the `str.encode()` method. `encoding` defaults to 'utf-8'. `errors` defaults to 'strict', meaning unsupported characters raise a `UnicodeEncodeError`. `encoding` and `errors` must not be supplied if `string` is a `bytes`, or a `TypeError` is raised.

Note that `quote(string, safe, encoding, errors)` is equivalent to `quote_from_bytes(string.encode(encoding, errors), safe)`. 
Example: `quote('/El Niño/')` yields '/El%20Ni%C3%B1o/'.

`urllib.parse.quote_plus(string, safe='', encoding=None, errors=None)`

Like `quote()`, but also replace spaces by plus signs, as required for quoting HTML form values when building up a query string to go into a URL. Plus signs in the original string are escaped unless they are included in `safe`. It also does not have `safe` default to '/'.

Example: `quote_plus('/El Niño/')` yields '%2FEl+Ni%C3%B1o%2F'.

`urllib.parse.quote_from_bytes(bytes, safe='')`  
Like `quote()`, but accepts a `bytes` object rather than a `str`, and does not perform string-to-bytes encoding.

Example: `quote_from_bytes(b'a&\xef')` yields 'a%26%EF'.

`urllib.parse.unquote(string, encoding='utf-8', errors='replace')`  
Replace %xx escapes by their single-character equivalent. The optional `encoding` and `errors` parameters specify how to decode percent-encoded sequences into Unicode characters, as accepted by the `bytes.decode()` method.

`string` must be a `str`.

`encoding` defaults to 'utf-8'. `errors` defaults to 'replace', meaning invalid sequences are replaced by a placeholder character.

Example: `unquote('/El%20Ni%C3%B1o/')` yields '/El Niño/'.

urllib.parse.unquote_plus(string, encoding='utf-8', errors='replace')

Like unquote(), but also replace plus signs by spaces, as required for unquoting HTML form values.

string must be a str.

Example: unquote_plus('/El+Ni%C3%B1o/') yields '/El Niño/'.

urllib.parse.unquote_to_bytes(string)

Replace %xx escapes by their single-octet equivalent, and return a bytes object.

string may be either a str or a bytes.

If it is a str, unescaped non-ASCII characters in string are encoded into UTF-8 bytes.

Example: unquote_to_bytes('a%26%EF') yields b'a&\xef'.

urllib.parse.urlencode(query, doseq=False, safe='', encoding=None, errors=None, quote_via=quote_plus)

Convert a mapping object or a sequence of two-element tuples, which may contain str or bytes objects, to a “percent-encoded” string. If the resultant string is to be used as a data for POST operation with urlopen() function, then it should be properly encoded to bytes, otherwise it would result in a TypeError.

The resulting string is a series of key=value pairs separated by '&' characters, where both key and value are quoted using the quote_via function. By default, quote_plus() is used to quote
the values, which means spaces are quoted as a ' + ' character and '/' characters are encoded as %2F, which follows the standard for GET requests (application/x-www-form-urlencoded). An alternate function that can be passed as quote_via is quote(), which will encode spaces as %20 and not encode '/' characters. For maximum control of what is quoted, use quote and specify a value for safe.

When a sequence of two-element tuples is used as the query argument, the first element of each tuple is a key and the second is a value. The value element in itself can be a sequence and in that case, if the optional parameter doseq is evaluates to True, individual key=value pairs separated by '& ' are generated for each element of the value sequence for the key. The order of parameters in the encoded string will match the order of parameter tuples in the sequence.

The safe, encoding, and errors parameters are passed down to quote_via (the encoding and errors parameters are only passed when a query element is a str).

To reverse this encoding process, parse_qs() and parse_qsl() are provided in this module to parse query strings into Python data structures.

Refer to urllib examples to find out how urlencode method can be used for generating query string for a URL or data for POST.

Changed in version 3.2: Query parameter supports bytes and string objects.

New in version 3.5: quote_via parameter.
See also:

**RFC 3986 - Uniform Resource Identifiers**  
This is the current standard (STD66). Any changes to urllib.parse module should conform to this. Certain deviations could be observed, which are mostly for backward compatibility purposes and for certain de-facto parsing requirements as commonly observed in major browsers.

**RFC 2732 - Format for Literal IPv6 Addresses in URL's.**  
This specifies the parsing requirements of IPv6 URLs.

**RFC 2396 - Uniform Resource Identifiers (URI): Generic Syntax**  
Document describing the generic syntactic requirements for both Uniform Resource Names (URNs) and Uniform Resource Locators (URLs).

**RFC 2368 - The mailto URL scheme.**  
Parsing requirements for mailto url schemes.

**RFC 1808 - Relative Uniform Resource Locators**  
This Request For Comments includes the rules for joining an absolute and a relative URL, including a fair number of “Abnormal Examples” which govern the treatment of border cases.

**RFC 1738 - Uniform Resource Locators (URL)**  
This specifies the formal syntax and semantics of absolute URLs.
21.9. `urllib.error` — Exception classes raised by `urllib.request`

The `urllib.error` module defines the exception classes for exceptions raised by `urllib.request`. The base exception class is `URLError`.

The following exceptions are raised by `urllib.error` as appropriate:

**exception `urllib.error.URLError`**

The handlers raise this exception (or derived exceptions) when they run into a problem. It is a subclass of `OSError`.

**reason**

The reason for this error. It can be a message string or another exception instance.

*Changed in version 3.3: `URLError` has been made a subclass of `OSError` instead of `IOError`.*

**exception `urllib.error.HTTPError`**

Though being an exception (a subclass of `URLError`), an `HTTPError` can also function as a non-exceptional file-like return value (the same thing that `urlopen()` returns). This is useful when handling exotic HTTP errors, such as requests for authentication.

**code**

An HTTP status code as defined in RFC 2616. This numeric
value corresponds to a value found in the dictionary of codes as found in `http.server.BaseHTTPRequestHandler.responses`.

**reason**
This is usually a string explaining the reason for this error.

**headers**
The HTTP response headers for the HTTP request that caused the `HTTPError`.

*New in version 3.4.*

**exception `urllib.error.ContentTooShortError(msg, content)`**
This exception is raised when the `urlretrieve()` function detects that the amount of the downloaded data is less than the expected amount (given by the `Content-Length` header). The `content` attribute stores the downloaded (and supposedly truncated) data.
21.10. **urllib.robotparser** — Parser for robots.txt

This module provides a single class, `RobotFileParser`, which answers questions about whether or not a particular user agent can fetch a URL on the Web site that published the robots.txt file. For more details on the structure of robots.txt files, see [http://www.robotstxt.org/orig.html](http://www.robotstxt.org/orig.html).

class urllib.robotparser.RobotFileParser(url='')

This class provides methods to read, parse and answer questions about the robots.txt file at `url`.

**set_url(url)**

Sets the URL referring to a robots.txt file.

**read()**

Reads the robots.txt URL and feeds it to the parser.

**parse(lines)**

Parses the lines argument.

**can_fetch(useragent, url)**

Returns True if the `useragent` is allowed to fetch the `url` according to the rules contained in the parsed robots.txt file.

**mtime()**

Returns the time the robots.txt file was last fetched. This is useful for long-running web spiders that need to check for new
robots.txt files periodically.

**modified()**

Sets the time the robots.txt file was last fetched to the current time.

The following example demonstrates basic use of the RobotFileParser class.

```python
>>> import urllib.robotparser
>>> rp = urllib.robotparser.RobotFileParser()
>>> rp.set_url("http://www.musi-cal.com/robots.txt")
>>> rp.read()
>>> rp.can_fetch("*", "http://www.musi-cal.com/cgi-bin/search?city=San+Francisco")
False
>>> rp.can_fetch("*", "http://www.musi-cal.com/")
True
```
21.11. **http** — HTTP modules

**Source code:** Lib/http/__init__.py

http is a package that collects several modules for working with the HyperText Transfer Protocol:

- **http.client** is a low-level HTTP protocol client; for high-level URL opening use **urllib.request**
- **http.server** contains basic HTTP server classes based on **socketserver**
- **http.cookies** has utilities for implementing state management with cookies
- **http.cookiejar** provides persistence of cookies

http is also a module that defines a number of HTTP status codes and associated messages through the **http.HTTPStatus** enum:

**class** `http.HTTPStatus`

*New in version 3.5.*

A subclass of `enum.IntEnum` that defines a set of HTTP status codes, reason phrases and long descriptions written in English.

Usage:

```python
>>> from http import HTTPStatus
>>> HTTPStatus.OK
<HTTPStatus.OK: 200>
>>> HTTPStatus.OK == 200
True
>>> http.HTTPStatus.OK.value
200
```
HTTPStatus.OK.phrase
'OK'
HTTPStatus.OK.description
'Request fulfilled, document follows'
list(HTTPStatus)
[<HTTPStatus.CONTINUE: 100>, <HTTPStatus.SWITCHING_PROTOCOLS: 101>, ...]
21.11.1. HTTP status codes

Supported, IANA-registered status codes available in `http.HTTPStatus` are:

<table>
<thead>
<tr>
<th>Code</th>
<th>Enum Name</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>CONTINUE</td>
<td>HTTP/1.1 <a href="https://www.rfc-editor.org/rfc/rfc7231">RFC 7231</a>, Section 6.2.1</td>
</tr>
<tr>
<td>101</td>
<td>SWITCHING_PROTOCOLS</td>
<td>HTTP/1.1 <a href="https://www.rfc-editor.org/rfc/rfc7231">RFC 7231</a>, Section 6.2.2</td>
</tr>
<tr>
<td>102</td>
<td>PROCESSING</td>
<td>WebDAV <a href="https://www.rfc-editor.org/rfc/rfc2518">RFC 2518</a>, Section 10.1</td>
</tr>
<tr>
<td>200</td>
<td>OK</td>
<td>HTTP/1.1 <a href="https://www.rfc-editor.org/rfc/rfc7231">RFC 7231</a>, Section 6.3.1</td>
</tr>
<tr>
<td>201</td>
<td>CREATED</td>
<td>HTTP/1.1 <a href="https://www.rfc-editor.org/rfc/rfc7231">RFC 7231</a>, Section 6.3.2</td>
</tr>
<tr>
<td>202</td>
<td>ACCEPTED</td>
<td>HTTP/1.1 <a href="https://www.rfc-editor.org/rfc/rfc7231">RFC 7231</a>, Section 6.3.3</td>
</tr>
<tr>
<td>203</td>
<td>NON_AUTHORITATIVE_INFORMATION</td>
<td>HTTP/1.1 <a href="https://www.rfc-editor.org/rfc/rfc7231">RFC 7231</a>, Section 6.3.4</td>
</tr>
<tr>
<td>204</td>
<td>NO_CONTENT</td>
<td>HTTP/1.1 <a href="https://www.rfc-editor.org/rfc/rfc7231">RFC 7231</a>, Section 6.3.5</td>
</tr>
<tr>
<td>Code</td>
<td>Status Code</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>205</td>
<td>RESET_CONTENT</td>
<td></td>
</tr>
<tr>
<td>206</td>
<td>PARTIAL_CONTENT</td>
<td></td>
</tr>
<tr>
<td>207</td>
<td>MULTI_STATUS</td>
<td></td>
</tr>
<tr>
<td>208</td>
<td>ALREADY_REPORTED</td>
<td></td>
</tr>
<tr>
<td>226</td>
<td>IM_USED</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>MULTIPLE_CHOICES</td>
<td></td>
</tr>
<tr>
<td>301</td>
<td>MOVED_PERMANENTLY</td>
<td></td>
</tr>
<tr>
<td>302</td>
<td>FOUND</td>
<td></td>
</tr>
<tr>
<td>303</td>
<td>SEE_OTHER</td>
<td></td>
</tr>
<tr>
<td>304</td>
<td>NOT_MODIFIED</td>
<td></td>
</tr>
<tr>
<td>Status Code</td>
<td>Description</td>
<td>Reference</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>305</td>
<td>USE_PROXY</td>
<td>HTTP/1.1 RFC 7231, Section 6.4.5</td>
</tr>
<tr>
<td>307</td>
<td>TEMPORARY_REDIRECT</td>
<td>HTTP/1.1 RFC 7231, Section 6.4.7</td>
</tr>
<tr>
<td>308</td>
<td>PERMANENT_REDIRECT</td>
<td>Permanent Redirect RFC 7238, Section 3 (Experimental)</td>
</tr>
<tr>
<td>400</td>
<td>BAD_REQUEST</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.1</td>
</tr>
<tr>
<td>401</td>
<td>UNAUTHORIZED</td>
<td>HTTP/1.1 Authentication RFC 7235, Section 3.1</td>
</tr>
<tr>
<td>402</td>
<td>PAYMENT_REQUIRED</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.2</td>
</tr>
<tr>
<td>403</td>
<td>FORBIDDEN</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.3</td>
</tr>
<tr>
<td>404</td>
<td>NOT_FOUND</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.4</td>
</tr>
<tr>
<td>405</td>
<td>METHOD_NOT_ALLOWED</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.5</td>
</tr>
<tr>
<td>406</td>
<td>NOT_ACCEPTABLE</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HTTP/1.1</td>
</tr>
<tr>
<td>Status Code</td>
<td>Reason-Phrase</td>
<td>RFC Reference</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>407</td>
<td>PROXY_AUTHENTICATION_REQUIRED</td>
<td>RFC 7235, Section 3.2</td>
</tr>
<tr>
<td>408</td>
<td>REQUEST_TIMEOUT</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.7</td>
</tr>
<tr>
<td>409</td>
<td>CONFLICT</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.8</td>
</tr>
<tr>
<td>410</td>
<td>GONE</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.9</td>
</tr>
<tr>
<td>411</td>
<td>LENGTH_REQUIRED</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.10</td>
</tr>
<tr>
<td>412</td>
<td>PRECONDITION_FAILED</td>
<td>HTTP/1.1 RFC 7232, Section 4.2</td>
</tr>
<tr>
<td>413</td>
<td>REQUEST_ENTITY_TOO_LARGE</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.11</td>
</tr>
<tr>
<td>414</td>
<td>REQUEST_URI_TOO_LONG</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.12</td>
</tr>
<tr>
<td>415</td>
<td>UNSUPPORTED_MEDIA_TYPE</td>
<td>HTTP/1.1 RFC 7231, Section 6.5.13</td>
</tr>
<tr>
<td>416</td>
<td>REQUEST_RANGE_NOT_SATISFIABLE</td>
<td>HTTP/1.1 Range Requests RFC 7233, Section 4.4</td>
</tr>
<tr>
<td>Status Code</td>
<td>Code Description</td>
<td>Reference</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td>417</td>
<td>EXPECTATION_FAILED</td>
<td><a href="https://tools.ietf.org/rfc/rfc7231.txt">RFC 7231</a>, Section 6.5.14</td>
</tr>
<tr>
<td>422</td>
<td>UNPROCESSABLE_ENTITY</td>
<td>WebDAV <a href="https://tools.ietf.org/rfc/rfc4918.txt">RFC 4918</a>, Section 11.2</td>
</tr>
<tr>
<td>423</td>
<td>LOCKED</td>
<td>WebDAV <a href="https://tools.ietf.org/rfc/rfc4918.txt">RFC 4918</a>, Section 11.3</td>
</tr>
<tr>
<td>424</td>
<td>FAILED_DEPENDENCY</td>
<td>WebDAV <a href="https://tools.ietf.org/rfc/rfc4918.txt">RFC 4918</a>, Section 11.4</td>
</tr>
<tr>
<td>426</td>
<td>UPGRADE_REQUIRED</td>
<td><a href="https://tools.ietf.org/rfc/rfc7231.txt">HTTP/1.1 RFC 7231</a>, Section 6.5.15</td>
</tr>
<tr>
<td>428</td>
<td>PRECONDITION_REQUIRED</td>
<td>Additional HTTP Status Codes <a href="https://tools.ietf.org/rfc/rfc6585.txt">RFC 6585</a></td>
</tr>
<tr>
<td>429</td>
<td>TOO_MANY_REQUESTS</td>
<td>Additional HTTP Status Codes <a href="https://tools.ietf.org/rfc/rfc6585.txt">RFC 6585</a></td>
</tr>
<tr>
<td>431</td>
<td>REQUEST_HEADER_FIELDS_TOO_LARGE</td>
<td>Additional HTTP Status Codes <a href="https://tools.ietf.org/rfc/rfc6585.txt">RFC 6585</a></td>
</tr>
<tr>
<td>500</td>
<td>INTERNAL_SERVER_ERROR</td>
<td><a href="https://tools.ietf.org/rfc/rfc7231.txt">HTTP/1.1 RFC 7231</a>, Section 6.6.1</td>
</tr>
<tr>
<td>501</td>
<td>NOT_IMPLEMENTED</td>
<td><a href="https://tools.ietf.org/rfc/rfc7231.txt">HTTP/1.1 RFC 7231</a>, Section 6.6.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="https://tools.ietf.org/rfc/rfc7231.txt">HTTP/1.1 RFC</a></td>
</tr>
<tr>
<td>Status Code</td>
<td>Reason Phrase</td>
<td>Additional Information</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------</td>
<td>-------------------------------------------------------------</td>
</tr>
<tr>
<td>502</td>
<td>BAD_GATEWAY</td>
<td>HTTP/1.1 RFC 7231, Section 6.6.3</td>
</tr>
<tr>
<td>503</td>
<td>SERVICE_UNAVAILABLE</td>
<td>HTTP/1.1 RFC 7231, Section 6.6.4</td>
</tr>
<tr>
<td>504</td>
<td>GATEWAY_TIMEOUT</td>
<td>HTTP/1.1 RFC 7231, Section 6.6.5</td>
</tr>
<tr>
<td>505</td>
<td>HTTP_VERSION_NOT_SUPPORTED</td>
<td>HTTP/1.1 RFC 7231, Section 6.6.6</td>
</tr>
<tr>
<td>506</td>
<td>VARIANT_ALSO_NEGOTIATES</td>
<td>Transparent Content Negotiation in HTTP RFC 2295, Section 8.1 (Experimental)</td>
</tr>
<tr>
<td>507</td>
<td>INSUFFICIENT_STORAGE</td>
<td>WebDAV RFC 4918, Section 11.5</td>
</tr>
<tr>
<td>508</td>
<td>LOOP_DETECTED</td>
<td>WebDAV Binding Extensions RFC 5842, Section 7.2 (Experimental)</td>
</tr>
<tr>
<td>510</td>
<td>NOT_EXTENDED</td>
<td>An HTTP Extension Framework RFC 2774, Section 7 (Experimental)</td>
</tr>
</tbody>
</table>

Additional
In order to preserve backwards compatibility, enum values are also present in the `http.client` module in the form of constants. The enum name is equal to the constant name (i.e. `http.HTTPStatus.OK` is also available as `http.client.OK`).

<table>
<thead>
<tr>
<th>Status Code</th>
<th>Reason Phrase</th>
<th>RFC 6585, Section 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>511</td>
<td>NETWORK_AUTHENTICATION_REQUIRED</td>
<td></td>
</tr>
</tbody>
</table>

Source code: Lib/http/client.py

This module defines classes which implement the client side of the HTTP and HTTPS protocols. It is normally not used directly — the module urllib.request uses it to handle URLs that use HTTP and HTTPS.

See also: The Requests package is recommended for a higher-level http client interface.

Note: HTTPS support is only available if Python was compiled with SSL support (through the ssl module).

The module provides the following classes:

```python
class http.client.HTTPConnection(host, port=None, [timeout, ]source_address=None)
```

An HTTPConnection instance represents one transaction with an HTTP server. It should be instantiated passing it a host and optional port number. If no port number is passed, the port is extracted from the host string if it has the form host:port, else the default HTTP port (80) is used. If the optional timeout parameter is given, blocking operations (like connection attempts) will timeout after that many seconds (if it is not given, the global default timeout setting is used). The optional source_address parameter may be a tuple of a (host, port) to use as the source
address the HTTP connection is made from.

For example, the following calls all create instances that connect to the server at the same host and port:

```python
>>> h1 = http.client.HTTPConnection('www.python.org')
>>> h2 = http.client.HTTPConnection('www.python.org:80')
>>> h3 = http.client.HTTPConnection('www.python.org')
>>> h4 = http.client.HTTPConnection('www.python.org')
```

*Changed in version 3.2:* `source_address` was added.

*Changed in version 3.4:* The `strict` parameter was removed. HTTP 0.9-style “Simple Responses” are not longer supported.

class http.client.**HTTPSConnection**(host, port=None, key_file=None, cert_file=None, [timeout, ]source_address=None, *, context=None, check_hostname=None)

A subclass of **HTTPConnection** that uses SSL for communication with secure servers. Default port is 443. If `context` is specified, it must be a `ssl.SSLContext` instance describing the various SSL options.

`key_file` and `cert_file` are deprecated, please use `ssl.SSLContext.load_cert_chain()` instead, or let `ssl.create_default_context()` select the system’s trusted CA certificates for you. The `check_hostname` parameter is also deprecated; the `ssl.SSLContext.check_hostname` attribute of `context` should be used instead.

Please read **Security considerations** for more information on best practices.
Changed in version 3.2: `source_address`, `context` and `check_hostname` were added.

Changed in version 3.2: This class now supports HTTPS virtual hosts if possible (that is, if `ssl.HAS_SNI` is true).

Changed in version 3.4: The `strict` parameter was removed. HTTP 0.9-style “Simple Responses” are no longer supported.

Changed in version 3.4.3: This class now performs all the necessary certificate and hostname checks by default. To revert to the previous, unverified, behavior `ssl._create_unverified_context()` can be passed to the `context` parameter.

class http.client.HTTPResponse(sock, debuglevel=0, method=None, url=None)

Class whose instances are returned upon successful connection. Not instantiated directly by user.

Changed in version 3.4: The `strict` parameter was removed. HTTP 0.9 style “Simple Responses” are no longer supported.

The following exceptions are raised as appropriate:

exception http.client.HTTPException

The base class of the other exceptions in this module. It is a subclass of `Exception`.

exception http.client.NotConnected

A subclass of `HTTPException`.

exception http.client.InvalidURL

A subclass of `HTTPException`, raised if a port is given and is
either non-numeric or empty.

_exception http.client.UnknownProtocol
   A subclass of HTTPException.

_exception http.client.UnknownTransferEncoding
   A subclass of HTTPException.

_exception http.client.UnimplementedFileMode
   A subclass of HTTPException.

_exception http.client.IncompleteRead
   A subclass of HTTPException.

_exception http.client.ImproperConnectionState
   A subclass of HTTPException.

_exception http.client.CannotSendRequest
   A subclass of ImproperConnectionState.

_exception http.client.CannotSendHeader
   A subclass of ImproperConnectionState.

_exception http.client.ResponseNotReady
   A subclass of ImproperConnectionState.

_exception http.client.BadStatusLine
   A subclass of HTTPException. Raised if a server responds with a HTTP status code that we don’t understand.

_exception http.client.LineTooLong
   A subclass of HTTPException. Raised if an excessively long line is received in the HTTP protocol from the server.
exception http.client.RemoteDisconnected
   A subclass of ConnectionResetError and BadStatusLine. Raised by HTTPConnection.getresponse() when the attempt to read the response results in no data read from the connection, indicating that the remote end has closed the connection.

   New in version 3.5: Previously, BadStatusLine('') was raised.

The constants defined in this module are:

http.client.HTTP_PORT
   The default port for the HTTP protocol (always 80).

http.client.HTTPS_PORT
   The default port for the HTTPS protocol (always 443).

http.client.responses
   This dictionary maps the HTTP 1.1 status codes to the W3C names.

   Example:
   http.client.responses[http.client.NOT_FOUND] is 'Not Found'.

See HTTP status codes for a list of HTTP status codes that are available in this module as constants.
21.12.1. HTTPConnection Objects

HTTPConnection instances have the following methods:

HTTPConnection.request(method, url, body=None, headers={})

This will send a request to the server using the HTTP request method method and the selector url.

If body is specified, the specified data is sent after the headers are finished. It may be a string, a bytes-like object, an open file object, or an iterable of bytes-like objects. If body is a string, it is encoded as ISO-8851-1, the default for HTTP. If it is a bytes-like object the bytes are sent as is. If it is a file object, the contents of the file is sent; this file object should support at least the read() method. If the file object has a mode attribute, the data returned by the read() method will be encoded as ISO-8851-1 unless the mode attribute contains the substring b, otherwise the data returned by read() is sent as is. If body is an iterable, the elements of the iterable are sent as is until the iterable is exhausted.

The headers argument should be a mapping of extra HTTP headers to send with the request.

If headers does not contain a Content-Length item, one is added automatically if possible. If body is None, the Content-Length header is set to 0 for methods that expect a body (PUT, POST, and PATCH). If body is a string or bytes object, the Content-Length header is set to its length. If body is a file object and it works to call fstat() on the result of its fileno() method, then the Content-Length header is set to the st_size reported by the fstat call. Otherwise no Content-Length header is added.
New in version 3.2: body can now be an iterable.

`HTTPConnection.getresponse()`

Should be called after a request is sent to get the response from the server. Returns an `HTTPResponse` instance.

**Note:** Note that you must have read the whole response before you can send a new request to the server.

*Changed in version 3.5:* If a `ConnectionError` or subclass is raised, the `HTTPConnection` object will be ready to reconnect when a new request is sent.

`HTTPConnection.set_debuglevel(level)`

Set the debugging level. The default debug level is 0, meaning no debugging output is printed. Any value greater than 0 will cause all currently defined debug output to be printed to stdout. The debuglevel is passed to any new `HTTPResponse` objects that are created.

*New in version 3.1.*

`HTTPConnection.set_tunnel(host, port=None, headers=None)`

Set the host and the port for HTTP Connect Tunnelling. This allows running the connection through a proxy server.

The host and port arguments specify the endpoint of the tunneled connection (i.e. the address included in the CONNECT request, *not* the address of the proxy server).

The headers argument should be a mapping of extra HTTP headers to send with the CONNECT request.
For example, to tunnel through a HTTPS proxy server running locally on port 8080, we would pass the address of the proxy to the `HTTPSConnection` constructor, and the address of the host that we eventually want to reach to the `set_tunnel()` method:

```python
>>> import http.client
>>> conn = http.client.HTTPSConnection("localhost")
>>> conn.set_tunnel("www.python.org")
>>> conn.request("HEAD","/index.html")
```

*New in version 3.2.*

`HTTPConnection.connect()`

Connect to the server specified when the object was created. By default, this is called automatically when making a request if the client does not already have a connection.

`HTTPConnection.close()`

Close the connection to the server.

As an alternative to using the `request()` method described above, you can also send your request step by step, by using the four functions below.

`HTTPConnection.putrequest(request, selector, skip_host=False, skip_accept_encoding=False)`

This should be the first call after the connection to the server has been made. It sends a line to the server consisting of the `request` string, the `selector` string, and the HTTP version (HTTP/1.1). To disable automatic sending of Host: or Accept-Encoding: headers (for example to accept additional content encodings), specify `skip_host` or `skip_accept_encoding` with non-False values.
HTTPConnection.putheader(header, argument[, ...])

Send an **RFC 822**-style header to the server. It sends a line to the server consisting of the header, a colon and a space, and the first argument. If more arguments are given, continuation lines are sent, each consisting of a tab and an argument.

HTTPConnection.endheaders(message_body=None)

Send a blank line to the server, signalling the end of the headers. The optional `message_body` argument can be used to pass a message body associated with the request. The message body will be sent in the same packet as the message headers if it is string, otherwise it is sent in a separate packet.

HTTPConnection.send(data)

Send data to the server. This should be used directly only after the `endheaders()` method has been called and before `getresponse()` is called.
21.12.2. HTTPResponse Objects

An HTTPResponse instance wraps the HTTP response from the server. It provides access to the request headers and the entity body. The response is an iterable object and can be used in a with statement.

HTTPResponse.read([amt])
Reads and returns the response body, or up to the next amt bytes.

HTTPResponse.readinto(b)
Reads up to the next len(b) bytes of the response body into the buffer b. Returns the number of bytes read.

New in version 3.3.

HTTPResponse.getheader(name, default=None)
Return the value of the header name, or default if there is no header matching name. If there is more than one header with the name name, return all of the values joined by ‘,’. If ‘default’ is any iterable other than a single string, its elements are similarly returned joined by commas.

HTTPResponse.getheaders()
Return a list of (header, value) tuples.

HTTPResponse.fileno()
Return the fileno of the underlying socket.

HTTPResponse.msg
A http.client.HTTPMessage instance containing the response headers. http.client.HTTPMessage is a subclass of
email.message.Message.

HTTPResponse.version
    HTTP protocol version used by server. 10 for HTTP/1.0, 11 for HTTP/1.1.

HTTPResponse.status
    Status code returned by server.

HTTPResponse.reason
    Reason phrase returned by server.

HTTPResponse.debuglevel
    A debugging hook. If debuglevel is greater than zero, messages will be printed to stdout as the response is read and parsed.

HTTPResponse.closed
    Is True if the stream is closed.
21.12.3. Examples

Here is an example session that uses the GET method:

```python
>>> import http.client
>>> conn = http.client.HTTPSConnection("www.python.org")
>>> conn.request("GET", "/")
>>> r1 = conn.getresponse()
>>> print(r1.status, r1.reason)
200 OK
>>> data1 = r1.read()  # This will return entire content.
>>> # The following example demonstrates reading data in chunks.
>>> conn.request("GET", "/")
>>> r1 = conn.getresponse()
>>> while not r1.closed:
...    print(r1.read(200))  # 200 bytes
b'<!doctype html>\n
...# Example of an invalid request
>>> conn.request("GET", "/parrot.spam")
>>> r2 = conn.getresponse()
>>> print(r2.status, r2.reason)
404 Not Found
>>> data2 = r2.read()
>>> conn.close()
```

Here is an example session that uses the HEAD method. Note that the HEAD method never returns any data.

```python
>>> import http.client
>>> conn = http.client.HTTPSConnection("www.python.org")
>>> conn.request("HEAD", "/")
>>> res = conn.getresponse()
>>> print(res.status, res.reason)
```
Here is an example session that shows how to POST requests:

```python
>>> import http.client, urllib.parse
>>> params = urllib.parse.urlencode({'@number': 12524})
>>> headers = {"Content-type": "application/x-www-form-urlencoded", "Accept": "text/plain"}
>>> conn = http.client.HTTPConnection("bugs.python.org")
>>> conn.request("POST", ", params, headers)
>>> response = conn.getresponse()
>>> print(response.status, response.reason)
302 Found
>>> data = response.read()
>>> data
b'Redirecting to <a href="http://bugs.python.org/issue12524">http://bugs.python.org/issue12524</a>'
>>> conn.close()
```

Client side HTTP PUT requests are very similar to POST requests. The difference lies only the server side where HTTP server will allow resources to be created via PUT request. It should be noted that custom HTTP methods are also handled in `urllib.request.Request` by sending the appropriate `+method` attribute. Here is an example session that shows how to do PUT request using `http.client`:

```python
>>> # This creates an HTTP message
>>> # with the content of BODY as the enclosed representation
>>> # for the resource http://localhost:8080/file
```
>>> import http.client
>>> BODY = "***filecontents***"
>>> conn = http.client.HTTPConnection("localhost", &
>>> conn.request("PUT", "/file", BODY)
>>> response = conn.getresponse()
>>> print(response.status, response.reason)
200, OK
21.12.4. HTTPMessage Objects

An http.client.HTTPMessage instance holds the headers from an HTTP response. It is implemented using the email.message.Message class.
21.13. ftplib — FTP protocol client

Source code: Lib/ftplib.py

This module defines the class FTP and a few related items. The FTP class implements the client side of the FTP protocol. You can use this to write Python programs that perform a variety of automated FTP jobs, such as mirroring other ftp servers. It is also used by the module urllib.request to handle URLs that use FTP. For more information on FTP (File Transfer Protocol), see Internet RFC 959.

Here’s a sample session using the ftplib module:

```python
>>> from ftplib import FTP
>>> ftp = FTP('ftp.debian.org')  # connect to host
>>> ftp.login()                 # user anonymous
'230 Login successful.'
>>> ftp.cwd('debian')          # change into "debian" directory
>>> ftp.retrlines('LIST')      # list directory contents
-rw-rw-r-- 1 1176 1176 1063 Jun 15 10:18 README
...  
drwxr-sr-x 5 1176 1176 4096 Dec 19 2000 pool
drwxr-sr-x 4 1176 1176 4096 Nov 17 2008 project
drwxr-xr-x 3 1176 1176 4096 Oct 10 2012 tools
'226 Directory send OK.'
>>> ftp.retrbinary('RETR README', open('README', 'wb'))
'226 Transfer complete.'
>>> ftp.quit()
```

The module defines the following items:
class ftplib.**FTP**(*host*="", *user="", *passwd="", *acct="", *timeout=None, source_address=None*)

Return a new instance of the **FTP** class. When *host* is given, the method call `connect(host)` is made. When *user* is given, additionally the method call `login(user, passwd, acct)` is made (where *passwd* and *acct* default to the empty string when not given). The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if is not specified, the global default timeout setting will be used). *source_address* is a 2-tuple (*host*, *port*) for the socket to bind to as its source address before connecting.

The **FTP** class supports the **with** statement, e.g.:

```python
>>> from ftplib import FTP
>>> with FTP("ftp1.at.proftpd.org") as ftp:
...     ftp.login()
...     ftp.dir()
...
'230 Anonymous login ok, restrictions apply.'
```

*Changed in version 3.2*: Support for the **with** statement was added.

*Changed in version 3.3*: *source_address* parameter was added.

class ftplib.**FTP_TLS**(*host="", *user="", *passwd="", *acct="", keyfile=None, certfile=None, context=None, timeout=None, source_address=None*)
A FTP subclass which adds TLS support to FTP as described in RFC 4217. Connect as usual to port 21 implicitly securing the FTP control connection before authenticating. Securing the data connection requires the user to explicitly ask for it by calling the prot_p() method. context is a ssl.SSLContext object which allows bundling SSL configuration options, certificates and private keys into a single (potentially long-lived) structure. Please read Security considerations for best practices.

keyfile and certfile are a legacy alternative to context – they can point to PEM-formatted private key and certificate chain files (respectively) for the SSL connection.

New in version 3.2.

Changed in version 3.3: source_address parameter was added.

Changed in version 3.4: The class now supports hostname check with ssl.SSLContext.check_hostname and Server Name Indication (see ssl.HAS_SNI).

Here’s a sample session using the FTP_TLS class:

```python
>>> ftps = FTP_TLS('ftp.pureftpd.org')
>>> ftps.login()
'230 Anonymous user logged in'
>>> ftps.prot_p()
'200 Data protection level set to "private"
>>> ftps.nlst()
['6jack', 'OpenBSD', 'antilink', 'blogbench', 'bs...]
```

exception ftplib.error_reply
Exception raised when an unexpected reply is received from the server.

*exception* `ftplib.error_temp`

Exception raised when an error code signifying a temporary error (response codes in the range 400–499) is received.

*exception* `ftplib.error_perm`

Exception raised when an error code signifying a permanent error (response codes in the range 500–599) is received.

*exception* `ftplib.error_proto`

Exception raised when a reply is received from the server that does not fit the response specifications of the File Transfer Protocol, i.e. begin with a digit in the range 1–5.

`ftplib.all_errors`

The set of all exceptions (as a tuple) that methods of FTP instances may raise as a result of problems with the FTP connection (as opposed to programming errors made by the caller). This set includes the four exceptions listed above as well as `OSError`.

**See also:**

**Module netrc**

Parser for the `.netrc` file format. The file `.netrc` is typically used by FTP clients to load user authentication information before prompting the user.

The file `Tools/scripts/ftpmirror.py` in the Python source distribution is a script that can mirror FTP sites, or portions thereof, using the `ftplib` module. It can be used as an extended example that applies this module.
21.13.1. FTP Objects

Several methods are available in two flavors: one for handling text files and another for binary files. These are named for the command which is used followed by lines for the text version or binary for the binary version.

FTP instances have the following methods:

`FTP.set_debuglevel(level)`

Set the instance's debugging level. This controls the amount of debugging output printed. The default, 0, produces no debugging output. A value of 1 produces a moderate amount of debugging output, generally a single line per request. A value of 2 or higher produces the maximum amount of debugging output, logging each line sent and received on the control connection.

`FTP.connect(host='', port=0, timeout=None, source_address=None)`

Connect to the given host and port. The default port number is 21, as specified by the FTP protocol specification. It is rarely needed to specify a different port number. This function should be called only once for each instance; it should not be called at all if a host was given when the instance was created. All other methods can only be used after a connection has been made. The optional `timeout` parameter specifies a timeout in seconds for the connection attempt. If no `timeout` is passed, the global default timeout setting will be used. `source_address` is a 2-tuple `(host, port)` for the socket to bind to as its source address before connecting.

*Changed in version 3.3*: `source_address` parameter was added.
FTP. `getwelcome()`

Return the welcome message sent by the server in reply to the initial connection. (This message sometimes contains disclaimers or help information that may be relevant to the user.)

FTP. `login(user='anonymous', passwd='', acct='')`

Log in as the given `user`. The `passwd` and `acct` parameters are optional and default to the empty string. If no `user` is specified, it defaults to 'anonymous'. If `user` is 'anonymous', the default `passwd` is 'anonymous@'. This function should be called only once for each instance, after a connection has been established; it should not be called at all if a host and user were given when the instance was created. Most FTP commands are only allowed after the client has logged in. The `acct` parameter supplies “accounting information”; few systems implement this.

FTP. `abort()`

Abort a file transfer that is in progress. Using this does not always work, but it's worth a try.

FTP. `sendcmd(cmd)`

Send a simple command string to the server and return the response string.

FTP. `voidcmd(cmd)`

Send a simple command string to the server and handle the response. Return nothing if a response code corresponding to success (codes in the range 200–299) is received. Raise `error_reply` otherwise.

FTP. `retrbinary(cmd, callback, blocksize=8192, rest=None)`

Retrieve a file in binary transfer mode. `cmd` should be an
appropriate RETR command: 'RETR filename'. The callback function is called for each block of data received, with a single string argument giving the data block. The optional blocksize argument specifies the maximum chunk size to read on the low-level socket object created to do the actual transfer (which will also be the largest size of the data blocks passed to callback). A reasonable default is chosen. rest means the same thing as in the transfercmd() method.

FTP.retrlines(cmd, callback=None)
Retrieve a file or directory listing in ASCII transfer mode. cmd should be an appropriate RETR command (see retrbinary()) or a command such as LIST or NLST (usually just the string 'LIST'). LIST retrieves a list of files and information about those files. NLST retrieves a list of file names. The callback function is called for each line with a string argument containing the line with the trailing CRLF stripped. The default callback prints the line to sys.stdout.

FTP.set_pasv(boolean)
Enable “passive” mode if boolean is true, other disable passive mode. Passive mode is on by default.

FTP.storbinary(cmd, fp, blocksize=8192, callback=None, rest=None)
Store a file in binary transfer mode. cmd should be an appropriate STOR command: "STOR filename". fp is a file object (opened in binary mode) which is read until EOF using its read() method in blocks of size blocksize to provide the data to be stored. The blocksize argument defaults to 8192. callback is an optional single parameter callable that is called on each block of data after it is
sent. rest means the same thing as in the transfercmd() method.

*Changed in version 3.2: rest parameter added.*

**FTP. storlines(cmd, fp, callback=None)**

Store a file in ASCII transfer mode. cmd should be an appropriate STOR command (see storbinary()). Lines are read until EOF from the file object fp (opened in binary mode) using its readline() method to provide the data to be stored. callback is an optional single parameter callable that is called on each line after it is sent.

**FTP. transfercmd(cmd, rest=None)**

Initiate a transfer over the data connection. If the transfer is active, send an EPRT or PORT command and the transfer command specified by cmd, and accept the connection. If the server is passive, send an EPSV or PASV command, connect to it, and start the transfer command. Either way, return the socket for the connection.

If optional rest is given, a REST command is sent to the server, passing rest as an argument. rest is usually a byte offset into the requested file, telling the server to restart sending the file’s bytes at the requested offset, skipping over the initial bytes. Note however that RFC 959 requires only that rest be a string containing characters in the printable range from ASCII code 33 to ASCII code 126. The transfercmd() method, therefore, converts rest to a string, but no check is performed on the string’s contents. If the server does not recognize the REST command, an error_reply exception will be raised. If this happens, simply call transfercmd() without a rest argument.
FTP. `nttransfercmd(cmd, rest=None)`

Like `transfercmd()`, but returns a tuple of the data connection and the expected size of the data. If the expected size could not be computed, `None` will be returned as the expected size. `cmd` and `rest` means the same thing as in `transfercmd()`.

FTP. `mlsd(path='', facts=[])`  

List a directory in a standardized format by using MLSD command (RFC 3659). If `path` is omitted the current directory is assumed. `facts` is a list of strings representing the type of information desired (e.g. ["type", "size", "perm"]). Return a generator object yielding a tuple of two elements for every file found in path. First element is the file name, the second one is a dictionary containing facts about the file name. Content of this dictionary might be limited by the `facts` argument but server is not guaranteed to return all requested facts.

*New in version 3.3.*

FTP. `nlst(argument[, ...])`  

Return a list of file names as returned by the NLST command. The optional `argument` is a directory to list (default is the current server directory). Multiple arguments can be used to pass non-standard options to the NLST command.

*Deprecated since version 3.3: use `mlsd()` instead.*

FTP. `dir(argument[, ...])`  

Produce a directory listing as returned by the LIST command, printing it to standard output. The optional `argument` is a directory to list (default is the current server directory). Multiple arguments can be used to pass non-standard options to the LIST command.
If the last argument is a function, it is used as a *callback* function as for `retrlines()`; the default prints to `sys.stdout`. This method returns None.

*Deprecated since version 3.3*: use `mlsd()` instead.

**FTP. rename(fromname, toname)**

Rename file *fromname* on the server to *toname*.

**FTP. delete(filename)**

Remove the file named *filename* from the server. If successful, returns the text of the response, otherwise raises `error_perm` on permission errors or `error_reply` on other errors.

**FTP. cwd(pathname)**

Set the current directory on the server.

**FTP. mkd(pathname)**

Create a new directory on the server.

**FTP. pwd()**

Return the pathname of the current directory on the server.

**FTP. rmd(dirname)**

Remove the directory named *dirname* on the server.

**FTP. size(filename)**

Request the size of the file named *filename* on the server. On success, the size of the file is returned as an integer, otherwise None is returned. Note that the SIZE command is not standardized, but is supported by many common server implementations.
FTP. **quit()**

Send a QUIT command to the server and close the connection. This is the “polite” way to close a connection, but it may raise an exception if the server responds with an error to the QUIT command. This implies a call to the `close()` method which renders the FTP instance useless for subsequent calls (see below).

FTP. **close()**

Close the connection unilaterally. This should not be applied to an already closed connection such as after a successful call to `quit()`. After this call the FTP instance should not be used any more (after a call to `close()` or `quit()` you cannot reopen the connection by issuing another `login()` method).
21.13.2. FTP_TLS Objects

**FTP_TLS** class inherits from **FTP**, defining these additional objects:

**FTP_TLS.ssl_version**
The SSL version to use (defaults to `ssl.PROTOCOL_SSLv23`).

**FTP_TLS.auth()**
Set up a secure control connection by using TLS or SSL, depending on what is specified in the `ssl_version` attribute.

*Changed in version 3.4:* The method now supports hostname check with `ssl.SSLContext.check_hostname` and *Server Name Indication* (see `ssl.HAS_SNI`).

**FTP_TLS.ccc()**
Revert control channel back to plaintext. This can be useful to take advantage of firewalls that know how to handle NAT with non-secure FTP without opening fixed ports.

*New in version 3.3.*

**FTP_TLS.prot_p()**
Set up secure data connection.

**FTP_TLS.prot_c()**
Set up clear text data connection.
21.14. poplib — POP3 protocol client

Source code: Lib/poplib.py

This module defines a class, POP3, which encapsulates a connection to a POP3 server and implements the protocol as defined in RFC 1939. The POP3 class supports both the minimal and optional command sets from RFC 1939. The POP3 class also supports the STLS command introduced in RFC 2595 to enable encrypted communication on an already established connection.

Additionally, this module provides a class POP3_SSL, which provides support for connecting to POP3 servers that use SSL as an underlying protocol layer.

Note that POP3, though widely supported, is obsolescent. The implementation quality of POP3 servers varies widely, and too many are quite poor. If your mailserver supports IMAP, you would be better off using the imaplib.IMAP4 class, as IMAP servers tend to be better implemented.

The poplib module provides two classes:

```
class poplib.POP3(host, port=POP3_PORT[, timeout])
```

This class implements the actual POP3 protocol. The connection is created when the instance is initialized. If `port` is omitted, the standard POP3 port (110) is used. The optional `timeout` parameter specifies a timeout in seconds for the connection attempt (if not
specified, the global default timeout setting will be used).

class poplib.POP3_SSL(host, port=POP3_SSL_PORT, keyfile=None, certfile=None, timeout=None, context=None)

This is a subclass of POP3 that connects to the server over an SSL encrypted socket. If port is not specified, 995, the standard POP3-over-SSL port is used. timeout works as in the POP3 constructor. context is an optional ssl.SSLContext object which allows bundling SSL configuration options, certificates and private keys into a single (potentially long-lived) structure. Please read Security considerations for best practices.

keyfile and certfile are a legacy alternative to context - they can point to PEM-formatted private key and certificate chain files, respectively, for the SSL connection.

Changed in version 3.2: context parameter added.

Changed in version 3.4: The class now supports hostname check with ssl.SSLContext.check_hostname and Server Name Indication (see ssl.HAS_SNI).

One exception is defined as an attribute of the poplib module:

element poplib.error_proto

Exception raised on any errors from this module (errors from socket module are not caught). The reason for the exception is passed to the constructor as a string.

See also:

Module imaplib
The standard Python IMAP module.
<table>
<thead>
<tr>
<th>Frequently Asked Questions About Fetchmail</th>
</tr>
</thead>
<tbody>
<tr>
<td>The FAQ for the <strong>fetchmail</strong> POP/IMAP client collects information on POP3 server variations and RFC noncompliance that may be useful if you need to write an application based on the POP protocol.</td>
</tr>
</tbody>
</table>
21.14.1. POP3 Objects

All POP3 commands are represented by methods of the same name, in lower-case; most return the response text sent by the server.

An POP3 instance has the following methods:

**POP3.set_debuglevel(level)**

Set the instance's debugging level. This controls the amount of debugging output printed. The default, 0, produces no debugging output. A value of 1 produces a moderate amount of debugging output, generally a single line per request. A value of 2 or higher produces the maximum amount of debugging output, logging each line sent and received on the control connection.

**POP3.getwelcome()**

Returns the greeting string sent by the POP3 server.

**POP3.capa()**

Query the server's capabilities as specified in RFC 2449. Returns a dictionary in the form {'name': ['param'...]}.

_New in version 3.4._

**POP3.user(username)**

Send user command, response should indicate that a password is required.

**POP3.pass_(password)**

Send password, response includes message count and mailbox size. Note: the mailbox on the server is locked until quit() is called.
POP3. **apop**(user, secret)

Use the more secure APOP authentication to log into the POP3 server.

POP3. **rpop**(user)

Use RPOP authentication (similar to UNIX r-commands) to log into POP3 server.

POP3. **stat()**

Get mailbox status. The result is a tuple of 2 integers: (message count, mailbox size).

POP3. **list([which])**

Request message list, result is in the form (response, ['mesg_num octets', ...], octets). If which is set, it is the message to list.

POP3. **retr**(which)

Retrieve whole message number which, and set its seen flag. Result is in form (response, ['line', ...], octets).

POP3. **dele**(which)

Flag message number which for deletion. On most servers deletions are not actually performed until QUIT (the major exception is Eudora QPOP, which deliberately violates the RFCs by doing pending deletes on any disconnect).

POP3. **rset()**

Remove any deletion marks for the mailbox.

POP3. **noop()**

Do nothing. Might be used as a keep-alive.
**POP3.**\texttt{quit}()

Signoff: commit changes, unlock mailbox, drop connection.

**POP3.**\texttt{top}(\texttt{which}, \texttt{howmuch})

Retrieves the message header plus \textit{howmuch} lines of the message after the header of message number \texttt{which}. Result is in form (\texttt{response}, ['\texttt{line}', ...], \texttt{octets}).

The POP3 TOP command this method uses, unlike the RETR command, doesn’t set the message’s seen flag; unfortunately, TOP is poorly specified in the RFCs and is frequently broken in off-brand servers. Test this method by hand against the POP3 servers you will use before trusting it.

**POP3.**\texttt{uidl}(\texttt{which}=\texttt{None})

Return message digest (unique id) list. If \texttt{which} is specified, result contains the unique id for that message in the form 'response \texttt{mesgnum uid}', otherwise result is list (\texttt{response}, ['\texttt{mesgnum uid}', ...], \texttt{octets}).

**POP3.**\texttt{utf8}()

Try to switch to UTF-8 mode. Returns the server response if successful, raises \texttt{error\_proto} if not. Specified in \texttt{RFC 6856}.

\textit{New in version 3.5.}

**POP3.**\texttt{stls}(\texttt{context}=\texttt{None})

Start a TLS session on the active connection as specified in \texttt{RFC 2595}. This is only allowed before user authentication

\texttt{context} parameter is a \texttt{ssl\_SSLContext} object which allows bundling SSL configuration options, certificates and private keys into a single (potentially long-lived) structure. Please read \texttt{Security}
considerations for best practices.

This method supports hostname checking via `ssl.SSLContext.check_hostname` and `Server Name Indication` (see `ssl.HAS_SNI`).

*New in version 3.4.*

Instances of `POP3_SSL` have no additional methods. The interface of this subclass is identical to its parent.
21.14.2. POP3 Example

Here is a minimal example (without error checking) that opens a mailbox and retrieves and prints all messages:

```python
import getpass, poplib

M = poplib.POP3('localhost')
M.user(getpass.getuser())
M.pass_(getpass.getpass())
numMessages = len(M.list()[1])
for i in range(numMessages):
    for j in M.retr(i+1)[1]:
        print(j)
```

At the end of the module, there is a test section that contains a more extensive example of usage.
This module defines three classes, `IMAP4`, `IMAP4_SSL` and `IMAP4_stream`, which encapsulate a connection to an IMAP4 server and implement a large subset of the IMAP4rev1 client protocol as defined in RFC 2060. It is backward compatible with IMAP4 (RFC 1730) servers, but note that the STATUS command is not supported in IMAP4.

Three classes are provided by the `imaplib` module, `IMAP4` is the base class:

```python
class imaplib.IMAP4(host='', port=IMAP4_PORT)
```

This class implements the actual IMAP4 protocol. The connection is created and protocol version (IMAP4 or IMAP4rev1) is determined when the instance is initialized. If `host` is not specified, '' (the local host) is used. If `port` is omitted, the standard IMAP4 port (143) is used.

The `IMAP4` class supports the `with` statement. When used like this, the IMAP4 LOGOUT command is issued automatically when the `with` statement exits. E.g.:

```python
>>> from imaplib import IMAP4
>>> with IMAP4("domain.org") as M:
...     M.noop()
...```
Changed in version 3.5: Support for the `with` statement was added.

Three exceptions are defined as attributes of the `IMAP4` class:

*exception* `IMAP4.error`

Exception raised on any errors. The reason for the exception is passed to the constructor as a string.

*exception* `IMAP4.abort`

IMAP4 server errors cause this exception to be raised. This is a sub-class of `IMAP4.error`. Note that closing the instance and instantiating a new one will usually allow recovery from this exception.

*exception* `IMAP4.readonly`

This exception is raised when a writable mailbox has its status changed by the server. This is a sub-class of `IMAP4.error`. Some other client now has write permission, and the mailbox will need to be re-opened to re-obtain write permission.

There’s also a subclass for secure connections:

```python
class imaplib.IMAP4_SSL(host='', port=IMAP4_SSL_PORT, keyfile=None, certfile=None, ssl_context=None)
```

This is a subclass derived from `IMAP4` that connects over an SSL encrypted socket (to use this class you need a socket module that was compiled with SSL support). If `host` is not specified, '' (the local host) is used. If `port` is omitted, the standard IMAP4-over-SSL port (993) is used. `ssl_context` is a `ssl.SSLContext` object which
allows bundling SSL configuration options, certificates and private keys into a single (potentially long-lived) structure. Please read Security considerations for best practices.

`keyfile` and `certfile` are a legacy alternative to `ssl_context` - they can point to PEM-formatted private key and certificate chain files for the SSL connection. Note that the `keyfile/certfile` parameters are mutually exclusive with `ssl_context`, a `ValueError` is raised if `keyfile/certfile` is provided along with `ssl_context`.

*Changed in version 3.3:* `ssl_context` parameter added.

*Changed in version 3.4:* The class now supports hostname check with `ssl.SSLContext.check_hostname` and Server Name Indication (see `ssl.HAS_SNI`).

The second subclass allows for connections created by a child process:

```python
class imaplib.IMAP4_stream(command)
```

This is a subclass derived from `IMAP4` that connects to the stdin/stdout file descriptors created by passing `command` to `subprocess.Popen()`.

The following utility functions are defined:

```python
imaplib.Internaldate2tuple(datestr)
```

Parse an IMAP4 INTERNALDATE string and return corresponding local time. The return value is a `time.struct_time` tuple or None if the string has wrong format.

```python
imaplib.Int2AP(num)
```

Converts an integer into a string representation using characters
from the set [A .. P].

imaplib.ParseFlags(flagstr)
Converts an IMAP4 FLAGS response to a tuple of individual flags.

imaplib.Time2Internaldate(date_time)
Convert date_time to an IMAP4 INTERNALDATE representation. The return value is a string in the form: "DD-Mmm-YYYY HH:MM:SS +HHMM" (including double-quotes). The date_time argument can be a number (int or float) representing seconds since epoch (as returned by time.time()), a 9-tuple representing local time an instance of time.struct_time (as returned by time.localtime()), an aware instance of datetime.datetime, or a double-quoted string. In the last case, it is assumed to already be in the correct format.

Note that IMAP4 message numbers change as the mailbox changes; in particular, after an EXPUNGE command performs deletions the remaining messages are renumbered. So it is highly advisable to use UIDs instead, with the UID command.

At the end of the module, there is a test section that contains a more extensive example of usage.

See also: Documents describing the protocol, and sources and binaries for servers implementing it, can all be found at the University of Washington's IMAP Information Center (http://www.washington.edu/imap/).
21.15.1. IMAP4 Objects

All IMAP4rev1 commands are represented by methods of the same name, either upper-case or lower-case.

All arguments to commands are converted to strings, except for AUTHENTICATE, and the last argument to APPEND which is passed as an IMAP4 literal. If necessary (the string contains IMAP4 protocol-sensitive characters and isn’t enclosed with either parentheses or double quotes) each string is quoted. However, the password argument to the LOGIN command is always quoted. If you want to avoid having an argument string quoted (eg: the flags argument to STORE) then enclose the string in parentheses (eg: r'("Deleted")').

Each command returns a tuple: (type, [data, ...]) where type is usually 'OK' or 'NO', and data is either the text from the command response, or mandated results from the command. Each data is either a string, or a tuple. If a tuple, then the first part is the header of the response, and the second part contains the data (ie: 'literal' value).

The message_set options to commands below is a string specifying one or more messages to be acted upon. It may be a simple message number ('1'), a range of message numbers ('2:4'), or a group of non-contiguous ranges separated by commas ('1:3,6:9'). A range can contain an asterisk to indicate an infinite upper bound ('3:*').

An IMAP4 instance has the following methods:

IMAP4.append(mailbox, flags, date_time, message)

Append message to named mailbox.

IMAP4.authenticate(mechanism, authobject)
Authenticate command — requires response processing.

*mecanism* specifies which authentication mechanism is to be used - it should appear in the instance variable capabilities in the form AUTH=mecanism.

*authobject* must be a callable object:

```
data = authobject(response)
```

It will be called to process server continuation responses; the *response* argument it is passed will be bytes. It should return bytes *data* that will be base64 encoded and sent to the server. It should return None if the client abort response * should be sent instead.

*Changed in version 3.5:* string usernames and passwords are now encoded to utf-8 instead of being limited to ASCII.

**IMAP4.check()**

Checkpoint mailbox on server.

**IMAP4.close()**

Close currently selected mailbox. Deleted messages are removed from writable mailbox. This is the recommended command before LOGOUT.

**IMAP4.copy(message_set, new_mailbox)**

Copy *message_set* messages onto end of *new_mailbox*.

**IMAP4.create(mailbox)**

Create new mailbox named *mailbox*. 
IMAP4.\texttt{delete}(\texttt{mailbox})

Delete old mailbox named \texttt{mailbox}.

IMAP4.\texttt{deleteacl}(\texttt{mailbox}, \texttt{who})

Delete the ACLs (remove any rights) set for who on mailbox.

IMAP4.\texttt{enable}(\texttt{capability})

Enable \texttt{capability} (see \texttt{RFC 5161}). Most capabilities do not need to be enabled. Currently only the \texttt{UTF8=ACCEPT} capability is supported (see \texttt{RFC 6855}).

\textit{New in version 3.5}: The \texttt{enable()} method itself, and \texttt{RFC 6855} support.

IMAP4.\texttt{expunge}()

Permanently remove deleted items from selected mailbox. Generates an \texttt{EXPUNGE} response for each deleted message. Returned data contains a list of \texttt{EXPUNGE} message numbers in order received.

IMAP4.\texttt{fetch}(\texttt{message\_set}, \texttt{message\_parts})

Fetch (parts of) messages. \texttt{message\_parts} should be a string of message part names enclosed within parentheses, eg: "(UID BODY[TEXT])". Returned data are tuples of message part envelope and data.

IMAP4.\texttt{getacl}(\texttt{mailbox})

Get the ACLs for \texttt{mailbox}. The method is non-standard, but is supported by the Cyrus server.

IMAP4.\texttt{getannotation}(\texttt{mailbox}, \texttt{entry}, \texttt{attribute})

Retrieve the specified \texttt{ANNOTATION}s for \texttt{mailbox}. The method is
non-standard, but is supported by the Cyrus server.

**IMAP4.** `getquota(root)`
Get the quota `root`'s resource usage and limits. This method is part of the IMAP4 QUOTA extension defined in rfc2087.

**IMAP4.** `getquotaroot(mailbox)`
Get the list of quota roots for the named `mailbox`. This method is part of the IMAP4 QUOTA extension defined in rfc2087.

**IMAP4.** `list([directory[, pattern]])`
List mailbox names in `directory` matching `pattern`. `directory` defaults to the top-level mail folder, and `pattern` defaults to match anything. Returned data contains a list of LIST responses.

**IMAP4.** `login(user, password)`
Identify the client using a plaintext password. The `password` will be quoted.

**IMAP4.** `login_cram_md5(user, password)`
Force use of CRAM-MD5 authentication when identifying the client to protect the password. Will only work if the server CAPABILITY response includes the phrase AUTH=CRAM-MD5.

**IMAP4.** `logout()`
Shutdown connection to server. Returns server BYE response.

**IMAP4.** `lsub(directory="", pattern="*")`
List subscribed mailbox names in directory matching pattern. `directory` defaults to the top level directory and `pattern` defaults to match any mailbox. Returned data are tuples of message part envelope and data.
**IMAP4.myrights(mailbox)**
Show my ACLs for a mailbox (i.e. the rights that I have on mailbox).

**IMAP4.namespace()**
Returns IMAP namespaces as defined in RFC2342.

**IMAP4.noop()**
Send NOOP to server.

**IMAP4.open(host, port)**
Opens socket to port at host. This method is implicitly called by the IMAP4 constructor. The connection objects established by this method will be used in the IMAP4.read(), IMAP4.readline(), IMAP4.send(), and IMAP4shutdown() methods. You may override this method.

**IMAP4.partial(message_num, message_part, start, length)**
Fetch truncated part of a message. Returned data is a tuple of message part envelope and data.

**IMAP4.proxyauth(user)**
Assume authentication as user. Allows an authorised administrator to proxy into any user’s mailbox.

**IMAP4.read(size)**
Reads size bytes from the remote server. You may override this method.

**IMAP4.readline()**
Reads one line from the remote server. You may override this method.
**IMAP4**. `recent()`  
Prompt server for an update. Returned data is `None` if no new messages, else value of RECENT response.

**IMAP4**. `rename(oldmailbox, newmailbox)`  
Rename mailbox named `oldmailbox` to `newmailbox`.

**IMAP4**. `response(code)`  
Return data for response `code` if received, or `None`. Returns the given code, instead of the usual type.

**IMAP4**. `search(charset, criterion[, ...])`  
Search mailbox for matching messages. `charset` may be `None`, in which case no CHARSET will be specified in the request to the server. The IMAP protocol requires that at least one criterion be specified; an exception will be raised when the server returns an error. `charset` must be `None` if the UTF8=ACCEPT capability was enabled using the `enable()` command.

Example:

```python
# M is a connected IMAP4 instance...
typ, msgnums = M.search(None, 'FROM', '"LDJ"')
# or:
typ, msgnums = M.search(None, '(FROM "LDJ")')
```

**IMAP4**. `select(mailbox='INBOX', readonly=False)`  
Select a mailbox. Returned data is the count of messages in `mailbox` (EXISTS response). The default `mailbox` is 'INBOX'. If the `readonly` flag is set, modifications to the mailbox are not allowed.
**IMAP4.send(data)**
Sends data to the remote server. You may override this method.

**IMAP4.setacl(mailbox, who, what)**
Set an ACL for mailbox. The method is non-standard, but is supported by the Cyrus server.

**IMAP4.setannotation(mailbox, entry, attribute[,...])**
Set ANNOTATIONs for mailbox. The method is non-standard, but is supported by the Cyrus server.

**IMAP4.setquota(root, limits)**
Set the quota root's resource limits. This method is part of the IMAP4 QUOTA extension defined in rfc2087.

**IMAP4.shutdown()**
Close connection established in open. This method is implicitly called by IMAP4.logout(). You may override this method.

**IMAP4.socket()**
Returns socket instance used to connect to server.

**IMAP4.sort(sort_criteria, charset, search_criterion[,...])**
The sort command is a variant of search with sorting semantics for the results. Returned data contains a space separated list of matching message numbers.

Sort has two arguments before the search_criterion argument(s); a parenthesized list of sort_criteria, and the searching charset. Note that unlike search, the searching charset argument is mandatory. There is also a uid sort command which corresponds to sort
the way that uid search corresponds to search. The sort command first searches the mailbox for messages that match the given searching criteria using the charset argument for the interpretation of strings in the searching criteria. It then returns the numbers of matching messages.

This is an IMAP4rev1 extension command.

**IMAP4.starttls**(*ssl_context=None*)

Send a STARTTLS command. The *ssl_context* argument is optional and should be a *ssl.SSLContext* object. This will enable encryption on the IMAP connection. Please read Security considerations for best practices.

*New in version 3.2.*

*Changed in version 3.4:* The method now supports hostname check with *ssl.SSLContext.check_hostname* and Server Name Indication (see *ssl.HAS_SNI*).

**IMAP4.status**(*mailbox, names*)

Request named status conditions for *mailbox*.

**IMAP4.store**(*message_set, command, flag_list*)

Alters flag dispositions for messages in mailbox. *command* is specified by section 6.4.6 of RFC 2060 as being one of “FLAGS”, “+FLAGS”, or “-FLAGS”, optionally with a suffix of ”.SILENT”.

For example, to set the delete flag on all messages:

```python
typ, data = M.search(None, 'ALL')
for num in data[0].split():
    M.store(num, '+FLAGS', '\\Deleted')
```
IMAP4. **subscribe**(mailbox)
   Subscribe to new mailbox.

IMAP4. **thread**(threading_algorithm, charset, search_criterion[, ...])
   The thread command is a variant of search with threading semantics for the results. Returned data contains a space separated list of thread members.

   Thread members consist of zero or more messages numbers, delimited by spaces, indicating successive parent and child.

   Thread has two arguments before the search_criterion argument(s); a threading_algorithm, and the searching charset. Note that unlike search, the searching charset argument is mandatory. There is also a uid thread command which corresponds to thread the way that uid search corresponds to search. The thread command first searches the mailbox for messages that match the given searching criteria using the charset argument for the interpretation of strings in the searching criteria. It then returns the matching messages threaded according to the specified threading algorithm.

   This is an IMAP4rev1 extension command.

IMAP4. **uid**(command, arg[, ...])
   Execute command args with messages identified by UID, rather than message number. Returns response appropriate to command. At least one argument must be supplied; if none are provided, the server will return an error and an exception will be raised.
**IMAP4.** `unsubscribe(mailbox)`
Unsubscribe from old mailbox.

**IMAP4.** `xatom(name[, ...])`
Allow simple extension commands notified by server in CAPABILITY response.

The following attributes are defined on instances of **IMAP4**:

**IMAP4.** `PROTOCOL_VERSION`
The most recent supported protocol in the CAPABILITY response from the server.

**IMAP4.** `debug`
Integer value to control debugging output. The initialize value is taken from the module variable `Debug`. Values greater than three trace each command.

**IMAP4.** `utf8_enabled`
Boolean value that is normally False, but is set to True if an `enable()` command is successfully issued for the UTF8=ACCEPT capability.

*New in version 3.5.*
21.15.2. IMAP4 Example

Here is a minimal example (without error checking) that opens a mailbox and retrieves and prints all messages:

```python
import getpass, imaplib

M = imaplib.IMAP4()
M.login(getpass.getuser(), getpass.getpass())
M.select()
typ, data = M.search(None, 'ALL')
for num in data[0].split():
    typ, data = M.fetch(num, '(RFC822)')
    print('Message %s
%s
' % (num, data[0][1]))
M.close()
M.logout()
```
This module defines the class **NNTP** which implements the client side of the Network News Transfer Protocol. It can be used to implement a news reader or poster, or automated news processors. It is compatible with **RFC 3977** as well as the older **RFC 977** and **RFC 2980**.

Here are two small examples of how it can be used. To list some statistics about a newsgroup and print the subjects of the last 10 articles:

```python
>>> s = nntplib.NNTP('news.gmane.org')
>>> resp, count, first, last, name = s.group('gmane.comp.python.committers')
>>> print('Group', name, 'has', count, 'articles, range', first, 'to', last)
Group gmane.comp.python.committers has 1096 articles, range 1 to 1096
>>> resp, overviews = s.overviews((last - 9, last))
>>> for id, over in overviews:
...     print(id, nntplib.decode_header(over['subject']))
1087 Re: Commit privileges for Łukasz Langa
1088 Re: 3.2 alpha 2 freeze
1089 Re: 3.2 alpha 2 freeze
1090 Re: Commit privileges for Łukasz Langa
1091 Re: Commit privileges for Łukasz Langa
1092 Updated ssh key
1093 Re: Updated ssh key
1094 Re: Updated ssh key
1095 Hello fellow committers!
1096 Re: Hello fellow committers!
```
To post an article from a binary file (this assumes that the article has valid headers, and that you have right to post on the particular newsgroup):

```python
>>> s.quit()
'205 Bye!'
```

```python
>>> s = nntplib.NNTP('news.gmane.org')
>>> f = open('article.txt', 'rb')
>>> s.post(f)
'240 Article posted successfully.'
>>> s.quit()
'205 Bye!'
```

The module itself defines the following classes:

```python
class nntplib.NNTP(host, port=119, user=None, password=None,
readermode=None, usenetrc=False[, timeout])
```

Return a new NNTP object, representing a connection to the NNTP server running on host `host`, listening at port `port`. An optional `timeout` can be specified for the socket connection. If the optional `user` and `password` are provided, or if suitable credentials are present in `/.netrc` and the optional flag `usenetrc` is true, the AUTHINFO USER and AUTHINFO PASS commands are used to identify and authenticate the user to the server. If the optional flag `readermode` is true, then a `mode reader` command is sent before authentication is performed. Reader mode is sometimes necessary if you are connecting to an NNTP server on the local machine and intend to call reader-specific commands, such as `group`. If you get unexpected `NNTPPermanentErrors`, you might need to set `readermode`. The `NNTP` class supports the `with` statement to unconditionally consume `OSError` exceptions and to close the
NNTP connection when done, e.g.:

```python
>>> from nntplib import NNTP
>>> with NNTP('news.gmane.org') as n:
...     n.group('gmane.comp.python.committers')
... ('211 1755 1 1755 gmane.comp.python.committers',
```

*Changed in version 3.2:* `usenetrc` is now `False` by default.

*Changed in version 3.3:* Support for the `with` statement was added.

```python
class nntplib.NNTP_SSL(host, port=563, user=None, 
password=None, ssl_context=None, readermode=None, 
usenetrc=False[, timeout])
```

Return a new `NNTP_SSL` object, representing an encrypted connection to the NNTP server running on host `host`, listening at port `port`. `NNTP_SSL` objects have the same methods as `NNTP` objects. If `port` is omitted, port 563 (NNTPS) is used. `ssl_context` is also optional, and is a `SSLContext` object. Please read Security considerations for best practices. All other parameters behave the same as for `NNTP`.

Note that SSL-on-563 is discouraged per RFC 4642, in favor of STARTTLS as described below. However, some servers only support the former.

*New in version 3.2.*

*Changed in version 3.4:* The class now supports hostname check with `ssl.SSLContext.check_hostname` and *Server Name*
Indication (see ssl.HAS_SNI).

**exception nntplib.NNTPError**

Derived from the standard exception `Exception`, this is the base class for all exceptions raised by the `nntplib` module. Instances of this class have the following attribute:

**response**

The response of the server if available, as a `str` object.

**exception nntplib.NNTPReplyError**

Exception raised when an unexpected reply is received from the server.

**exception nntplib.NNTPTemporaryError**

Exception raised when a response code in the range 400–499 is received.

**exception nntplib.NNTPPermanentError**

Exception raised when a response code in the range 500–599 is received.

**exception nntplib.NNTPProtocolError**

Exception raised when a reply is received from the server that does not begin with a digit in the range 1–5.

**exception nntplib.NNTPDataError**

Exception raised when there is some error in the response data.
21.16.1. NNTP Objects

When connected, NNTP and NNTP_SSL objects support the following methods and attributes.

21.16.1.1. Attributes

NNTP.nntp_version
An integer representing the version of the NNTP protocol supported by the server. In practice, this should be 2 for servers advertising RFC 3977 compliance and 1 for others.

New in version 3.2.

NNTP.nntp_implementation
A string describing the software name and version of the NNTP server, or None if not advertised by the server.

New in version 3.2.

21.16.1.2. Methods

The response that is returned as the first item in the return tuple of almost all methods is the server’s response: a string beginning with a three-digit code. If the server’s response indicates an error, the method raises one of the above exceptions.

Many of the following methods take an optional keyword-only argument file. When the file argument is supplied, it must be either a file object opened for binary writing, or the name of an on-disk file to be written to. The method will then write any data returned by the
server (except for the response line and the terminating dot) to the file; any list of lines, tuples or objects that the method normally returns will be empty.

*Changed in version 3.2:* Many of the following methods have been reworked and fixed, which makes them incompatible with their 3.1 counterparts.

**NNTP.quit()**

Send a QUIT command and close the connection. Once this method has been called, no other methods of the NNTP object should be called.

**NNTP.getwelcome()**

Return the welcome message sent by the server in reply to the initial connection. (This message sometimes contains disclaimers or help information that may be relevant to the user.)

**NNTP.getcapabilities()**

Return the RFC 3977 capabilities advertised by the server, as a `dict` instance mapping capability names to (possibly empty) lists of values. On legacy servers which don’t understand the CAPABILITIES command, an empty dictionary is returned instead.

```python
>>> s = NNTP('news.gmane.org')
>>> 'POST' in s.getcapabilities()
True
```

*New in version 3.2.*

**NNTP.login(user=None, password=None, usenetrc=True)**

Send AUTHINFO commands with the user name and password. If
user and password are None and usenetrc is true, credentials from ~/.netrc will be used if possible.

Unless intentionally delayed, login is normally performed during the NNTP object initialization and separately calling this function is unnecessary. To force authentication to be delayed, you must not set user or password when creating the object, and must set usenetrc to False.

New in version 3.2.

NNTP.starttls(ssl_context=None)
Send a STARTTLS command. This will enable encryption on the NNTP connection. The ssl_context argument is optional and should be a ssl.SSLContext object. Please read Security considerations for best practices.

Note that this may not be done after authentication information has been transmitted, and authentication occurs by default if possible during a NNTP object initialization. See NNTP.login() for information on suppressing this behavior.

New in version 3.2.

Changed in version 3.4: The method now supports hostname check with ssl.SSLContext.check_hostname and Server Name Indication (see ssl.HAS_SNI).

NNTP.newgroups(date, *, file=None)
Send a NEWGROUPS command. The date argument should be a datetime.date or datetime.datetime object. Return a pair (response, groups) where groups is a list representing the groups that are new since the given date. If file is supplied, though,
then groups will be empty.

```python
>>> from datetime import date, timedelta
>>> resp, groups = s.newgroups(date.today()) - timedelta
>>> len(groups)
85
>>> groups[0]
GroupInfo(group='gmane.network.tor.devel', last=''.
```

**NNTP .newnews(group, date, *, file=None)**

Send a NEWNEWS command. Here, group is a group name or ' * ', and date has the same meaning as for newgroups(). Return a pair (response, articles) where articles is a list of message ids.

This command is frequently disabled by NNTP server administrators.

**NNTP .list(group_pattern=None, *, file=None)**

Send a LIST or LIST ACTIVE command. Return a pair (response, list) where list is a list of tuples representing all the groups available from this NNTP server, optionally matching the pattern string group_pattern. Each tuple has the form (group, last, first, flag), where group is a group name, last and first are the last and first article numbers, and flag usually takes one of these values:

- **y**: Local postings and articles from peers are allowed.
- **m**: The group is moderated and all postings must be approved.
- **n**: No local postings are allowed, only articles from peers.
- **j**: Articles from peers are filed in the junk group instead.
- **x**: No local postings, and articles from peers are ignored.
• =foo.bar: Articles are filed in the foo.bar group instead.

If flag has another value, then the status of the newsgroup should be considered unknown.

This command can return very large results, especially if group_pattern is not specified. It is best to cache the results offline unless you really need to refresh them.

*Changed in version 3.2: group_pattern was added.*

**NNTP.descriptions(group_pattern)**

Send a LIST NEWSGROUPS command, where group_pattern is a wildmat string as specified in RFC 3977 (it's essentially the same as DOS or UNIX shell wildcard strings). Return a pair (response, descriptions), where descriptions is a dictionary mapping group names to textual descriptions.

```python
>>> resp, descs = s.descriptions('gmane.comp.python.*')
>>> len(descs)
295
>>> descs.popitem()
('gmane.comp.python.bio.general', 'BioPython discussion list (Moderated)')
```

**NNTP.description(group)**

Get a description for a single group group. If more than one group matches (if 'group' is a real wildmat string), return the first match. If no group matches, return an empty string.

This elides the response code from the server. If the response code is needed, use descriptions().

**NNTP.group(name)**
Send a GROUP command, where name is the group name. The group is selected as the current group, if it exists. Return a tuple (response, count, first, last, name) where count is the (estimated) number of articles in the group, first is the first article number in the group, last is the last article number in the group, and name is the group name.

NNTP.over(message_spec, *, file=None)

Send an OVER command, or an XOVER command on legacy servers. message_spec can be either a string representing a message id, or a (first, last) tuple of numbers indicating a range of articles in the current group, or a (first, None) tuple indicating a range of articles starting from first to the last article in the current group, or None to select the current article in the current group.

Return a pair (response, overviews). overviews is a list of (article_number, overview) tuples, one for each article selected by message_spec. Each overview is a dictionary with the same number of items, but this number depends on the server. These items are either message headers (the key is then the lower-cased header name) or metadata items (the key is then the metadata name prepended with ":"). The following items are guaranteed to be present by the NNTP specification:

- the subject, from, date, message-id and references headers
- the :bytes metadata: the number of bytes in the entire raw article (including headers and body)
- the :lines metadata: the number of lines in the article body

The value of each item is either a string, or None if not present.
It is advisable to use the `decode_header()` function on header values when they may contain non-ASCII characters:

```python
>>> _, _, first, last, _ = s.group('gmane.comp.python.devel')
>>> resp, overviews = s.over((last, last))
>>> art_num, over = overviews[0]
>>> art_num
117216
>>> list(over.keys())
['xref', 'from', ':lines', ':bytes', 'references']
>>> over['from']
'=?UTF-8?B?Ik1hcnRpbjB2LiBm7Z3aXMi?= <martin@v.l
>>> nntplib.decode_header(over['from'])
'Martin v. Löwis' <martin@v.loewis.de>'
```

New in version 3.2.

**NNTP.**`.help(*, file=None)`

Send a HELP command. Return a pair `(response, list)` where `list` is a list of help strings.

**NNTP.stat**(message_spec=None)

Send a STAT command, where `message_spec` is either a message id (enclosed in '<' and '>') or an article number in the current group. If `message_spec` is omitted or `None`, the current article in the current group is considered. Return a triple `(response, number, id)` where `number` is the article number and `id` is the message id.

```python
>>> _, _, first, last, _ = s.group('gmane.comp.python.devel')
>>> resp, number, message_id = s.stat(first)
>>> number, message_id
(9099, '<20030112190404.GE29873@epoch.metaslash.com>')
```
NNTP.next()
    Send a NEXT command. Return as for stat().

NNTP.last()
    Send a LAST command. Return as for stat().

NNTP.article(message_spec=None, *, file=None)
    Send an ARTICLE command, where message_spec has the same
    meaning as for stat(). Return a tuple (response, info)
    where info is a namedtuple with three attributes number,
    message_id and lines (in that order). number is the article
    number in the group (or 0 if the information is not available),
    message_id the message id as a string, and lines a list of lines
    (without terminating newlines) comprising the raw message including
    headers and body.

>>> resp, info = s.article('<20030112190404.GE29873@epoch.metaslash.com>
>>> info.number
0
>>> info.message_id
'<20030112190404.GE29873@epoch.metaslash.com>'
>>> len(info.lines)
65
>>> info.lines[0]
b'Path: main.gmane.org!not-for-mail'
>>> info.lines[1]
b'From: Neal Norwitz <neal@metaslash.com>'
>>> info.lines[-3:]
[b'There is a patch for 2.3 as well as 2.2.', b''

NNTP.head(message_spec=None, *, file=None)
    Same as article(), but sends a HEAD command. The lines
returned (or written to file) will only contain the message headers, not the body.

NNTP.body(message_spec=None, *, file=None)
Same as article(), but sends a BODY command. The lines returned (or written to file) will only contain the message body, not the headers.

NNTP.post(data)
Post an article using the POST command. The data argument is either a file object opened for binary reading, or any iterable of bytes objects (representing raw lines of the article to be posted). It should represent a well-formed news article, including the required headers. The post() method automatically escapes lines beginning with . and appends the termination line.

If the method succeeds, the server’s response is returned. If the server refuses posting, a NNTPReplyError is raised.

NNTP.ihave(message_id, data)
Send an IHAVE command. message_id is the id of the message to send to the server (enclosed in '<' and '>'). The data parameter and the return value are the same as for post().

NNTP.date()
Return a pair (response, date). date is a datetime object containing the current date and time of the server.

NNTP.slave()
Send a SLAVE command. Return the server’s response.

NNTP.set_debuglevel(level)
Set the instance's debugging level. This controls the amount of debugging output printed. The default, 0, produces no debugging output. A value of 1 produces a moderate amount of debugging output, generally a single line per request or response. A value of 2 or higher produces the maximum amount of debugging output, logging each line sent and received on the connection (including message text).

The following are optional NNTP extensions defined in RFC 2980. Some of them have been superseded by newer commands in RFC 3977.

**NNTP.xhdr**(hdr, str, *, file=None)

Send an XHDR command. The *hdr* argument is a header keyword, e.g. 'subject'. The *str* argument should have the form 'first-last' where *first* and *last* are the first and last article numbers to search. Return a pair (response, list), where *list* is a list of pairs (*id*, *text*), where *id* is an article number (as a string) and *text* is the text of the requested header for that article. If the *file* parameter is supplied, then the output of the XHDR command is stored in a file. If *file* is a string, then the method will open a file with that name, write to it then close it. If *file* is a *file object*, then it will start calling *write()* on it to store the lines of the command output. If *file* is supplied, then the returned *list* is an empty list.

**NNTP.xover**(start, end, *, file=None)

Send an X0VER command. *start* and *end* are article numbers delimiting the range of articles to select. The return value is the same of for *over()* . It is recommended to use *over()* instead, since it will automatically use the newer OVER command if available.
NNTP.\texttt{xpath}(id)

Return a pair \((\texttt{resp}, \texttt{path})\), where \texttt{path} is the directory path to the article with message ID \textit{id}. Most of the time, this extension is not enabled by NNTP server administrators.

\textit{Deprecated since version 3.3}: The XPATH extension is not actively used.
21.16.2. Utility functions

The module also defines the following utility function:

\[ \text{nntplib.} \text{decode\_header}(header\_str) \]

Decode a header value, un-escaping any escaped non-ASCII characters. \textit{header\_str} must be a \texttt{str} object. The unescaped value is returned. Using this function is recommended to display some headers in a human readable form:

\[
\begin{align*}
>>> \text{decode\_header("Some subject")} \\
\text{'Some subject'} \\
>>> \text{decode\_header("=?ISO-8859-15?Q?D=E9buter\_en\_P\n\text'Débuter en Python'} \\
>>> \text{decode\_header("Re: =?UTF-8?B?cHJvYmzDqG1lIGRL\n\text'Re: problème de matrice'}
\end{align*}
\]

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21.17. **smtplib — SMTP protocol client**

**Source code:** Lib/smtplib.py

The `smtplib` module defines an SMTP client session object that can be used to send mail to any Internet machine with an SMTP or ESMTP listener daemon. For details of SMTP and ESMTP operation, consult **RFC 821** (Simple Mail Transfer Protocol) and **RFC 1869** (SMTP Service Extensions).

```python
class smtplib.SMTP(host='', port=0, local_hostname=None, timeout=None, source_address=None)
```

An SMTP instance encapsulates an SMTP connection. It has methods that support a full repertoire of SMTP and ESMTP operations. If the optional host and port parameters are given, the SMTP `connect()` method is called with those parameters during initialization. If specified, `local_hostname` is used as the FQDN of the local host in the HELO/EHLO command. Otherwise, the local hostname is found using `socket.getfqdn()`. If the `connect()` call returns anything other than a success code, an `SMTPConnectError` is raised. The optional `timeout` parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used). If the timeout expires, `socket.timeout` is raised. The optional `source_address` parameter allows to bind to some specific source address in a machine with multiple network interfaces, and/or to some specific source TCP port. It takes a 2-tuple (host, port), for the socket to bind to as its source address.
before connecting. If omitted (or if host or port are '' and/or 0 respectively) the OS default behavior will be used.

For normal use, you should only require the initialization/connect, sendmail(), and quit() methods. An example is included below.

The **SMTP** class supports the *with* statement. When used like this, the SMTP QUIT command is issued automatically when the *with* statement exits. E.g.:

```python
>>> from smtplib import SMTP
>>> with SMTP("domain.org") as smtp:
...     smtp.noop()
... (250, b'0k')
```

*Changed in version 3.3:* Support for the *with* statement was added.

*Changed in version 3.3:* source_address argument was added.

*New in version 3.5:* The SMTPUTF8 extension (**RFC 6531**) is now supported.

```python
class smtplib.SMTP_SSL(host='', port=0, local_hostname=None, keyfile=None, certfile=None, [timeout, ]context=None, source_address=None)
```

An **SMTP_SSL** instance behaves exactly the same as instances of **SMTP**. **SMTP_SSL** should be used for situations where SSL is required from the beginning of the connection and using starttls() is not appropriate. If *host* is not specified, the local
host is used. If port is zero, the standard SMTP-over-SSL port (465) is used. The optional arguments local_hostname, timeout and source_address have the same meaning as they do in the SMTP class. context, also optional, can contain a SSLContext and allows to configure various aspects of the secure connection. Please read Security considerations for best practices.

keyfile and certfile are a legacy alternative to context, and can point to a PEM formatted private key and certificate chain file for the SSL connection.

*Changed in version 3.3:* context was added.

*Changed in version 3.3:* source_address argument was added.

*Changed in version 3.4:* The class now supports hostname check with ssl.SSLContext.check_hostname and Server Name Indication (see ssl.HAS_SNI).

class smtplib.LMTP(host='', port=LMTP_PORT, local_hostname=None, source_address=None)

The LMTP protocol, which is very similar to ESMTP, is heavily based on the standard SMTP client. It's common to use Unix sockets for LMTP, so our connect() method must support that as well as a regular host:port server. The optional arguments local_hostname and source_address have the same meaning as they do in the SMTP class. To specify a Unix socket, you must use an absolute path for host, starting with a ‘/’.

Authentication is supported, using the regular SMTP mechanism. When using a Unix socket, LMTP generally don’t support or require any authentication, but your mileage might vary.
A nice selection of exceptions is defined as well:

```python
exception smtplib.SMTPException
```

Subclass of `OSError` that is the base exception class for all the other exceptions provided by this module.

*Changed in version 3.4:* SMTPException became subclass of `OSError`

```python
exception smtplib.SMTPServerDisconnected
```

This exception is raised when the server unexpectedly disconnects, or when an attempt is made to use the SMTP instance before connecting it to a server.

```python
exception smtplib.SMTPResponseException
```

Base class for all exceptions that include an SMTP error code. These exceptions are generated in some instances when the SMTP server returns an error code. The error code is stored in the `smtp_code` attribute of the error, and the `smtp_error` attribute is set to the error message.

```python
exception smtplib.SMTPSenderRefused
```

Sender address refused. In addition to the attributes set by on all `SMTPResponseException` exceptions, this sets ‘sender’ to the string that the SMTP server refused.

```python
exception smtplib.SMTPRecipientsRefused
```

All recipient addresses refused. The errors for each recipient are accessible through the attribute `recipients`, which is a dictionary of exactly the same sort as `SMTP.sendmail()` returns.

```python
exception smtplib.SMTPDataError
```

The SMTP server refused to accept the message data.
exception smtplib.SMTPConnectError
Error occurred during establishment of a connection with the server.

exception smtplib.SMTPHeloError
The server refused our HELO message.

exception smtplib.SMTPNotSupportedError
The command or option attempted is not supported by the server.

New in version 3.5.

exception smtplib.SMTPAuthenticationError
SMTP authentication went wrong. Most probably the server didn’t accept the username/password combination provided.

See also:

RFC 821 - Simple Mail Transfer Protocol
Protocol definition for SMTP. This document covers the model, operating procedure, and protocol details for SMTP.

RFC 1869 - SMTP Service Extensions
Definition of the ESMTP extensions for SMTP. This describes a framework for extending SMTP with new commands, supporting dynamic discovery of the commands provided by the server, and defines a few additional commands.
21.17.1. SMTP Objects

An SMTP instance has the following methods:

SMTP.set_debuglevel(level)
Set the debug output level. A value of 1 or True for level results in debug messages for connection and for all messages sent to and received from the server. A value of 2 for level results in these messages being timestamped.

*Changed in version 3.5:* Added debuglevel 2.

SMTP.docmd(cmd, args="")
Send a command cmd to the server. The optional argument args is simply concatenated to the command, separated by a space.

This returns a 2-tuple composed of a numeric response code and the actual response line (multiline responses are joined into one long line.)

In normal operation it should not be necessary to call this method explicitly. It is used to implement other methods and may be useful for testing private extensions.

If the connection to the server is lost while waiting for the reply, SMTPServerDisconnected will be raised.

SMTP.connect(host='localhost', port=0)
Connect to a host on a given port. The defaults are to connect to the local host at the standard SMTP port (25). If the hostname ends with a colon (':') followed by a number, that suffix will be stripped off and the number interpreted as the port number to use. This
method is automatically invoked by the constructor if a host is specified during instantiation. Returns a 2-tuple of the response code and message sent by the server in its connection response.

**SMTP.helo(name="")**
Identify yourself to the SMTP server using HELO. The hostname argument defaults to the fully qualified domain name of the local host. The message returned by the server is stored as the helo_resp attribute of the object.

In normal operation it should not be necessary to call this method explicitly. It will be implicitly called by the `sendmail()` when necessary.

**SMTP.ehlo(name="")**
Identify yourself to an ESMTP server using EHLO. The hostname argument defaults to the fully qualified domain name of the local host. Examine the response for ESMTP option and store them for use by `has_extn()`. Also sets several informational attributes: the message returned by the server is stored as the ehlo_resp attribute, does_esmtp is set to true or false depending on whether the server supports ESMTP, and esmtp_features will be a dictionary containing the names of the SMTP service extensions this server supports, and their parameters (if any).

Unless you wish to use `has_extn()` before sending mail, it should not be necessary to call this method explicitly. It will be implicitly called by `sendmail()` when necessary.

**SMTP.ehlo_or_helo_if_needed()**
This method call `ehlo()` and or `helo()` if there has been no previous EHLO or HELO command this session. It tries ESMTP
EHLO first.

**SMTPHeloError**

The server didn’t reply properly to the HELO greeting.

**SMTP**.has_extn(name)

Return True if name is in the set of SMTP service extensions returned by the server, False otherwise. Case is ignored.

**SMTP**.verify(address)

Check the validity of an address on this server using SMTP VRFY. Returns a tuple consisting of code 250 and a full RFC 822 address (including human name) if the user address is valid. Otherwise returns an SMTP error code of 400 or greater and an error string.

**Note:** Many sites disable SMTP VRFY in order to foil spammers.

**SMTP**.login(user, password, *, initial_response_ok=True)

Log in on an SMTP server that requires authentication. The arguments are the username and the password to authenticate with. If there has been no previous EHLO or HELO command this session, this method tries ESMTP EHLO first. This method will return normally if the authentication was successful, or may raise the following exceptions:

**SMTPHeloError**

The server didn’t reply properly to the HELO greeting.

**SMTPAuthenticationError**

The server didn’t accept the username/password combination.

**SMTPNotSupportedError**

The AUTH command is not supported by the server.
SMTPException

No suitable authentication method was found.

Each of the authentication methods supported by `smtplib` are tried in turn if they are advertised as supported by the server. See `auth()` for a list of supported authentication methods. `initial_response_ok` is passed through to `auth()`.

Optional keyword argument `initial_response_ok` specifies whether, for authentication methods that support it, an “initial response” as specified in RFC 4954 can be sent along with the AUTH command, rather than requiring a challenge/response.

*Changed in version 3.5:* `SMTPNotSupportedError` may be raised, and the `initial_response_ok` parameter was added.

```python
SMTP.auth(mechanism, authobject, *, initial_response_ok=True)
```

Issue an SMTP AUTH command for the specified authentication `mechanism`, and handle the challenge response via `authobject`.

`mechanism` specifies which authentication mechanism is to be used as argument to the AUTH command; the valid values are those listed in the `auth` element of `esmtp_features`.

`authobject` must be a callable object taking an optional single argument:

```
data = authobject(challenge=None)
```

If optional keyword argument `initial_response_ok` is true, `authobject()` will be called first with no argument. It can return the RFC 4954 “initial response” bytes which will be encoded and sent with the AUTH command as below. If the `authobject()`
does not support an initial response (e.g. because it requires a challenge), it should return None when called with challenge=None. If `initial_response_ok` is false, then `authobject()` will not be called first with None.

If the initial response check returns None, or if `initial_response_ok` is false, `authobject()` will be called to process the server's challenge response; the `challenge` argument it is passed will be a bytes. It should return bytes `data` that will be base64 encoded and sent to the server.

The SMTP class provides authobjects for the CRAM-MD5, PLAIN, and LOGIN mechanisms; they are named `SMTP.auth_cram_md5`, `SMTP.auth_plain`, and `SMTP.auth_login` respectively. They all require that the user and password properties of the SMTP instance are set to appropriate values.

User code does not normally need to call auth directly, but can instead call the `login()` method, which will try each of the above mechanisms in turn, in the order listed. auth is exposed to facilitate the implementation of authentication methods not (or not yet) supported directly by smtplib.

New in version 3.5.

**SMTP.starttls(keyfile=None, certfile=None, context=None)**

Put the SMTP connection in TLS (Transport Layer Security) mode. All SMTP commands that follow will be encrypted. You should then call `ehlo()` again.

If `keyfile` and `certfile` are provided, these are passed to the `socket`
module's `ssl()` function.

Optional `context` parameter is a `ssl.SSLContext` object; This is an alternative to using a keyfile and a certfile and if specified both `keyfile` and `certfile` should be None.

If there has been no previous EHLO or HELO command this session, this method tries ESMTP EHLO first.

**SMTPHeloError**

The server didn’t reply properly to the HELO greeting.

**SMTPNotSupportedError**

The server does not support the STARTTLS extension.

**RuntimeError**

SSL/TLS support is not available to your Python interpreter.

*Changed in version 3.3:* `context` was added.

*Changed in version 3.4:* The method now supports hostname check with `SSLContext.check_hostname` and `Server Name Indicator` (see `HAS_SNI`).

*Changed in version 3.5:* The error raised for lack of STARTTLS support is now the `SMTPNotSupportedError` subclass instead of the base `SMTPException`.

```python
SMTP.sendmail(from_addr, to_addrs, msg, mail_options=[], rcpt_options=[])
```

Send mail. The required arguments are an RFC 822 from-address string, a list of RFC 822 to-address strings (a bare string will be treated as a list with 1 address), and a message string. The caller may pass a list of ESMTP options (such as 8bitmime) to be used
in MAIL FROM commands as mail_options. ESMTP options (such as DSN commands) that should be used with all RCPT commands can be passed as rcpt_options. (If you need to use different ESMTP options to different recipients you have to use the low-level methods such as mail(), rcpt() and data() to send the message.)

**Note:** The from_addr and to_addrs parameters are used to construct the message envelope used by the transport agents. sendmail does not modify the message headers in any way.

`msg` may be a string containing characters in the ASCII range, or a byte string. A string is encoded to bytes using the ascii codec, and lone \r and \n characters are converted to \r\n characters. A byte string is not modified.

If there has been no previous EHLO or HELO command this session, this method tries ESMTP EHLO first. If the server does ESMTP, message size and each of the specified options will be passed to it (if the option is in the feature set the server advertises). If EHLO fails, HELO will be tried and ESMTP options suppressed.

This method will return normally if the mail is accepted for at least one recipient. Otherwise it will raise an exception. That is, if this method does not raise an exception, then someone should get your mail. If this method does not raise an exception, it returns a dictionary, with one entry for each recipient that was refused. Each entry contains a tuple of the SMTP error code and the accompanying error message sent by the server.

If SMTPUTF8 is included in mail_options, and the server supports it, from_addr and to_addr may contain non-ASCII characters.
This method may raise the following exceptions:

**SMTPRecipientsRefused**
All recipients were refused. Nobody got the mail. The recipients attribute of the exception object is a dictionary with information about the refused recipients (like the one returned when at least one recipient was accepted).

**SMTPHeloError**
The server didn’t reply properly to the HELO greeting.

**SMTPSenderRefused**
The server didn’t accept the `from_addr`.

**SMTPDataError**
The server replied with an unexpected error code (other than a refusal of a recipient).

**SMTPNotSupportedError**
SMTPUTF8 was given in the `mail_options` but is not supported by the server.

Unless otherwise noted, the connection will be open even after an exception is raised.

*Changed in version 3.2:* `msg` may be a byte string.

*Changed in version 3.5:* SMTPUTF8 support added, and `SMTPNotSupportedError` may be raised if SMTPUTF8 is specified but the server does not support it.

**SMTP.send_message**(`msg`, `from_addr=None`, `to_addrs=None`, `mail_options=[], rcpt_options=[]`)
This is a convenience method for calling `sendmail()` with the message represented by an `email.message.Message` object. The arguments have the same meaning as for `sendmail()`,
except that msg is a Message object.

If from_addr is None or to_addrs is None, send_message fills those arguments with addresses extracted from the headers of msg as specified in RFC 5322: from_addr is set to the Sender field if it is present, and otherwise to the From field. to_addresses combines the values (if any) of the To, Cc, and Bcc fields from msg. If exactly one set of Resent-* headers appear in the message, the regular headers are ignored and the Resent-* headers are used instead. If the message contains more than one set of Resent-* headers, a ValueError is raised, since there is no way to unambiguously detect the most recent set of Resent-headers.

send_message serializes msg using BytesGenerator with \r\n as the linesep, and calls sendmail() to transmit the resulting message. Regardless of the values of from_addr and to_addrs, send_message does not transmit any Bcc or Resent-Bcc headers that may appear in msg. If any of the addresses in from_addr and to_addrs contain non-ASCII characters and the server does not advertise SMTPUTF8 support, an SMTPNotSupported error is raised. Otherwise the Message is serialized with a clone of its policy with the utf8 attribute set to True, and SMTPUTF8 and BODY=8BITMIME are added to mail_options.

New in version 3.2.

New in version 3.5: Support for internationalized addresses (SMTPUTF8).

SMTP.quit()
Terminate the SMTP session and close the connection. Return the result of the SMTP QUIT command.

Low-level methods corresponding to the standard SMTP/ESMTP commands HELP, RSET, NOOP, MAIL, RCPT, and DATA are also supported. Normally these do not need to be called directly, so they are not documented here. For details, consult the module code.
21.17.2. SMTP Example

This example prompts the user for addresses needed in the message envelope (‘To’ and ‘From’ addresses), and the message to be delivered. Note that the headers to be included with the message must be included in the message as entered; this example doesn’t do any processing of the RFC 822 headers. In particular, the ‘To’ and ‘From’ addresses must be included in the message headers explicitly.

```python
import smtplib

def prompt(prompt):
    return input(prompt).strip()

fromaddr = prompt("From: ")
toaddrs  = prompt("To: ").split()
print("Enter message, end with ^D (Unix) or ^Z (Windows):")

# Add the From: and To: headers at the start!
msg = ("From: %s\n\nTo: %s\n\n" % (fromaddr, ", ".join(toaddrs)))

while True:
    try:
        line = input()
    except EOFError:
        break
    if not line:
        break
    msg = msg + line

print("Message length is", len(msg))

server = smtplib.SMTP('localhost')
server.set_debuglevel(1)
server.sendmail(fromaddr, toaddrs, msg)
```
server.quit()

**Note:** In general, you will want to use the `email` package's features to construct an email message, which you can then send via `send_message()`; see `email: Examples`. 
21.18. `smtpd` — SMTP Server

**Source code:** Lib/smtpd.py

This module offers several classes to implement SMTP (email) servers.

Several server implementations are present; one is a generic do-nothing implementation, which can be overridden, while the other two offer specific mail-sending strategies.

Additionally the SMTPChannel may be extended to implement very specific interaction behaviour with SMTP clients.

The code supports RFC 5321, plus the RFC 1870 SIZE and RFC 6531 SMTPUTF8 extensions.
21.18.1. SMTPServer Objects

```python
class smtplib.SMTPServer(localaddr, remoteaddr, 
data_size_limit=33554432, map=None, enable_SMTPUTF8=False, 
decode_data=True)
```

Create a new SMTPServer object, which binds to local address `localaddr`. It will treat `remoteaddr` as an upstream SMTP relayer. It inherits from `asyncore.dispatcher`, and so will insert itself into `asyncore`'s event loop on instantiation.

`data_size_limit` specifies the maximum number of bytes that will be accepted in a DATA command. A value of None or 0 means no limit.

`map` is the socket map to use for connections (an initially empty dictionary is a suitable value). If not specified the `asyncore` global socket map is used.

`enable_SMTPUTF8` determines whether the SMTPUTF8 extension (as defined in RFC 6531) should be enabled. The default is False. If set to True, `decode_data` must be False (otherwise an error is raised). When True, SMTPUTF8 is accepted as a parameter to the MAIL command and when present is passed to `process_message()` in the `kwargs['mail_options']` list.

`decode_data` specifies whether the data portion of the SMTP transaction should be decoded using UTF-8. The default is True for backward compatibility reasons, but will change to False in Python 3.6; specify the keyword value explicitly to avoid the DeprecationWarning. When `decode_data` is set to False the server advertises the 8BITMIME extension (RFC 6152), accepts
the BODY=8BITMIME parameter to the MAIL command, and when present passes it to \texttt{process_message()} in the \texttt{kwargs['mail_options']} list.

\textbf{process_message}(\textit{peer, mailfrom, rcpttos, data, **kwargs})

Raise a \texttt{NotImplementedError} exception. Override this in subclasses to do something useful with this message. Whatever was passed in the constructor as \texttt{remoteaddr} will be available as the \texttt{_remoteaddr} attribute. \textit{peer} is the remote host's address, \textit{mailfrom} is the envelope originator, \textit{rcpttos} are the envelope recipients and \textit{data} is a string containing the contents of the e-mail (which should be in \texttt{RFC 5321} format).

If the \texttt{decode_data} constructor keyword is set to \texttt{True}, the \textit{data} argument will be a unicode string. If it is set to \texttt{False}, it will be a bytes object.

\texttt{kwargs} is a dictionary containing additional information. It is empty unless at least one of \texttt{decode_data=False} or \texttt{enable_SMTPUTF8=True} was given as an init parameter, in which case it contains the following keys:

- \textit{mail_options}:
  a list of all received parameters to the MAIL command (the elements are uppercase strings; example: \texttt{['BODY=8BITMIME', 'SMTPUTF8']}).

- \textit{rcpt_options}:
  same as \textit{mail_options} but for the RCPT command. Currently no RCPT TO options are supported, so for now this will always be an empty list.

Implementations of \texttt{process_message} should use the
**kwargs signature to accept arbitrary keyword arguments, since future feature enhancements may add keys to the kwargs dictionary.

Return None to request a normal 250 Ok response; otherwise return the desired response string in RFC 5321 format.

**channel_class**

Override this in subclasses to use a custom SMTPChannel for managing SMTP clients.

*New in version 3.4:* The map constructor argument.

*Changed in version 3.5:* localaddr and remoteaddr may now contain IPv6 addresses.

*New in version 3.5:* the decode_data and enable_SMTPUTF8 constructor arguments, and the kwargs argument to process_message() when one or more of these is specified.
21.18.2. DebuggingServer Objects

class smtpd.DebuggingServer(localaddr, remoteaddr)

Create a new debugging server. Arguments are as per SMTPServer. Messages will be discarded, and printed on stdout.
21.18.3. PureProxy Objects

class smtPD.PureProxy(localaddr, remoteaddr)

Create a new pure proxy server. Arguments are as per SMTPServer. Everything will be relayed to remoteaddr. Note that running this has a good chance to make you into an open relay, so please be careful.
21.18.4. MailmanProxy Objects

class smtpd.MailmanProxy(localaddr, remoteaddr)

Create a new pure proxy server. Arguments are as per SMTPServer. Everything will be relayed to remoteaddr, unless local mailman configurations knows about an address, in which case it will be handled via mailman. Note that running this has a good chance to make you into an open relay, so please be careful.
21.18.5. SMTPChannel Objects

```python
class smtplib.SMTPChannel(server, conn, addr,
data_size_limit=33554432, map=None, enable_SMTPUTF8=False,
decode_data=True)
```

Create a new `SMTPChannel` object which manages the communication between the server and a single SMTP client.

`conn` and `addr` are as per the instance variables described below.

`data_size_limit` specifies the maximum number of bytes that will be accepted in a DATA command. A value of None or 0 means no limit.

`enable_SMTPUTF8` determines whether the SMTPUTF8 extension (as defined in RFC 6531) should be enabled. The default is False. A `ValueError` is raised if both `enable_SMTPUTF8` and `decode_data` are set to True at the same time.

A dictionary can be specified in `map` to avoid using a global socket map.

`decode_data` specifies whether the data portion of the SMTP transaction should be decoded using UTF-8. The default is True for backward compatibility reasons, but will change to False in Python 3.6. Specify the keyword value explicitly to avoid the `DeprecationWarning`.

To use a custom SMTPChannel implementation you need to override the `SMTPServer.channel_class` of your `SMTPServer`. 
Changed in version 3.5: the `decode_data` and `enable_SMTPUTF8` arguments were added.

The `SMTPChannel` has the following instance variables:

**smtp_server**
- Holds the `SMTPServer` that spawned this channel.

**conn**
- Holds the socket object connecting to the client.

**addr**
- Holds the address of the client, the second value returned by `socket.accept`

**received_lines**
- Holds a list of the line strings (decoded using UTF-8) received from the client. The lines have their "\r\n" line ending translated to "\n".

**smtp_state**
- Holds the current state of the channel. This will be either `COMMAND` initially and then `DATA` after the client sends a “DATA” line.

**seen_greeting**
- Holds a string containing the greeting sent by the client in its “HELO”.

**mailfrom**
- Holds a string containing the address identified in the “MAIL FROM:” line from the client.
rcpttos
Holds a list of strings containing the addresses identified in the "RCPT TO:" lines from the client.

received_data
Holds a string containing all of the data sent by the client during the DATA state, up to but not including the terminating "\r\n\r\n".

fqdn
Holds the fully-qualified domain name of the server as returned by socket.getfqdn().

peer
Holds the name of the client peer as returned by conn.getpeername() where conn is conn.

The SMTPChannel operates by invoking methods named smtp_<command> upon reception of a command line from the client. Built into the base SMTPChannel class are methods for handling the following commands (and responding to them appropriately):

<table>
<thead>
<tr>
<th>Command</th>
<th>Action taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>HELO</td>
<td>Accepts the greeting from the client and stores it in seen_greeting. Sets server to base command mode.</td>
</tr>
<tr>
<td>EHLO</td>
<td>Accepts the greeting from the client and stores it in seen_greeting. Sets server to extended command mode.</td>
</tr>
<tr>
<td>NOOP</td>
<td>Takes no action.</td>
</tr>
<tr>
<td>QUIT</td>
<td>Closes the connection cleanly.</td>
</tr>
<tr>
<td>Command</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>MAIL</td>
<td>Accepts the “MAIL FROM:” syntax and stores the supplied address as <code>mailfrom</code>. In extended command mode, accepts the RFC 1870 SIZE attribute and responds appropriately based on the value of <code>data_size_limit</code>.</td>
</tr>
<tr>
<td>RCPT</td>
<td>Accepts the “RCPT TO:” syntax and stores the supplied addresses in the <code>rcpttos</code> list.</td>
</tr>
<tr>
<td>RSET</td>
<td>Resets the <code>mailfrom</code>, <code>rcpttos</code>, and <code>received_data</code>, but not the greeting.</td>
</tr>
<tr>
<td>DATA</td>
<td>Sets the internal state to DATA and stores remaining lines from the client in <code>received_data</code> until the terminator &quot;\r\n\r\n&quot; is received.</td>
</tr>
<tr>
<td>HELP</td>
<td>Returns minimal information on command syntax</td>
</tr>
<tr>
<td>VRFY</td>
<td>Returns code 252 (the server doesn’t know if the address is valid)</td>
</tr>
<tr>
<td>EXPN</td>
<td>Reports that the command is not implemented.</td>
</tr>
</tbody>
</table>

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Last updated on Dec 06, 2015. Found a bug?
Created using Sphinx 1.3.1.
The `telnetlib` module provides a `Telnet` class that implements the Telnet protocol. See RFC 854 for details about the protocol. In addition, it provides symbolic constants for the protocol characters (see below), and for the telnet options. The symbolic names of the telnet options follow the definitions in arpa/telnet.h, with the leading TEL0PT_ removed. For symbolic names of options which are traditionally not included in arpa/telnet.h, see the module source itself.

The symbolic constants for the telnet commands are: IAC, DONT, DO, WONT, WILL, SE (Subnegotiation End), NOP (No Operation), DM (Data Mark), BRK (Break), IP (Interrupt process), AO (Abort output), AYT (Are You There), EC (Erase Character), EL (Erase Line), GA (Go Ahead), SB (Subnegotiation Begin).

```python
class telnetlib.Telnet(host=None, port=0[, timeout])
```

`Telnet` represents a connection to a Telnet server. The instance is initially not connected by default; the `open()` method must be used to establish a connection. Alternatively, the host name and optional port number can be passed to the constructor too, in which case the connection to the server will be established before the constructor returns. The optional `timeout` parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used).
Do not reopen an already connected instance.

This class has many read_*( ) methods. Note that some of them raise EOFError when the end of the connection is read, because they can return an empty string for other reasons. See the individual descriptions below.

See also:

**RFC 854 - Telnet Protocol Specification**
Definition of the Telnet protocol.
21.19.1. Telnet Objects

**Telnet** instances have the following methods:

**Telnet**.read_until*(expected, timeout=None)*

Read until a given byte string, *expected*, is encountered or until *timeout* seconds have passed.

When no match is found, return whatever is available instead, possibly empty bytes. Raise **EOFError** if the connection is closed and no cooked data is available.

**Telnet**.read_all()

Read all data until EOF as bytes; block until connection closed.

**Telnet**.read_some()

Read at least one byte of cooked data unless EOF is hit. Return b'' if EOF is hit. Block if no data is immediately available.

**Telnet**.read_very_eager()

Read everything that can be without blocking in I/O (eager).

Raise **EOFError** if connection closed and no cooked data available. Return b'' if no cooked data available otherwise. Do not block unless in the midst of an IAC sequence.

**Telnet**.read_eager()

Read readily available data.

Raise **EOFError** if connection closed and no cooked data available. Return b'' if no cooked data available otherwise. Do not block unless in the midst of an IAC sequence.
Telnet.read_lazy()

Process and return data already in the queues (lazy).

Raise EOFError if connection closed and no data available. Return b'' if no cooked data available otherwise. Do not block unless in the midst of an IAC sequence.

Telnet.read_very_lazy()

Return any data available in the cooked queue (very lazy).

Raise EOFError if connection closed and no data available. Return b'' if no cooked data available otherwise. This method never blocks.

Telnet.read_sb_data()

Return the data collected between a SB/SE pair (suboption begin/end). The callback should access these data when it was invoked with a SE command. This method never blocks.

Telnet.open(host, port=0[, timeout])

Connect to a host. The optional second argument is the port number, which defaults to the standard Telnet port (23). The optional timeout parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used).

Do not try to reopen an already connected instance.

Telnet.msg(msg, *args)

Print a debug message when the debug level is > 0. If extra arguments are present, they are substituted in the message using the standard string formatting operator.
Telnet.set_debuglevel(debuglevel)
   Set the debug level. The higher the value of debuglevel, the more debug output you get (on sys.stdout).

Telnet.close()
   Close the connection.

Telnet.get_socket()
   Return the socket object used internally.

Telnet.fileno()
   Return the file descriptor of the socket object used internally.

Telnet.write(buffer)
   Write a byte string to the socket, doubling any IAC characters. This can block if the connection is blocked. May raise OSError if the connection is closed.

   Changed in version 3.3: This method used to raise socket.error, which is now an alias of OSError.

Telnet.interact()
   Interaction function, emulates a very dumb Telnet client.

Telnet.mt_interact()
   Multithreaded version of interact().

Telnet.expect(list, timeout=None)
   Read until one from a list of a regular expressions matches.

   The first argument is a list of regular expressions, either compiled (regex objects) or uncompiled (byte strings). The optional second argument is a timeout, in seconds; the default is to block
Return a tuple of three items: the index in the list of the first regular expression that matches; the match object returned; and the bytes read up till and including the match.

If end of file is found and no bytes were read, raise **EOFError**. Otherwise, when nothing matches, return (-1, None, data) where *data* is the bytes received so far (may be empty bytes if a timeout happened).

If a regular expression ends with a greedy match (such as .* ) or if more than one expression can match the same input, the results are non-deterministic, and may depend on the I/O timing.

**Telnet.set_option_negotiation_callback** *(callback)*

Each time a telnet option is read on the input flow, this *callback* (if set) is called with the following parameters: callback(telnet socket, command (DO/DONT/WILL/WONT), option). No other action is done afterwards by telnetlib.
21.19.2. Telnet Example

A simple example illustrating typical use:

```python
import getpass
import telnetlib

HOST = "localhost"
user = input("Enter your remote account: ")
password = getpass.getpass()

tn = telnetlib.Telnet(HOST)
	nn.read_until(b"login: ")

tn.write(user.encode('ascii') + b"\n")

if password:
    tn.read_until(b"Password: ")
    tn.write(password.encode('ascii') + b"\n")


tn.write(b"ls\n")

tn.write(b"exit\n")

print(tn.read_all().decode('ascii'))
```
21.20. **uuid** — UUID objects according to RFC 4122

This module provides immutable UUID objects (the **UUID** class) and the functions `uuid1()`, `uuid3()`, `uuid4()`, `uuid5()` for generating version 1, 3, 4, and 5 UUIDs as specified in **RFC 4122**.

If all you want is a unique ID, you should probably call `uuid1()` or `uuid4()`. Note that `uuid1()` may compromise privacy since it creates a UUID containing the computer's network address. `uuid4()` creates a random UUID.

```python
class uuid.UUID(hex=None, bytes=None, bytes_le=None, fields=None, int=None, version=None):
    Create a UUID from either a string of 32 hexadecimal digits, a string of 16 bytes as the bytes argument, a string of 16 bytes in little-endian order as the bytes_le argument, a tuple of six integers (32-bit time_low, 16-bit time_mid, 16-bit time_hi_version, 8-bit clock_seq_hi_variant, 8-bit clock_seq_low, 48-bit node) as the fields argument, or a single 128-bit integer as the int argument. When a string of hex digits is given, curly braces, hyphens, and aURN prefix are all optional. For example, these expressions all yield the same UUID:
```

```
UUID( '{12345678-1234-5678-1234-567812345678}' )
UUID( '12345678123456781234567812345678' )
UUID( 'urn:uuid:12345678-1234-5678-1234-567812345678' )
UUID( bytes=b'\x12\x34\x56\x78'*4 )
UUID( bytes_le=b'\x78\x56\x34\x12\x34\x12\x78\x56' b'\x12\x34\x56\x78\x12\x34\x56\x78' )
UUID( fields=(0x12345678, 0x1234, 0x5678, 0x12, 0x
```
Exactly one of `hex`, `bytes`, `bytes_le`, `fields`, or `int` must be given. The `version` argument is optional; if given, the resulting UUID will have its variant and version number set according to RFC 4122, overriding bits in the given `hex`, `bytes`, `bytes_le`, `fields`, or `int`.

**UUID** instances have these read-only attributes:

**UUID.bytes**

The UUID as a 16-byte string (containing the six integer fields in big-endian byte order).

**UUID.bytes_le**

The UUID as a 16-byte string (with `time_low`, `time_mid`, and `time_hi_version` in little-endian byte order).

**UUID.fields**

A tuple of the six integer fields of the UUID, which are also available as six individual attributes and two derived attributes:

<table>
<thead>
<tr>
<th>Field</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>time_low</td>
<td>the first 32 bits of the UUID</td>
</tr>
<tr>
<td>time_mid</td>
<td>the next 16 bits of the UUID</td>
</tr>
<tr>
<td>time_hi_version</td>
<td>the next 16 bits of the UUID</td>
</tr>
<tr>
<td>clock_seq_hi_variant</td>
<td>the next 8 bits of the UUID</td>
</tr>
<tr>
<td>clock_seq_low</td>
<td>the next 8 bits of the UUID</td>
</tr>
<tr>
<td>node</td>
<td>the last 48 bits of the UUID</td>
</tr>
<tr>
<td>time</td>
<td>the 60-bit timestamp</td>
</tr>
<tr>
<td>clock_seq</td>
<td>the 14-bit sequence number</td>
</tr>
</tbody>
</table>
The UUID as a 32-character hexadecimal string.

The UUID as a 128-bit integer.

The UUID as aURN as specified in RFC 4122.

The UUID variant, which determines the internal layout of the UUID. This will be one of the integer constants RESERVED_NCS, RFC_4122, RESERVED_MICROSOFT, or RESERVED_FUTURE.

The UUID version number (1 through 5, meaningful only when the variant is RFC_4122).

The uuid module defines the following functions:

\section*{uuid\texttt{.getnode}()}

Get the hardware address as a 48-bit positive integer. The first time this runs, it may launch a separate program, which could be quite slow. If all attempts to obtain the hardware address fail, we choose a random 48-bit number with its eighth bit set to 1 as recommended in RFC 4122. “Hardware address” means the MAC address of a network interface, and on a machine with multiple network interfaces the MAC address of any one of them may be returned.

\section*{uuid\texttt{.uuid1}(node=None, clock_seq=None)}

Generate a UUID from a host ID, sequence number, and the current time. If \texttt{node} is not given, \texttt{getnode()} is used to obtain the
hardware address. If \textit{clock_seq} is given, it is used as the sequence number; otherwise a random 14-bit sequence number is chosen.

\texttt{uuid.uuid3}(\textit{namespace}, \textit{name})

Generate a UUID based on the MD5 hash of a namespace identifier (which is a UUID) and a name (which is a string).

\texttt{uuid.uuid4()}

Generate a random UUID.

\texttt{uuid.uuid5}(\textit{namespace}, \textit{name})

Generate a UUID based on the SHA-1 hash of a namespace identifier (which is a UUID) and a name (which is a string).

The \texttt{uuid} module defines the following namespace identifiers for use with \texttt{uuid3()} or \texttt{uuid5()}.

\texttt{uuid.NAMESPACE_DNS}

When this namespace is specified, the \textit{name} string is a fully-qualified domain name.

\texttt{uuid.NAMESPACE_URL}

When this namespace is specified, the \textit{name} string is a URL.

\texttt{uuid.NAMESPACE_OID}

When this namespace is specified, the \textit{name} string is an ISO OID.

\texttt{uuid.NAMESPACE_X500}

When this namespace is specified, the \textit{name} string is an X.500 DN in DER or a text output format.

The \texttt{uuid} module defines the following constants for the possible values of the variant attribute:
uuid.**RESERVED_NCS**
Reserved for NCS compatibility.

uuid.**RFC_4122**

uuid.**RESERVED_MICROSOFT**
Reserved for Microsoft compatibility.

uuid.**RESERVED_FUTURE**
Reserved for future definition.

**See also:**

[RFC 4122 - A Universally Unique IDentifier (UUID) URN Namespace](https://tools.ietf.org/html/rfc4122)
This specification defines a Uniform Resource Name namespace for UUIDs, the internal format of UUIDs, and methods of generating UUIDs.
21.20.1. Example

Here are some examples of typical usage of the `uuid` module:

```python
>>> import uuid

>>> # make a UUID based on the host ID and current time
>>> uuid.uuid1()
UUID('a8098c1a-f86e-11da-bd1a-00112444be1e')

>>> # make a UUID using an MD5 hash of a namespace UUID
>>> uuid.uuid3(uuid.NAMESPACE_DNS, 'python.org')
UUID('6fa459ea-ee8a-3ca4-894e-db77e160355e')

>>> # make a random UUID
>>> uuid.uuid4()
UUID('16fd2706-8baf-433b-82eb-8c7fada847da')

>>> # make a UUID using a SHA-1 hash of a namespace UUID
>>> uuid.uuid5(uuid.NAMESPACE_DNS, 'python.org')
UUID('886313e1-3b8a-5372-9b90-0c9aee199e5d')

>>> # make a UUID from a string of hex digits (braces and hyphens ignored)
>>> x = uuid.UUID('{00010203-0405-0607-0809-0a0b0c0d0e0f}')

>>> # convert a UUID to a string of hex digits in standard form
>>> str(x)
'00010203-0405-0607-0809-0a0b0c0d0e0f'

>>> # get the raw 16 bytes of the UUID
>>> x.bytes
b'\x00\x01\x02\x03\x04\x05\x06\x07\x08\t\n\0b\0c\r

>>> # make a UUID from a 16-byte string
>>> uuid.UUID(bytes=x.bytes)
```
21.21. socketserver — A framework for network servers

Source code: Lib/socketserver.py

The socketserver module simplifies the task of writing network servers.

There are four basic server classes: TCPServer uses the Internet TCP protocol, which provides for continuous streams of data between the client and server. UDPServer uses datagrams, which are discrete packets of information that may arrive out of order or be lost while in transit. The more infrequently used UnixStreamServer and UnixDatagramServer classes are similar, but use Unix domain sockets; they're not available on non-Unix platforms. For more details on network programming, consult a book such as W. Richard Steven's UNIX Network Programming or Ralph Davis's Win32 Network Programming.

These four classes process requests synchronously; each request must be completed before the next request can be started. This isn't suitable if each request takes a long time to complete, because it requires a lot of computation, or because it returns a lot of data which the client is slow to process. The solution is to create a separate process or thread to handle each request; the ForkingMixIn and ThreadingMixIn mix-in classes can be used to support asynchronous behaviour.

Creating a server requires several steps. First, you must create a
request handler class by subclassing the BaseRequestHandler class and overriding its handle() method; this method will process incoming requests. Second, you must instantiate one of the server classes, passing it the server's address and the request handler class. Then call the handle_request() or serve_forever() method of the server object to process one or many requests. Finally, call server_close() to close the socket.

When inheriting from ThreadingMixIn for threaded connection behavior, you should explicitly declare how you want your threads to behave on an abrupt shutdown. The ThreadingMixIn class defines an attribute daemon_threads, which indicates whether or not the server should wait for thread termination. You should set the flag explicitly if you would like threads to behave autonomously; the default is False, meaning that Python will not exit until all threads created by ThreadingMixIn have exited.

Server classes have the same external methods and attributes, no matter what network protocol they use.
21.21.1. Server Creation Notes

There are five classes in an inheritance diagram, four of which represent synchronous servers of four types:

```
+------------+
| BaseServer |
+------------+
    |
    v
+------------+------------------+
| TCPServer  |------->| UnixStreamServer |
+------------+------------------+
    |
    v
+------------+------------------+
| UDPServer  |------->| UnixDatagramServer |
+------------+------------------+
```

Note that UnixDatagramServer derives from UDPServer, not from UnixStreamServer — the only difference between an IP and a Unix stream server is the address family, which is simply repeated in both Unix server classes.

Forking and threading versions of each type of server can be created using the ForkingMixIn and ThreadingMixIn mix-in classes. For instance, a threading UDP server class is created as follows:

```
class ThreadingUDPServer(ThreadingMixIn, UDPServer):
```

The mix-in class must come first, since it overrides a method defined in UDPServer. Setting the various attributes also change the behavior of the underlying server mechanism.
To implement a service, you must derive a class from BaseRequestHandler and redefine its handle() method. You can then run various versions of the service by combining one of the server classes with your request handler class. The request handler class must be different for datagram or stream services. This can be hidden by using the handler subclasses StreamRequestHandler or DatagramRequestHandler.

Of course, you still have to use your head! For instance, it makes no sense to use a forking server if the service contains state in memory that can be modified by different requests, since the modifications in the child process would never reach the initial state kept in the parent process and passed to each child. In this case, you can use a threading server, but you will probably have to use locks to protect the integrity of the shared data.

On the other hand, if you are building an HTTP server where all data is stored externally (for instance, in the file system), a synchronous class will essentially render the service “deaf” while one request is being handled – which may be for a very long time if a client is slow to receive all the data it has requested. Here a threading or forking server is appropriate.

In some cases, it may be appropriate to process part of a request synchronously, but to finish processing in a forked child depending on the request data. This can be implemented by using a synchronous server and doing an explicit fork in the request handler class handle() method.

Another approach to handling multiple simultaneous requests in an environment that supports neither threads nor fork() (or where these are too expensive or inappropriate for the service) is to maintain
an explicit table of partially finished requests and to use selectors to decide which request to work on next (or whether to handle a new incoming request). This is particularly important for stream services where each client can potentially be connected for a long time (if threads or subprocesses cannot be used). See asyncore for another way to manage this.
21.21.2. Server Objects

class socketserver.BaseServer

This is the superclass of all Server objects in the module. It defines the interface, given below, but does not implement most of the methods, which is done in subclasses.

BaseServer.fileno()

Return an integer file descriptor for the socket on which the server is listening. This function is most commonly passed to selectors, to allow monitoring multiple servers in the same process.

BaseServer.handle_request()

Process a single request. This function calls the following methods in order: get_request(), verify_request(), and process_request(). If the user-provided handle() method of the handler class raises an exception, the server's handle_error() method will be called. If no request is received within self.timeout seconds, handle_timeout() will be called and handle_request() will return.

BaseServer.serve_forever(poll_interval=0.5)

Handle requests until an explicit shutdown() request. Poll for shutdown every poll_interval seconds. Ignores self.timeout. It also calls service_actions(), which may be used by a subclass or mixin to provide actions specific to a given service. For example, the ForkingMixIn class uses service_actions() to clean up zombie child processes.

Changed in version 3.3: Added service_actions call to the serve_forever method.
BaseServer\texttt{.service\_actions()}

This is called in the \texttt{serve\_forever()} loop. This method can be overridden by subclasses or mixin classes to perform actions specific to a given service, such as cleanup actions.

\textit{New in version 3.3.}

BaseServer\texttt{.shutdown()}

Tell the \texttt{serve\_forever()} loop to stop and wait until it does.

BaseServer\texttt{.server\_close()}

Clean up the server. May be overridden.

\textit{New in version 2.6.}

BaseServer\texttt{.address\_family}

The family of protocols to which the server’s socket belongs. Common examples are \texttt{socket.AF_INET} and \texttt{socket.AF_UNIX}.

BaseServer\texttt{.RequestHandlerClass}

The user-provided request handler class; an instance of this class is created for each request.

BaseServer\texttt{.server\_address}

The address on which the server is listening. The format of addresses varies depending on the protocol family; see the documentation for the socket module for details. For Internet protocols, this is a tuple containing a string giving the address, and an integer port number: (\texttt{'127.0.0.1', 80}), for example.

BaseServer\texttt{.socket}

The socket object on which the server will listen for incoming
requests.

The server classes support the following class variables:

**BaseServer**. `allow_reuse_address`  
Whether the server will allow the reuse of an address. This defaults to `False`, and can be set in subclasses to change the policy.

**BaseServer**. `request_queue_size`  
The size of the request queue. If it takes a long time to process a single request, any requests that arrive while the server is busy are placed into a queue, up to `request_queue_size` requests. Once the queue is full, further requests from clients will get a “Connection denied” error. The default value is usually 5, but this can be overridden by subclasses.

**BaseServer**. `socket_type`  
The type of socket used by the server; `socket.SOCK_STREAM` and `socket.SOCK_DGRAM` are two common values.

**BaseServer**. `timeout`  
Timeout duration, measured in seconds, or `None` if no timeout is desired. If `handle_request()` receives no incoming requests within the timeout period, the `handle_timeout()` method is called.

There are various server methods that can be overridden by subclasses of base server classes like TCPServer; these methods aren't useful to external users of the server object.

**BaseServer**. `finish_request()`  
Actually processes the request by instantiating `RequestHandlerClass` and calling its `handle()` method.
**BaseServer.get_request()**

Must accept a request from the socket, and return a 2-tuple containing the new socket object to be used to communicate with the client, and the client’s address.

**BaseServer.handle_error(request, client_address)**

This function is called if the RequestHandlerClass's handle() method raises an exception. The default action is to print the traceback to standard output and continue handling further requests.

**BaseServer.handle_timeout()**

This function is called when the timeout attribute has been set to a value other than None and the timeout period has passed with no requests being received. The default action for forking servers is to collect the status of any child processes that have exited, while in threading servers this method does nothing.

**BaseServer.process_request(request, client_address)**

Calls finish_request() to create an instance of the RequestHandlerClass. If desired, this function can create a new process or thread to handle the request; the ForkingMixIn and ThreadingMixIn classes do this.

**BaseServer.server_activate()**

Called by the server’s constructor to activate the server. The default behavior just listen()s to the server’s socket. May be overridden.

**BaseServer.server_bind()**

Called by the server’s constructor to bind the socket to the desired address. May be overridden.
BaseServer.**verify_request**(request, client_address)

Must return a Boolean value; if the value is **True**, the request will be processed, and if it's **False**, the request will be denied. This function can be overridden to implement access controls for a server. The default implementation always returns **True**.
21.21.3. RequestHandler Objects

The request handler class must define a new handle() method, and can override any of the following methods. A new instance is created for each request.

RequestHandler.finish()
Called after the handle() method to perform any clean-up actions required. The default implementation does nothing. If setup() raises an exception, this function will not be called.

RequestHandler.handle()
This function must do all the work required to service a request. The default implementation does nothing. Several instance attributes are available to it; the request is available as self.request; the client address as self.client_address; and the server instance as self.server, in case it needs access to per-server information.

The type of self.request is different for datagram or stream services. For stream services, self.request is a socket object; for datagram services, self.request is a pair of string and socket. However, this can be hidden by using the request handler subclasses StreamRequestHandler or DatagramRequestHandler, which override the setup() and finish() methods, and provide self.rfile and self.wfile attributes. self.rfile and self.wfile can be read or written, respectively, to get the request data or return data to the client.

RequestHandler.setup()
Called before the handle() method to perform any initialization
actions required. The default implementation does nothing.
21.21.4. Examples

21.21.4.1. socketserver.TCPServer Example

This is the server side:

```python
import socketserver

class MyTCPHandler(socketserver.BaseRequestHandler):
    ""
    The RequestHandler class for our server.

    It is instantiated once per connection to the server, and must
    override the handle() method to implement communication with
    a client.
    ""

    def handle(self):
        # self.request is the TCP socket connected to the
        # client.
        self.data = self.request.recv(1024).strip()
        print("{} wrote:").format(self.client_address)
        print(self.data)
        # just send back the same data, but upper-cased
        self.request.sendall(self.data.upper())

if __name__ == "__main__":
    HOST, PORT = "localhost", 9999

    # Create the server, binding to localhost on port 9999
    server = socketserver.TCPServer((HOST, PORT), MyTCPHandler)

    # Activate the server; this will keep running until
    # interrupt the program with Ctrl-C
    server.serve_forever()
```
An alternative request handler class that makes use of streams (file-like objects that simplify communication by providing the standard file interface):

```python
class MyTCPHandler(socketserver.StreamRequestHandler):
    def handle(self):
        # self.rfile is a file-like object created by the handler;
        # we can now use e.g. readline() instead of
        self.data = self.rfile.readline().strip()
        print("{} wrote:").format(self.client_address)
        print(self.data)
        # Likewise, self.wfile is a file-like object
        # to the client
        self.wfile.write(self.data.upper())
```

The difference is that the readline() call in the second handler will call recv() multiple times until it encounters a newline character, while the single recv() call in the first handler will just return what has been sent from the client in one sendall() call.

This is the client side:

```python
import socket
import sys
HOST, PORT = "localhost", 9999
data = " ".join(sys.argv[1:])

# Create a socket (SOCK_STREAM means a TCP socket)
sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
try:
    # Connect to server and send data
    sock.connect((HOST, PORT))
```
sock.sendall(bytes(data + "\n", "utf-8"))

# Receive data from the server and shut down
received = str(sock.recv(1024), "utf-8")

finally:
    sock.close()

print("Sent: {}".format(data))
print("Received: {}".format(received))

The output of the example should look something like this:

Server:

$ python TCPServer.py
127.0.0.1 wrote:
b'hello world with TCP'
127.0.0.1 wrote:
b'python is nice'

Client:

$ python TCPClient.py hello world with TCP
Sent: hello world with TCP
Received: HELLO WORLD WITH TCP
$ python TCPClient.py python is nice
Sent: python is nice
Received: PYTHON IS NICE

21.21.4.2. socketserver.UDPServer Example

This is the server side:

import socketserver
class MyUDPHandler(socketserver.BaseRequestHandler):
    ""
    This class works similar to the TCP handler class.
    self.request consists of a pair of data and client.
    there is no connection the client address must be
    when sending data back via sendto().
    ""

    def handle(self):
        data = self.request[0].strip()
        socket = self.request[1]
        print('{} wrote:'.format(self.client_address)
        print(data)
        socket.sendto(data.upper(), self.client_address)

if __name__ == '__main__':
    HOST, PORT = "localhost", 9999
    server = socketserver.UDPServer((HOST, PORT), MyUDPHandler)
    server.serve_forever()

This is the client side:

import socket
import sys

HOST, PORT = "localhost", 9999
data = " ".join(sys.argv[1:]):

# SOCK_DGRAM is the socket type to use for UDP sockets
sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)

# As you can see, there is no connect() call; UDP has
# Instead, data is directly sent to the recipient via
sock.sendto(bytes(data + "\n", "utf-8"), (HOST, PORT))
received = str(sock.recv(1024), "utf-8")
The output of the example should look exactly like for the TCP server example.

21.21.4.3. Asynchronous Mixins

To build asynchronous handlers, use the ThreadingMixIn and ForkingMixIn classes.

An example for the ThreadingMixIn class:

```python
import socket
import threading
import socketserver

class ThreadedTCPRequestHandler(socketserver.BaseRequestHandler):
    def handle(self):
        data = str(self.request.recv(1024), 'ascii')
        cur_thread = threading.current_thread()
        response = bytes(f'{}: {{}}'.format(cur_thread), 'ascii')
        self.request.sendall(response)

class ThreadedTCPServer(socketserver.ThreadingMixIn, socketserver.TCPServer):
    pass
def client(ip, port, message):
    sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    sock.connect((ip, port))
    try:
        sock.sendall(bytes(message, 'ascii'))
        response = str(sock.recv(1024), 'ascii')
```

```
print("Received: {}".format(response))

finally:
    sock.close()

if __name__ == "__main__":
    # Port 0 means to select an arbitrary unused port
    HOST, PORT = "localhost", 0

    server = ThreadedTCPServer((HOST, PORT), ThreadedTCPRequestHandler)
    ip, port = server.server_address

    # Start a thread with the server -- that thread
    # more thread for each request
    server_thread = threading.Thread(target=server.serve_forever)

    # Exit the server thread when the main thread terminates
    server_thread.daemon = True
    server_thread.start()

    print("Server loop running in thread:", server_thread)

    client(ip, port, "Hello World 1")
    client(ip, port, "Hello World 2")
    client(ip, port, "Hello World 3")

    server.shutdown()
    server.server_close()

The output of the example should look something like this:

```
$ python ThreadedTCPServer.py
Server loop running in thread: Thread-1
Received: Thread-2: Hello World 1
Received: Thread-3: Hello World 2
Received: Thread-4: Hello World 3
```

The ForkingMixIn class is used in the same way, except that the server will spawn a new process for each request.
This module defines classes for implementing HTTP servers (Web servers).

One class, `HTTPServer`, is a `socketserver.TCPServer` subclass. It creates and listens at the HTTP socket, dispatching the requests to a handler. Code to create and run the server looks like this:

```python
def run(server_class=HTTPServer, handler_class=BaseHTTPRequestHandler, server_address=('', 8000)):
    httpd = server_class(server_address, handler_class)
    httpd.serve_forever()
```

```python
class http.server.HTTPServer(server_address, RequestHandlerClass):
    This class builds on the TCPServer class by storing the server address as instance variables named `server_name` and `server_port`. The server is accessible by the handler, typically through the handler’s server instance variable.
```

The `HTTPServer` must be given a `RequestHandlerClass` on instantiation, of which this module provides three different variants:

```python
class http.server.BaseHTTPRequestHandler(request, client_address, server)
```
This class is used to handle the HTTP requests that arrive at the server. By itself, it cannot respond to any actual HTTP requests; it must be subclassed to handle each request method (e.g. GET or POST). `BaseHTTPRequestHandler` provides a number of class and instance variables, and methods for use by subclasses.

The handler will parse the request and the headers, then call a method specific to the request type. The method name is constructed from the request. For example, for the request method SPAM, the `do_SPAM()` method will be called with no arguments. All of the relevant information is stored in instance variables of the handler. Subclasses should not need to override or extend the `__init__()` method.

`BaseHTTPRequestHandler` has the following instance variables:

**client_address**
Contains a tuple of the form `(host, port)` referring to the client's address.

**server**
Contains the server instance.

**close_connection**
Boolean that should be set before `handle_one_request()` returns, indicating if another request may be expected, or if the connection should be shut down.

**requestline**
Contains the string representation of the HTTP request line. The terminating CRLF is stripped. This attribute should be set by `handle_one_request()`. If no valid request line was processed, it should be set to the empty string.
command
Contains the command (request type). For example, 'GET'.

path
Contains the request path.

request_version
Contains the version string from the request. For example, 'HTTP/1.0'.

headers
Holds an instance of the class specified by the MessageClass class variable. This instance parses and manages the headers in the HTTP request. The parse_headers() function from http.client is used to parse the headers and it requires that the HTTP request provide a valid RFC 2822 style header.

rfile
Contains an input stream, positioned at the start of the optional input data.

wfile
Contains the output stream for writing a response back to the client. Proper adherence to the HTTP protocol must be used when writing to this stream.

BaseHTTPRequestHandler has the following class variables:

server_version
Specifies the server software version. You may want to override this. The format is multiple whitespace-separated strings, where each string is of the form name[/version]. For example, 'BaseHTTP/0.2'.
**sys_version**

Contains the Python system version, in a form usable by the `version_string` method and the `server_version` class variable. For example, 'Python/1.4'.

**error_message_format**

 Specifies a format string for building an error response to the client. It uses parenthesized, keyed format specifiers, so the format operand must be a dictionary. The `code` key should be an integer, specifying the numeric HTTP error code value. `message` should be a string containing a (detailed) error message of what occurred, and `explain` should be an explanation of the error code number. Default `message` and `explain` values can be found in the `responses` class variable.

**error_content_type**

Specifies the Content-Type HTTP header of error responses sent to the client. The default value is 'text/html'.

**protocol_version**

This specifies the HTTP protocol version used in responses. If set to 'HTTP/1.1', the server will permit HTTP persistent connections; however, your server must then include an accurate Content-Length header (using `send_header()`) in all of its responses to clients. For backwards compatibility, the setting defaults to 'HTTP/1.0'.

**MessageClass**

Specifies an `email.message.Message`-like class to parse HTTP headers. Typically, this is not overridden, and it defaults to `http.client.HTTPMessage`. 
responses

This variable contains a mapping of error code integers to two-element tuples containing a short and long message. For example, \{code: (shortmessage, longmessage)\}. The shortmessage is usually used as the message key in an error response, and longmessage as the explain key (see the error_message_format class variable).

A BaseHTTPRequestHandler instance has the following methods:

**handle()**

Calls handle_one_request() once (or, if persistent connections are enabled, multiple times) to handle incoming HTTP requests. You should never need to override it; instead, implement appropriate do_*() methods.

**handle_one_request()**

This method will parse and dispatch the request to the appropriate do_*() method. You should never need to override it.

**handle_expect_100()**

When a HTTP/1.1 compliant server receives an Expect: 100-continue request header it responds back with a 100 Continue followed by 200 OK headers. This method can be overridden to raise an error if the server does not want the client to continue. For e.g. server can chose to send 417 Expectation Failed as a response header and return False.

*New in version 3.2.*
**send_error**(*code, message=None, explain=None*)

Sends and logs a complete error reply to the client. The numeric *code* specifies the HTTP error code, with *message* as an optional, short, human readable description of the error. The *explain* argument can be used to provide more detailed information about the error; it will be formatted using the *error_message_format* class variable and emitted, after a complete set of headers, as the response body. The *responses* class variable holds the default values for *message* and *explain* that will be used if no value is provided; for unknown codes the default value for both is the string `???`.

*Changed in version 3.4:* The error response includes a Content-Length header. Added the *explain* argument.

**send_response**(*code, message=None*)

Adds a response header to the headers buffer and logs the accepted request. The HTTP response line is written to the internal buffer, followed by *Server* and *Date* headers. The values for these two headers are picked up from the *version_string()* and *date_time_string()* methods, respectively. If the server does not intend to send any other headers using the *send_header()* method, then *send_response()* should be followed by an *end_headers()* call.

*Changed in version 3.3:* Headers are stored to an internal buffer and *end_headers()* needs to be called explicitly.

**send_header**(*keyword, value*)

Adds the HTTP header to an internal buffer which will be written to the output stream when either *end_headers()* or
flush_headers() is invoked. keyword should specify the header keyword, with value specifying its value. Note that, after the send_header calls are done, end_headers() MUST BE called in order to complete the operation.

Changed in version 3.2: Headers are stored in an internal buffer.

send_response_only(code, message=None)
Sends the response header only, used for the purposes when 100 Continue response is sent by the server to the client. The headers not buffered and sent directly the output stream. If the message is not specified, the HTTP message corresponding the response code is sent.

New in version 3.2.

default_headers()}

end_headers()
Adds a blank line (indicating the end of the HTTP headers in the response) to the headers buffer and calls flush_headers().

Changed in version 3.2: The buffered headers are written to the output stream.

flush_headers()
Finally send the headers to the output stream and flush the internal headers buffer.

New in version 3.3.

log_request(code='-', size='-')
Logs an accepted (successful) request. code should specify the numeric HTTP code associated with the response. If a size of
the response is available, then it should be passed as the size parameter.

**log_error(...)**
Logs an error when a request cannot be fulfilled. By default, it passes the message to `log_message()`, so it takes the same arguments (`format` and additional values).

**log_message(format, ...)**
Logs an arbitrary message to `sys.stderr`. This is typically overridden to create custom error logging mechanisms. The `format` argument is a standard printf-style format string, where the additional arguments to `log_message()` are applied as inputs to the formatting. The client ip address and current date and time are prefixed to every message logged.

**version_string()**
Returns the server software’s version string. This is a combination of the `server_version` and `sys_version` class variables.

**date_time_string(timestamp=None)**
Returns the date and time given by `timestamp` (which must be None or in the format returned by `time.time()`), formatted for a message header. If `timestamp` is omitted, it uses the current date and time. The result looks like 'Sun, 06 Nov 1994 08:49:37 GMT'.

**log_date_time_string()**
Returns the current date and time, formatted for logging.
address_string()

Returns the client address.

Changed in version 3.3: Previously, a name lookup was performed. To avoid name resolution delays, it now always returns the IP address.

class http.server.SimpleHTTPRequestHandler(request, client_address, server)

This class serves files from the current directory and below, directly mapping the directory structure to HTTP requests.

A lot of the work, such as parsing the request, is done by the base class BaseHTTPRequestHandler. This class implements the do_GET() and do_HEAD() functions.

The following are defined as class-level attributes of SimpleHTTPRequestHandler:

server_version

This will be "SimpleHTTP/" + __version__, where __version__ is defined at the module level.

extensions_map

A dictionary mapping suffixes into MIME types. The default is signified by an empty string, and is considered to be application/octet-stream. The mapping is used case-insensitively, and so should contain only lower-cased keys.

The SimpleHTTPRequestHandler class defines the following methods:

do_HEAD()
This method serves the 'HEAD' request type: it sends the headers it would send for the equivalent GET request. See the do_GET() method for a more complete explanation of the possible headers.

**do_GET()**

The request is mapped to a local file by interpreting the request as a path relative to the current working directory.

If the request was mapped to a directory, the directory is checked for a file named index.html or index.htm (in that order). If found, the file's contents are returned; otherwise a directory listing is generated by calling the list_directory() method. This method uses os.listdir() to scan the directory, and returns a 404 error response if the listdir() fails.

If the request was mapped to a file, it is opened and the contents are returned. Any OSError exception in opening the requested file is mapped to a 404, 'File not found' error. Otherwise, the content type is guessed by calling the guess_type() method, which in turn uses the extensions_map variable.

A 'Content-type:' header with the guessed content type is output, followed by a 'Content-Length:' header with the file's size and a 'Last-Modified:' header with the file's modification time.

Then follows a blank line signifying the end of the headers, and then the contents of the file are output. If the file's MIME type starts with text/ the file is opened in text mode; otherwise
binary mode is used.

For example usage, see the implementation of the `test()` function invocation in the `http.server` module.

The `SimpleHTTPRequestHandler` class can be used in the following manner in order to create a very basic webserver serving files relative to the current directory:

```python
import http.server
import socketserver

PORT = 8000
Handler = http.server.SimpleHTTPRequestHandler
httpd = socketserver.TCPServer(("", PORT), Handler)
print("serving at port", PORT)
httpd.serve_forever()
```

`http.server` can also be invoked directly using the `-m` switch of the interpreter with a `port` number argument. Similar to the previous example, this serves files relative to the current directory:

```bash
python -m http.server 8000
```

By default, server binds itself to all interfaces. The option `-b/`--bind` specifies a specific address to which it should bind. For example, the following command causes the server to bind to localhost only:

```bash
python -m http.server 8000 --bind 127.0.0.1
```

New in version 3.4: `--bind` argument was introduced.
class http.server.CGIHTTPRequestHandler(request, client_address, server)

This class is used to serve either files or output of CGI scripts from the current directory and below. Note that mapping HTTP hierarchic structure to local directory structure is exactly as in SimpleHTTPRequestHandler.

Note: CGI scripts run by the CGIHTTPRequestHandler class cannot execute redirects (HTTP code 302), because code 200 (script output follows) is sent prior to execution of the CGI script. This pre-empts the status code.

The class will however, run the CGI script, instead of serving it as a file, if it guesses it to be a CGI script. Only directory-based CGI are used — the other common server configuration is to treat special extensions as denoting CGI scripts.

The do_GET() and do_HEAD() functions are modified to run CGI scripts and serve the output, instead of serving files, if the request leads to somewhere below the cgi_directories path.

The CGIHTTPRequestHandler defines the following data member:

cgi_directories

This defaults to ['/cgi-bin', '/htbin'] and describes directories to treat as containing CGI scripts.

The CGIHTTPRequestHandler defines the following method:

do_POST()

This method serves the 'POST' request type, only allowed for CGI scripts. Error 501, "Can only POST to CGI scripts", is
output when trying to POST to a non-CGI url.

Note that CGI scripts will be run with UID of user nobody, for security reasons. Problems with the CGI script will be translated to error 403.

**CGIHTTPRequestHandler** can be enabled in the command line by passing the **--cgi** option:

```
python -m http.server --cgi 8000
```
21.23. **http.cookies** — HTTP state management

**Source code:** `Lib/http/cookies.py`

The `http.cookies` module defines classes for abstracting the concept of cookies, an HTTP state management mechanism. It supports both simple string-only cookies, and provides an abstraction for having any serializable data-type as cookie value.

The module formerly strictly applied the parsing rules described in the [RFC 2109](https://tools.ietf.org/html/rfc2109) and [RFC 2068](https://tools.ietf.org/html/rfc2068) specifications. It has since been discovered that MSIE 3.0x doesn’t follow the character rules outlined in those specs and also many current day browsers and servers have relaxed parsing rules when comes to Cookie handling. As a result, the parsing rules used are a bit less strict.

The character set, `string.ascii_letters`, `string.digits` and `!#$%&'*+-.^_`~: denote the set of valid characters allowed by this module in Cookie name (as key).

*Changed in version 3.3:* Allowed `:` as a valid Cookie name character.

**Note:** On encountering an invalid cookie, `CookieError` is raised, so if your cookie data comes from a browser you should always prepare for invalid data and catch `CookieError` on parsing.

```exception
http.cookies.CookieError
```

Exception failing because of [RFC 2109](https://tools.ietf.org/html/rfc2109) invalidity: incorrect
attributes, incorrect *Set-Cookie* header, etc.

```python
class http.cookies.BaseCookie([input])
```

This class is a dictionary-like object whose keys are strings and whose values are *Morsel* instances. Note that upon setting a key to a value, the value is first converted to a *Morsel* containing the key and the value.

If `input` is given, it is passed to the `load()` method.

```python
class http.cookies.SimpleCookie([input])
```

This class derives from `BaseCookie` and overrides `value_decode()` and `value_encode()` to be the identity and `str()` respectively.

---

See also:

**Module http.cookiejar**

HTTP cookie handling for web *clients*. The `http.cookiejar` and `http.cookies` modules do not depend on each other.

**RFC 2109 - HTTP State Management Mechanism**

This is the state management specification implemented by this module.
21.23.1. Cookie Objects

BaseCookie.value_decode(val)

Return a decoded value from a string representation. Return value can be any type. This method does nothing in BaseCookie — it exists so it can be overridden.

BaseCookie.value_encode(val)

Return an encoded value. val can be any type, but return value must be a string. This method does nothing in BaseCookie — it exists so it can be overridden.

In general, it should be the case that value_encode() and value_decode() are inverses on the range of value_decode.

BaseCookie.output(attrs=None, header='Set-Cookie:', sep='\r\n')

Return a string representation suitable to be sent as HTTP headers. attrs and header are sent to each Morsel's output() method. sep is used to join the headers together, and is by default the combination '\r\n' (CRLF).

BaseCookie.js_output(attrs=None)

Return an embeddable JavaScript snippet, which, if run on a browser which supports JavaScript, will act the same as if the HTTP headers was sent.

The meaning for attrs is the same as in output().

BaseCookie.load(rawdata)

If rawdata is a string, parse it as an HTTP_COOKIE and add the values found there as Morsels. If it is a dictionary, it is equivalent
for k, v in rawdata.items():
    cookie[k] = v
21.23.2. Morsel Objects

```python
class http.cookies.Morsel
    Abstract a key/value pair, which has some RFC 2109 attributes.

    Morsels are dictionary-like objects, whose set of keys is constant — the valid RFC 2109 attributes, which are

    • expires
    • path
    • comment
    • domain
    • max-age
    • secure
    • version
    • httponly

    The attribute httponly specifies that the cookie is only transferred in HTTP requests, and is not accessible through JavaScript. This is intended to mitigate some forms of cross-site scripting.

    The keys are case-insensitive.

    Changed in version 3.5: __eq__() now takes key and value into account.

Morsel.value
    The value of the cookie.

    Deprecated since version 3.5: assigning to value; use set() instead.
```
**Morsel.coded_value**

The encoded value of the cookie — this is what should be sent.

*Deprecated since version 3.5:* assigning to `coded_value`; use `set()` instead.

**Morsel.key**

The name of the cookie.

*Deprecated since version 3.5:* assigning to `key`; use `set()` instead.

**Morsel.set(key, value, coded_value)**

Set the `key`, `value` and `coded_value` attributes.

*Deprecated since version 3.5:* The undocumented `LegalChars` parameter is ignored and will be removed in a future version.

**Morsel.isReservedKey(K)**

Whether `K` is a member of the set of keys of a `Morsel`.

**Morsel.output(attr=None, header='Set-Cookie: ')**

Return a string representation of the Morsel, suitable to be sent as an HTTP header. By default, all the attributes are included, unless `attr` is given, in which case it should be a list of attributes to use. `header` is by default "Set-Cookie: ".

**Morsel.js_output(attr=None)**

Return an embeddable JavaScript snippet, which, if run on a browser which supports JavaScript, will act the same as if the HTTP header was sent.

The meaning for `attr` is the same as in `output()`.
Morsel.**OutputString**(attrs=None)

Return a string representing the Morsel, without any surrounding HTTP or JavaScript.

The meaning for `attrs` is the same as in `output()`.

Morsel.**update**(values)

Update the values in the Morsel dictionary with the values in the dictionary `values`. Raise an error if any of the keys in the `values` dict is not a valid **RFC 2109** attribute.

*Changed in version 3.5:* an error is raised for invalid keys.

Morsel.**copy**(value)

Return a shallow copy of the Morsel object.

*Changed in version 3.5:* return a Morsel object instead of a dict.

Morsel.**setdefault**(key, value=None)

Raise an error if key is not a valid **RFC 2109** attribute, otherwise behave the same as `dict.setdefault()`.
21.23.3. Example

The following example demonstrates how to use the `http.cookies` module.

```python
>>> from http import cookies
>>> C = cookies.SimpleCookie()
>>> C["fig"] = "newton"
>>> C["sugar"] = "wafer"
>>> print(C)  # generate HTTP headers
Set-Cookie: fig=newton
Set-Cookie: sugar=wafer
>>> print(C.output())  # same thing
Set-Cookie: fig=newton
Set-Cookie: sugar=wafer
>>> C = cookies.SimpleCookie()
>>> C["rocky"] = "road"
>>> C["rocky"]["path"] = "/cookie"
>>> print(C.output(header="Cookie:"))
Cookie: rocky=road; Path=/cookie
>>> print(C.output(attrs=[], header="Cookie:"))
Cookie: rocky=road
>>> C = cookies.SimpleCookie()
>>> C.load("chips=ahoy; vienna=finger")  # load from
>>> print(C)
Set-Cookie: chips=ahoy
Set-Cookie: vienna=finger
>>> C = cookies.SimpleCookie()
>>> C.load('keebler="E=everybody; L="Loves"; fudge')
>>> print(C)
Set-Cookie: keebler="E=everybody; L="Loves"; fudge
>>> C = cookies.SimpleCookie()
>>> C["oreo"] = "doublestuff"
>>> C["oreo"]["path"] = "/"
>>> print(C)
```
Set-Cookie: oreo=doublestuff; Path=/
>>> C = cookies.SimpleCookie()
>>> C["twix"] = "none for you"
>>> C["twix"].value
'none for you'
>>> C = cookies.SimpleCookie()
>>> C["number"] = 7 # equivalent to C["number"] = str(7)
>>> C["string"] = "seven"
>>> C["number"].value
'7'
>>> C["string"].value
'seven'
>>> print(C)
Set-Cookie: number=7
Set-Cookie: string=seven
21.24. **http.cookiejar** — Cookie handling for HTTP clients

**Source code:** [Lib/http/cookiejar.py](http://lib/http/cookiejar.py)

The `http.cookiejar` module defines classes for automatic handling of HTTP cookies. It is useful for accessing web sites that require small pieces of data – *cookies* – to be set on the client machine by an HTTP response from a web server, and then returned to the server in later HTTP requests.

Both the regular Netscape cookie protocol and the protocol defined by **RFC 2965** are handled. RFC 2965 handling is switched off by default. **RFC 2109** cookies are parsed as Netscape cookies and subsequently treated either as Netscape or RFC 2965 cookies according to the 'policy' in effect. Note that the great majority of cookies on the Internet are Netscape cookies. `http.cookiejar` attempts to follow the de-facto Netscape cookie protocol (which differs substantially from that set out in the original Netscape specification), including taking note of the `max-age` and `port` cookie-attributes introduced with RFC 2965.

**Note:** The various named parameters found in `Set-Cookie` and `Set-Cookie2` headers (eg. `domain` and `expires`) are conventionally referred to as *attributes*. To distinguish them from Python attributes, the documentation for this module uses the term *cookie-attribute* instead.

The module defines the following exception:
exception http.cookiejar.LoadError

Instances of FileCookieJar raise this exception on failure to load cookies from a file. LoadError is a subclass of OSError.

Changed in version 3.3: LoadError was made a subclass of OSError instead of IOError.

The following classes are provided:

class http.cookiejar.CookieJar(policy=None)

    policy is an object implementing the CookiePolicy interface.

    The CookieJar class stores HTTP cookies. It extracts cookies from HTTP requests, and returns them in HTTP responses. CookieJar instances automatically expire contained cookies when necessary. Subclasses are also responsible for storing and retrieving cookies from a file or database.

class http.cookiejar.FileCookieJar(filename, delayload=None, policy=None)

    policy is an object implementing the CookiePolicy interface. For the other arguments, see the documentation for the corresponding attributes.

    A CookieJar which can load cookies from, and perhaps save cookies to, a file on disk. Cookies are NOT loaded from the named file until either the load() or revert() method is called. Subclasses of this class are documented in section FileCookieJar subclasses and co-operation with web browsers.

class http.cookiejar.CookiePolicy

    This class is responsible for deciding whether each cookie should be accepted from / returned to the server.
class http.cookiejar.DefaultCookiePolicy(blocked_domains=None, allowed_domains=None, netscape=True, rfc2965=False, rfc2109_as_netscape=None, hide_cookie2=False, strict_domain=False, strict_rfc2965_unverifiable=True, strict_ns_unverifiable=False, strict_ns_domain=http.cookiejar.DefaultCookiePolicy.DomainLiberal, strict_ns_set_initial_dollar=False, strict_ns_set_path=False)

Constructor arguments should be passed as keyword arguments only. blocked_domains is a sequence of domain names that we never accept cookies from, nor return cookies to. allowed_domains if not None, this is a sequence of the only domains for which we accept and return cookies. For all other arguments, see the documentation for CookiePolicy and DefaultCookiePolicy objects.

DefaultCookiePolicy implements the standard accept / reject rules for Netscape and RFC 2965 cookies. By default, RFC 2109 cookies (ie. cookies received in a Set-Cookie header with a version cookie-attribute of 1) are treated according to the RFC 2965 rules. However, if RFC 2965 handling is turned off or rfc2109_as_netscape is True, RFC 2109 cookies are 'downgraded' by the CookieJar instance to Netscape cookies, by setting the version attribute of the Cookie instance to 0. DefaultCookiePolicy also provides some parameters to allow some fine-tuning of policy.

class http.cookiejar.Cookie

This class represents Netscape, RFC 2109 and RFC 2965 cookies. It is not expected that users of http.cookiejar construct their own Cookie instances. Instead, if necessary, call make_cookies() on a CookieJar instance.
See also:

**Module urllib.request**
URL opening with automatic cookie handling.

**Module http.cookies**
HTTP cookie classes, principally useful for server-side code. The `http.cookiejar` and `http.cookies` modules do not depend on each other.

[http://curl.haxx.se/rfc/cookie_spec.html](http://curl.haxx.se/rfc/cookie_spec.html)
The specification of the original Netscape cookie protocol. Though this is still the dominant protocol, the ‘Netscape cookie protocol’ implemented by all the major browsers (and `http.cookiejar`) only bears a passing resemblance to the one sketched out in cookie_spec.html.

**RFC 2109 - HTTP State Management Mechanism**
Obsoleted by RFC 2965. Uses `Set-Cookie` with version=1.

**RFC 2965 - HTTP State Management Mechanism**
The Netscape protocol with the bugs fixed. Uses `Set-Cookie2` in place of `Set-Cookie`. Not widely used.

[http://kristol.org/cookie/errata.html](http://kristol.org/cookie/errata.html)
Unfinished errata to RFC 2965.

**RFC 2964** - Use of HTTP State Management

CookieJar objects support the iterator protocol for iterating over contained Cookie objects.

CookieJar has the following methods:

CookieJar.add_cookie_header(request)
Add correct Cookie header to request.

If policy allows (ie. the rfc2965 and hide_cookie2 attributes of the CookieJar's CookiePolicy instance are true and false respectively), the Cookie2 header is also added when appropriate.

The request object (usually a urllib.request.Request instance) must support the methods get_full_url(), get_host(), get_type(), unverifiable(), has_header(), get_header(), header_items(), add_unredirected_header() and origin_req_host attribute as documented by urllib.request.

Changed in version 3.3: request object needs origin_req_host attribute. Dependency on a deprecated method get_origin_req_host() has been removed.

CookieJar.extract_cookies(response, request)
Extract cookies from HTTP response and store them in the CookieJar, where allowed by policy.

The CookieJar will look for allowable Set-Cookie and Set-
Cookie2 headers in the response argument, and store cookies as appropriate (subject to the CookiePolicy.set_ok() method's approval).

The response object (usually the result of a call to urllib.request.urlopen(), or similar) should support an info() method, which returns an email.message.Message instance.

The request object (usually a urllib.request.Request instance) must support the methods get_full_url(), get_host(), unverifiable(), and origin_req_host attribute, as documented by urllib.request. The request is used to set default values for cookie-attributes as well as for checking that the cookie is allowed to be set.

Changed in version 3.3: request object needs origin_req_host attribute. Dependency on a deprecated method get_origin_req_host() has been removed.

CookieJar.set_policy(policy)

Set the CookiePolicy instance to be used.

CookieJar.make_cookies(response, request)

Return sequence of Cookie objects extracted from response object.

See the documentation for extract_cookies() for the interfaces required of the response and request arguments.

CookieJar.set_cookie_if_ok(cookie, request)

Set a Cookie if policy says it's OK to do so.
CookieJar.set_cookie(cookie)
    Set a Cookie, without checking with policy to see whether or not it should be set.

CookieJar.clear([domain[, path[, name]]])
    Clear some cookies.
    If invoked without arguments, clear all cookies. If given a single argument, only cookies belonging to that domain will be removed. If given two arguments, cookies belonging to the specified domain and URL path are removed. If given three arguments, then the cookie with the specified domain, path and name is removed.
    Raises KeyError if no matching cookie exists.

CookieJar.clear_session_cookies()
    Discard all session cookies.
    Discards all contained cookies that have a true discard attribute (usually because they had either no max-age or expires cookie-attribute, or an explicit discard cookie-attribute). For interactive browsers, the end of a session usually corresponds to closing the browser window.
    Note that the save() method won’t save session cookies anyway, unless you ask otherwise by passing a true ignore_discard argument.

FileCookieJar implements the following additional methods:

FileCookieJar.save(filename=None, ignore_discard=False, ignoreExpires=False)
    Save cookies to a file.
This base class raises `NotImplementedError`. Subclasses may leave this method unimplemented.

`filename` is the name of file in which to save cookies. If `filename` is not specified, `self.filename` is used (whose default is the value passed to the constructor, if any); if `self.filename` is `None`, `ValueError` is raised.

`ignore_discard`: save even cookies set to be discarded. `ignore_expires`: save even cookies that have expired

The file is overwritten if it already exists, thus wiping all the cookies it contains. Saved cookies can be restored later using the `load()` or `revert()` methods.

FileCookieJar.**load**(filename=None, ignore_discard=False, ignore_expires=False)

Load cookies from a file.

Old cookies are kept unless overwritten by newly loaded ones.

Arguments are as for `save()`.

The named file must be in the format understood by the class, or `LoadError` will be raised. Also, `OSError` may be raised, for example if the file does not exist.

*Changed in version 3.3:* `IOError` used to be raised, it is now an alias of `OSError`.

FileCookieJar.**revert**(filename=None, ignore_discard=False, ignore_expires=False)

Clear all cookies and reload cookies from a saved file.
revert() can raise the same exceptions as load(). If there is a failure, the object's state will not be altered.

FileCookieJar instances have the following public attributes:

FileCookieJar.filename
Filename of default file in which to keep cookies. This attribute may be assigned to.

FileCookieJar.delayload
If true, load cookies lazily from disk. This attribute should not be assigned to. This is only a hint, since this only affects performance, not behaviour (unless the cookies on disk are changing). A CookieJar object may ignore it. None of the FileCookieJar classes included in the standard library lazily loads cookies.
21.24.2. FileCookieJar subclasses and cooperation with web browsers

The following CookieJar subclasses are provided for reading and writing.

```python
class http.cookiejar.MozillaCookieJar(filename, delayload=None, policy=None)
```

A FileCookieJar that can load from and save cookies to disk in the Mozilla cookies.txt file format (which is also used by the Lynx and Netscape browsers).

**Note:** This loses information about RFC 2965 cookies, and also about newer or non-standard cookie-attributes such as port.

**Warning:** Back up your cookies before saving if you have cookies whose loss / corruption would be inconvenient (there are some subtleties which may lead to slight changes in the file over a load / save round-trip).

Also note that cookies saved while Mozilla is running will get clobbered by Mozilla.

```python
class http.cookiejar.LWPCookieJar(filename, delayload=None, policy=None)
```

A FileCookieJar that can load from and save cookies to disk in format compatible with the libwww-perl library's Set-Cookie3 file format. This is convenient if you want to store cookies in a human-readable file.
21.24.3. CookiePolicy Objects

Objects implementing the `CookiePolicy` interface have the following methods:

**CookiePolicy.set_ok(cookie, request)**

Return boolean value indicating whether cookie should be accepted from server.

*cookie* is a `Cookie` instance. *request* is an object implementing the interface defined by the documentation for `CookieJar.extract_cookies()`.

**CookiePolicy.return_ok(cookie, request)**

Return boolean value indicating whether cookie should be returned to server.

*cookie* is a `Cookie` instance. *request* is an object implementing the interface defined by the documentation for `CookieJar.add_cookie_header()`.

**CookiePolicy.domain_return_ok(domain, request)**

Return false if cookies should not be returned, given cookie domain.

This method is an optimization. It removes the need for checking every cookie with a particular domain (which might involve reading many files). Returning true from `domain_return_ok()` and `path_return_ok()` leaves all the work to `return_ok()`.

If `domain_return_ok()` returns true for the cookie domain, `path_return_ok()` is called for the cookie path. Otherwise,
path_return_ok() and return_ok() are never called for that cookie domain. If path_return_ok() returns true, return_ok() is called with the Cookie object itself for a full check. Otherwise, return_ok() is never called for that cookie path.

Note that domain_return_ok() is called for every cookie domain, not just for the request domain. For example, the function might be called with both ".example.com" and "www.example.com" if the request domain is "www.example.com". The same goes for path_return_ok().

The request argument is as documented for return_ok().

CookiePolicy.path_return_ok(path, request)
Return false if cookies should not be returned, given cookie path.
See the documentation for domain_return_ok().

In addition to implementing the methods above, implementations of the CookiePolicy interface must also supply the following attributes, indicating which protocols should be used, and how. All of these attributes may be assigned to.

CookiePolicy.netscape
Implement Netscape protocol.

CookiePolicy.rfc2965
Implement RFC 2965 protocol.

CookiePolicy.hide_cookie2
Don’t add Cookie2 header to requests (the presence of this header indicates to the server that we understand RFC 2965 cookies).
The most useful way to define a `CookiePolicy` class is by subclassing from `DefaultCookiePolicy` and overriding some or all of the methods above. `CookiePolicy` itself may be used as a ‘null policy’ to allow setting and receiving any and all cookies (this is unlikely to be useful).
21.24.4. DefaultCookiePolicy Objects

Implements the standard rules for accepting and returning cookies.

Both RFC 2965 and Netscape cookies are covered. RFC 2965 handling is switched off by default.

The easiest way to provide your own policy is to override this class and call its methods in your overridden implementations before adding your own additional checks:

```python
import http.cookiejar

class MyCookiePolicy(http.cookiejar.DefaultCookiePolicy):
    def set_ok(self, cookie, request):
        if not http.cookiejar.DefaultCookiePolicy.set_ok(self, cookie, request):
            return False
        if i_dont_want_to_store_this_cookie(cookie):
            return False
        return True
```

In addition to the features required to implement the CookiePolicy interface, this class allows you to block and allow domains from setting and receiving cookies. There are also some strictness switches that allow you to tighten up the rather loose Netscape protocol rules a little bit (at the cost of blocking some benign cookies).

A domain blacklist and whitelist is provided (both off by default). Only domains not in the blacklist and present in the whitelist (if the whitelist is active) participate in cookie setting and returning. Use the blocked_domains constructor argument, and blocked_domains() and set_blocked_domains() methods (and the corresponding argument and methods for allowed_domains). If you set a whitelist,
you can turn it off again by setting it to None.

Domains in block or allow lists that do not start with a dot must equal the cookie domain to be matched. For example, "example.com" matches a blacklist entry of "example.com", but "www.example.com" does not. Domains that do start with a dot are matched by more specific domains too. For example, both "www.example.com" and "www.coyote.example.com" match ".example.com" (but "example.com" itself does not). IP addresses are an exception, and must match exactly. For example, if blocked_domains contains "192.168.1.2" and ".168.1.2", 192.168.1.2 is blocked, but 193.168.1.2 is not.

DefaultCookiePolicy implements the following additional methods:

DefaultCookiePolicy.blocked_domains()

   Return the sequence of blocked domains (as a tuple).

DefaultCookiePolicy.set_blocked_domains(blocked_domains)

   Set the sequence of blocked domains.

DefaultCookiePolicy.isBlocked(domain)

   Return whether domain is on the blacklist for setting or receiving cookies.

DefaultCookiePolicy.allowed_domains()

   Return None, or the sequence of allowed domains (as a tuple).

DefaultCookiePolicy.set_allowed_domains(allowed_domains)

   Set the sequence of allowed domains, or None.
DefaultCookiePolicy.is_not_allowed(domain)

Return whether domain is not on the whitelist for setting or receiving cookies.

DefaultCookiePolicy instances have the following attributes, which are all initialised from the constructor arguments of the same name, and which may all be assigned to.

DefaultCookiePolicy.rfc2109_as_netscape

If true, request that the CookieJar instance downgrade RFC 2109 cookies (ie. cookies received in a Set-Cookie header with a version cookie-attribute of 1) to Netscape cookies by setting the version attribute of the Cookie instance to 0. The default value is None, in which case RFC 2109 cookies are downgraded if and only if RFC 2965 handling is turned off. Therefore, RFC 2109 cookies are downgraded by default.

General strictness switches:

DefaultCookiePolicy.strict_domain

Don’t allow sites to set two-component domains with country-code top-level domains like .co.uk, .gov.uk, .co.nz etc. This is far from perfect and isn’t guaranteed to work!

RFC 2965 protocol strictness switches:

DefaultCookiePolicy.strict_rfc2965_unverifiable

Follow RFC 2965 rules on unverifiable transactions (usually, an unverifiable transaction is one resulting from a redirect or a request for an image hosted on another site). If this is false, cookies are never blocked on the basis of verifiability

Netscape protocol strictness switches:
DefaultCookiePolicy.\texttt{strict\_ns\_unverifiable}

Apply RFC 2965 rules on unverifiable transactions even to Netscape cookies.

DefaultCookiePolicy.\texttt{strict\_ns\_domain}

Flags indicating how strict to be with domain-matching rules for Netscape cookies. See below for acceptable values.

DefaultCookiePolicy.\texttt{strict\_ns\_set\_initial\_dollar}

Ignore cookies in Set-Cookie: headers that have names starting with '\$'.

DefaultCookiePolicy.\texttt{strict\_ns\_set\_path}

Don’t allow setting cookies whose path doesn’t path-match request URI.

\texttt{strict\_ns\_domain} is a collection of flags. Its value is constructed by or-ing together (for example, DomainStrictNoDots|DomainStrictNonDomain means both flags are set).

DefaultCookiePolicy.\texttt{DomainStrictNoDots}

When setting cookies, the ‘host prefix’ must not contain a dot (eg. www.foo.bar.com can’t set a cookie for .bar.com, because www.foo contains a dot).

DefaultCookiePolicy.\texttt{DomainStrictNonDomain}

Cookies that did not explicitly specify a domain cookie-attribute can only be returned to a domain equal to the domain that set the cookie (eg. spam.example.com won’t be returned cookies from example.com that had no domain cookie-attribute).

DefaultCookiePolicy.\texttt{DomainRFC2965Match}
When setting cookies, require a full RFC 2965 domain-match.

The following attributes are provided for convenience, and are the most useful combinations of the above flags:

DefaultCookiePolicy. **DomainLiberal**
Equivalent to 0 (i.e. all of the above Netscape domain strictness flags switched off).

DefaultCookiePolicy. **DomainStrict**
Equivalent to **DomainStrictNoDots|DomainStrictNonDomain**.
21.24.5. Cookie Objects

Cookie instances have Python attributes roughly corresponding to the standard cookie-attributes specified in the various cookie standards. The correspondence is not one-to-one, because there are complicated rules for assigning default values, because the max-age and expires cookie-attributes contain equivalent information, and because RFC 2109 cookies may be ‘downgraded’ by http.cookiejar from version 1 to version 0 (Netscape) cookies.

Assignment to these attributes should not be necessary other than in rare circumstances in a CookiePolicy method. The class does not enforce internal consistency, so you should know what you’re doing if you do that.

Cookie.version
   Integer or None. Netscape cookies have version 0. RFC 2965 and RFC 2109 cookies have a version cookie-attribute of 1. However, note that http.cookiejar may ‘downgrade’ RFC 2109 cookies to Netscape cookies, in which case version is 0.

Cookie.name
   Cookie name (a string).

Cookie.value
   Cookie value (a string), or None.

Cookie.port
   String representing a port or a set of ports (eg. ‘80’, or ‘80,8080’), or None.

Cookie.path
Cookie path (a string, eg. `/acme/rocket_launchers`).

**Cookie.secure**
True if cookie should only be returned over a secure connection.

**Cookie.expires**
Integer expiry date in seconds since epoch, or None. See also the is_expired() method.

**Cookie.discard**
True if this is a session cookie.

**Cookie.comment**
String comment from the server explaining the function of this cookie, or None.

**Cookie.comment_url**
URL linking to a comment from the server explaining the function of this cookie, or None.

**Cookie.rfc2109**
True if this cookie was received as an RFC 2109 cookie (ie. the cookie arrived in a Set-Cookie header, and the value of the Version cookie-attribute in that header was 1). This attribute is provided because http.cookiejar may ‘downgrade’ RFC 2109 cookies to Netscape cookies, in which case version is 0.

**Cookie.port_specified**
True if a port or set of ports was explicitly specified by the server (in the Set-Cookie / Set-Cookie2 header).

**Cookie.domain_specified**
True if a domain was explicitly specified by the server.

Cookie.domain_initial_dot
   True if the domain explicitly specified by the server began with a dot (\'\.\').

Cookies may have additional non-standard cookie-attributes. These may be accessed using the following methods:

Cookie.has_nonstandard_attr(name)
   Return true if cookie has the named cookie-attribute.

Cookie.get_nonstandard_attr(name, default=None)
   If cookie has the named cookie-attribute, return its value. Otherwise, return default.

Cookie.set_nonstandard_attr(name, value)
   Set the value of the named cookie-attribute.

The Cookie class also defines the following method:

Cookie.is_expired(now=None)
   True if cookie has passed the time at which the server requested it should expire. If now is given (in seconds since the epoch), return whether the cookie has expired at the specified time.
21.24.6. Examples

The first example shows the most common usage of `http.cookiejar`:

```python
import http.cookiejar, urllib.request
cj = http.cookiejar.CookieJar()
opener = urllib.request.build_opener(urllib.request.UserAgent(cj))
r = opener.open("http://example.com/")
```

This example illustrates how to open a URL using your Netscape, Mozilla, or Lynx cookies (assumes Unix/Netscape convention for location of the cookies file):

```python
import os, http.cookiejar, urllib.request
cj = http.cookiejar.MozillaCookieJar()
cj.load(os.path.join(os.path.expanduser("~"), ".netscape/cookies征求"))
opener = urllib.request.build_opener(urllib.request.UserAgent(cj))
r = opener.open("http://example.com/")
```

The next example illustrates the use of `DefaultCookiePolicy`. Turn on RFC 2965 cookies, be more strict about domains when setting and returning Netscape cookies, and block some domains from setting cookies or having them returned:

```python
import urllib.request
from http.cookiejar import CookieJar, DefaultCookiePolicy
policy = DefaultCookiePolicy(
    rfc2965=True, strict_ns_domain=Policy.DomainStrict
)
blocked_domains=["ads.net", ".ads.net"]
cj = CookieJar(policy)
opener = urllib.request.build_opener(urllib.request.UserAgent(cj))
r = opener.open("http://example.com/")
```
r = opener.open("http://example.com/")
21.25. xmlrpc — XMLRPC server and client modules

XML-RPC is a Remote Procedure Call method that uses XML passed via HTTP as a transport. With it, a client can call methods with parameters on a remote server (the server is named by a URI) and get back structured data.

xmlrpc is a package that collects server and client modules implementing XML-RPC. The modules are:

- xmlrpc.client
- xmlrpc.server
21.26. `xmlrpc.client` — XML-RPC client access

**Source code:** [Lib/xmlrpc/client.py](https://docs.python.org/3/library/xmlrpc/client.html)

XML-RPC is a Remote Procedure Call method that uses XML passed via HTTP as a transport. With it, a client can call methods with parameters on a remote server (the server is named by a URI) and get back structured data. This module supports writing XML-RPC client code; it handles all the details of translating between conformable Python objects and XML on the wire.

**Warning:** The `xmlrpc.client` module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see [XML vulnerabilities](https://docs.python.org/3/library/xmlrpc/client.html).

*Changed in version 3.5:* For https URIs, `xmlrpc.client` now performs all the necessary certificate and hostname checks by default.

```python
class xmlrpc.client.ServerProxy(uri, transport=None, encoding=None, verbose=False, allow_none=False, use_datetime=False, use_builtin_types=False, *, context=None)
```

*Changed in version 3.3:* The `use_builtin_types` flag was added.

A `ServerProxy` instance is an object that manages communication with a remote XML-RPC server. The required first argument is a URI (Uniform Resource Indicator), and will normally be the URL of the server. The optional second argument is a transport factory instance; by default it is an internal
SafeTransport instance for https: URLs and an internal HTTP Transport instance otherwise. The optional third argument is an encoding, by default UTF-8. The optional fourth argument is a debugging flag. If allow_none is true, the Python constant None will be translated into XML; the default behaviour is for None to raise a TypeError. This is a commonly-used extension to the XML-RPC specification, but isn’t supported by all clients and servers; see http://ontosys.com/xml-rpc/extensions.php for a description. The use_builtin_types flag can be used to cause date/time values to be presented as datetime.datetime objects and binary data to be presented as bytes objects; this flag is false by default. datetime.datetime and bytes objects may be passed to calls.

The obsolete use_datetime flag is similar to use_builtin_types but it applies only to date/time values.

Both the HTTP and HTTPS transports support the URL syntax extension for HTTP Basic Authentication: http://user:pass@host:port/path. The user:pass portion will be base64-encoded as an HTTP ‘Authorization’ header, and sent to the remote server as part of the connection process when invoking an XML-RPC method. You only need to use this if the remote server requires a Basic Authentication user and password. If an HTTPS url is provided, context may be ssl.SSLContext and configures the SSL settings of the underlying HTTPS connection.

The returned instance is a proxy object with methods that can be used to invoke corresponding RPC calls on the remote server. If the remote server supports the introspection API, the proxy can also be used to query the remote server for the methods it supports (service discovery) and fetch other server-associated metadata.
ServerProxy instance methods take Python basic types and objects as arguments and return Python basic types and classes. Types that are conformable (e.g. that can be marshalled through XML), include the following (and except where noted, they are unmarshalled as the same Python type):

<table>
<thead>
<tr>
<th>Name</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>boolean</td>
<td>The <code>True</code> and <code>False</code> constants</td>
</tr>
<tr>
<td>integers</td>
<td>Pass in directly</td>
</tr>
<tr>
<td>floating-point</td>
<td>Pass in directly</td>
</tr>
<tr>
<td>numbers</td>
<td>Pass in directly</td>
</tr>
<tr>
<td>strings</td>
<td>Pass in directly</td>
</tr>
<tr>
<td>arrays</td>
<td>Any Python sequence type containing conformable elements. Arrays are returned as lists</td>
</tr>
<tr>
<td>structures</td>
<td>A Python dictionary. Keys must be strings, values may be any conformable type. Objects of user-defined classes can be passed in; only their <code>__dict__</code> attribute is transmitted.</td>
</tr>
<tr>
<td>dates</td>
<td>In seconds since the epoch. Pass in an instance of the DateTime class or a <code>datetime.datetime</code> instance.</td>
</tr>
<tr>
<td>binary data</td>
<td>Pass in an instance of the Binary wrapper class or a <code>bytes</code> instance.</td>
</tr>
</tbody>
</table>

This is the full set of data types supported by XML-RPC. Method calls may also raise a special Fault instance, used to signal XML-RPC server errors, or ProtocolError used to signal an error in the HTTP/HTTPS transport layer. Both Fault and
ProtocolError derive from a base class called Error. Note that the xmlrpc client module currently does not marshal instances of subclasses of built-in types.

When passing strings, characters special to XML such as <, >, and & will be automatically escaped. However, it’s the caller’s responsibility to ensure that the string is free of characters that aren’t allowed in XML, such as the control characters with ASCII values between 0 and 31 (except, of course, tab, newline and carriage return); failing to do this will result in an XML-RPC request that isn’t well-formed XML. If you have to pass arbitrary bytes via XML-RPC, use the bytes class or the class:Binary wrapper class described below.

Server is retained as an alias for ServerProxy for backwards compatibility. New code should use ServerProxy.

*Changed in version 3.5:* Added the context argument.

**See also:**

**XML-RPC HOWTO**

A good description of XML-RPC operation and client software in several languages. Contains pretty much everything an XML-RPC client developer needs to know.

**XML-RPC Introspection**

Describes the XML-RPC protocol extension for introspection.

**XML-RPC Specification**

The official specification.

**Unofficial XML-RPC Errata**

Fredrik Lundh’s “unofficial errata, intended to clarify certain details in the XML-RPC specification, as well as hint at ‘best
practices’ to use when designing your own XML-RPC implementations.”

A ServerProxy instance has a method corresponding to each remote procedure call accepted by the XML-RPC server. Calling the method performs an RPC, dispatched by both name and argument signature (e.g. the same method name can be overloaded with multiple argument signatures). The RPC finishes by returning a value, which may be either returned data in a conformant type or a Fault or ProtocolError object indicating an error.

Servers that support the XML introspection API support some common methods grouped under the reserved system attribute:

ServerProxy.system.listMethods()

This method returns a list of strings, one for each (non-system) method supported by the XML-RPC server.

ServerProxy.system.methodSignature(name)

This method takes one parameter, the name of a method implemented by the XML-RPC server. It returns an array of possible signatures for this method. A signature is an array of types. The first of these types is the return type of the method, the rest are parameters.

Because multiple signatures (ie. overloading) is permitted, this method returns a list of signatures rather than a singleton.

Signatures themselves are restricted to the top level parameters expected by a method. For instance if a method expects one array of structs as a parameter, and it returns a string, its signature is simply “string, array”. If it expects three integers and returns a string, its signature is “string, int, int, int”.
If no signature is defined for the method, a non-array value is returned. In Python this means that the type of the returned value will be something other than list.

**ServerProxy.system.methodHelp(name)**

This method takes one parameter, the name of a method implemented by the XML-RPC server. It returns a documentation string describing the use of that method. If no such string is available, an empty string is returned. The documentation string may contain HTML markup.

*Changed in version 3.5:* Instances of `ServerProxy` support the **context manager** protocol for closing the underlying transport.

A working example follows. The server code:

```python
from xmlrpc.server import SimpleXMLRPCServer

def is_even(n):
    return n%2 == 0

server = SimpleXMLRPCServer(("localhost", 8000))
print("Listening on port 8000...")
server.register_function(is_even, "is_even")
server.serve_forever()
```

The client code for the preceding server:

```python
import xmlrpc.client

with xmlrpc.client.ServerProxy("http://localhost:8000") as proxy:
    print("3 is even: %s" % str(proxy.is_even(3)))
    print("100 is even: %s" % str(proxy.is_even(100)))
```
21.26.2. DateTime Objects

This class may be initialized with seconds since the epoch, a time
tuple, an ISO 8601 time/date string, or a `datetime.datetime`
instance. It has the following methods, supported mainly for internal
use by the marshalling/unmarshalling code:

DateTime. `decode(string)`
Accept a string as the instance's new time value.

DateTime. `encode(out)`
Write the XML-RPC encoding of this DateTime item to the `out`
stream object.

It also supports certain of Python's built-in operators through rich
comparison and `__repr__()` methods.

A working example follows. The server code:

```python
import datetime
from xmlrpc.server import SimpleXMLRPCServer
import xmlrpc.client

def today():
    today = datetime.datetime.today()
    return xmlrpc.client.DateTime(today)

server = SimpleXMLRPCServer(("localhost", 8000))
print("Listening on port 8000...")
server.register_function(today, "today")
server.serve_forever()
```

The client code for the preceding server:
import xmlrpc.client
import datetime


today = proxy.today()
# convert the ISO8601 string to a datetime object
converted = datetime.datetime.strptime(today.value, "%Y-%m-%d %H:%M:%S")

print("Today: %s" % converted.strftime("%d.%m.%Y, %H:%M"))
21.26.3. Binary Objects

This class may be initialized from bytes data (which may include NULs). The primary access to the content of a Binary object is provided by an attribute:

**Binary.data**

The binary data encapsulated by the Binary instance. The data is provided as a `bytes` object.

Binary objects have the following methods, supported mainly for internal use by the marshalling/unmarshalling code:

**Binary.decode**(bytes)

Accept a base64 `bytes` object and decode it as the instance's new data.

**Binary.encode**(out)

Write the XML-RPC base 64 encoding of this binary item to the output stream object.

The encoded data will have newlines every 76 characters as per [RFC 2045 section 6.8](https://tools.ietf.org/html/rfc2045), which was the de facto standard base64 specification when the XML-RPC spec was written.

It also supports certain of Python's built-in operators through `__eq__() and __ne__()` methods.

Example usage of the binary objects. We're going to transfer an image over XMLRPC:

```python
from xmlrpc.server import SimpleXMLRPCServer
```
import xmlrpc.client

def python_logo():
    with open("python_logo.jpg", "rb") as handle:
        return xmlrpc.client.Binary(handle.read())

server = SimpleXMLRPCServer(('localhost', 8000))
print("Listening on port 8000...")
server.register_function(python_logo, 'python_logo')

server.serve_forever()

The client gets the image and saves it to a file:

import xmlrpc.client

with open("fetched_python_logo.jpg", "wb") as handle:
    handle.write(proxy.python_logo().data)
21.26.4. Fault Objects

A Fault object encapsulates the content of an XML-RPC fault tag. Fault objects have the following attributes:

**Fault.faultCode**
A string indicating the fault type.

**Fault.faultString**
A string containing a diagnostic message associated with the fault.

In the following example we're going to intentionally cause a Fault by returning a complex type object. The server code:

```python
from xmlrpc.server import SimpleXMLRPCServer

# A marshalling error is going to occur because we're returning a complex number
def add(x, y):
    return x + y + 0j

server = SimpleXMLRPCServer(('localhost', 8000))
print('Listening on port 8000...')
sERVER.register_function(add, 'add')

server.serve_forever()
```

The client code for the preceding server:

```python
import xmlrpc.client


try:
```
proxy.add(2, 5)

```
except xmlrpc.client.Fault as err:
    print("A fault occurred")
    print("Fault code: %d" % err.faultCode)
    print("Fault string: %s" % err.faultString)
```
21.26.5. ProtocolError Objects

A ProtocolError object describes a protocol error in the underlying transport layer (such as a 404 ‘not found’ error if the server named by the URI does not exist). It has the following attributes:

**ProtocolError.** **url**
The URI or URL that triggered the error.

**ProtocolError.** **errcode**
The error code.

**ProtocolError.** **errmsg**
The error message or diagnostic string.

**ProtocolError.** **headers**
A dict containing the headers of the HTTP/HTTPS request that triggered the error.

In the following example we’re going to intentionally cause a ProtocolError by providing an invalid URI:

```python
import xmlrpc.client

# create a ServerProxy with an URI that doesn't respond
proxy = xmlrpc.client.ServerProxy("http://google.com/")

try:
    proxy.some_method()
except xmlrpc.client.ProtocolError as err:
    print("A protocol error occurred")
    print("URL: %s" % err.url)
    print("HTTP/HTTPS headers: %s" % err.headers)
    print("Error code: %d" % err.errcode)
```
print("Error message: \%s" % err.errmsg)
21.26.6. MultiCall Objects

The **MultiCall** object provides a way to encapsulate multiple calls to a remote server into a single request [1].

```python
class xmlrpc.client.MultiCall(server):
    Create an object used to boxcar method calls. server is the eventual target of the call. Calls can be made to the result object, but they will immediately return None, and only store the call name and parameters in the MultiCall object. Calling the object itself causes all stored calls to be transmitted as a single system.multicall request. The result of this call is a generator; iterating over this generator yields the individual results.
```

A usage example of this class follows. The server code:

```python
from xmlrpc.server import SimpleXMLRPCServer

def add(x, y):
    return x + y

def subtract(x, y):
    return x - y

def multiply(x, y):
    return x * y

def divide(x, y):
    return x // y

# A simple server with simple arithmetic functions
server = SimpleXMLRPCServer(("localhost", 8000))
print("Listening on port 8000...")
server.register_multicall_functions()
```
server.register_function(add, 'add')
server.register_function(subtract, 'subtract')
server.register_function(multiply, 'multiply')
server.register_function(divide, 'divide')
server.serve_forever()

The client code for the preceding server:

```
import xmlrpc.client

multicall = xmlrpc.client.MultiCall(proxy)
multicall.add(7, 3)
multicall.subtract(7, 3)
multicall.multiply(7, 3)
multicall.divide(7, 3)
result = multicall()

print("7+3=%d, 7-3=%d, 7*3=%d, 7//3=%d" % tuple(result))
```
21.26.7. Convenience Functions

```python
xmlrpc.client.dumps(params, methodname=None, methodresponse=None, encoding=None, allow_none=False)
```

Convert `params` into an XML-RPC request. or into a response if `methodresponse` is true. `params` can be either a tuple of arguments or an instance of the Fault exception class. If `methodresponse` is true, only a single value can be returned, meaning that `params` must be of length 1. `encoding`, if supplied, is the encoding to use in the generated XML; the default is UTF-8. Python’s `None` value cannot be used in standard XML-RPC; to allow using it via an extension, provide a true value for `allow_none`.

```python
xmlrpc.client.loads(data, use_datetime=False, use_builtin_types=False)
```

Convert an XML-RPC request or response into Python objects, a `(params, methodname)`. `params` is a tuple of argument; `methodname` is a string, or None if no method name is present in the packet. If the XML-RPC packet represents a fault condition, this function will raise a Fault exception. The `use_builtin_types` flag can be used to cause date/time values to be presented as `datetime.datetime` objects and binary data to be presented as `bytes` objects; this flag is false by default.

The obsolete `use_datetime` flag is similar to `use_builtin_types` but it applies only to date/time values.

*Changed in version 3.3:* The `use_builtin_types` flag was added.

```
# simple test program (from the XML-RPC specification)
from xmlrpc.client import ServerProxy, Error

# server = ServerProxy("http://localhost:8000")  # local server

with ServerProxy("http://betty.userland.com") as proxy:
    print(proxy)

    try:
        print(proxy.examples.getStateName(41))
    except Error as v:
        print("ERROR", v)
```

To access an XML-RPC server through a proxy, you need to define a custom transport. The following example shows how:

```
import xmlrpc.client, http.client

class ProxiedTransport(xmlrpc.client.Transport):
    def set_proxy(self, proxy):
        self.proxy = proxy
    def make_connection(self, host):
        self.realhost = host
        h = http.client.HTTP(self.proxy)
        return h
    def send_request(self, connection, handler, request_body):
        connection.putrequest("POST", 'http://%s%s'
    def send_host(self, connection, host):
        connection.putheader('Host', self.realhost)

p = ProxiedTransport()
p.set_proxy('proxy-server:8080')
```
print(server.currentTime.getCurrentTime())
21.26.9. Example of Client and Server Usage

See SimpleXMLRPCServer Example.

Footnotes

[1] This approach has been first presented in a discussion on xmlrpc.com.
The `xmlrpc.server` module provides a basic server framework for XML-RPC servers written in Python. Servers can either be free standing, using `SimpleXMLRPCServer`, or embedded in a CGI environment, using `CGIXMLRPCRequestHandler`.

**Warning:** The `xmlrpc.client` module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see XML vulnerabilities.

```python
class xmlrpc.server.SimpleXMLRPCServer(addr, requestHandler=SimpleXMLRPCRequestHandler, logRequests=True, allow_none=False, encoding=None, bind_and_activate=True, use_builtin_types=False)
```

Create a new server instance. This class provides methods for registration of functions that can be called by the XML-RPC protocol. The `requestHandler` parameter should be a factory for request handler instances; it defaults to `SimpleXMLRPCRequestHandler`. The `addr` and `requestHandler` parameters are passed to the `socketserver.TCPServer` constructor. If `logRequests` is true (the default), requests will be logged; setting this parameter to false will turn off logging. The `allow_none` and `encoding` parameters are passed on to `xmlrpc.client` and control the XML-RPC responses that will be returned from the server. The `bind_and_activate` parameter
controls whether server_bind() and server_activate() are called immediately by the constructor; it defaults to true. Setting it to false allows code to manipulate the allow_reuse_address class variable before the address is bound. The use_builtin_types parameter is passed to the loads() function and controls which types are processed when date/times values or binary data are received; it defaults to false.

*Changed in version 3.3:* The use_builtin_types flag was added.

class xmlrpc.server.CGIXMLRPCRequestHandler(allow_none=False, encoding=None, use_builtin_types=False)

Create a new instance to handle XML-RPC requests in a CGI environment. The allow_none and encoding parameters are passed on to xmlrpc.client and control the XML-RPC responses that will be returned from the server. The use_builtin_types parameter is passed to the loads() function and controls which types are processed when date/times values or binary data are received; it defaults to false.

*Changed in version 3.3:* The use_builtin_types flag was added.

class xmlrpc.server.SimpleXMLRPCRequestHandler

Create a new request handler instance. This request handler supports POST requests and modifies logging so that the logRequests parameter to the SimpleXMLRPCServer constructor parameter is honored.
21.27.1. SimpleXMLRPCServer Objects

The **SimpleXMLRPCServer** class is based on socketserver.TCPServer and provides a means of creating simple, stand alone XML-RPC servers.

SimpleXMLRPCServer.register_function(function, name=None)

Register a function that can respond to XML-RPC requests. If *name* is given, it will be the method name associated with *function*, otherwise *function*.__name__ will be used. *name* can be either a normal or Unicode string, and may contain characters not legal in Python identifiers, including the period character.

SimpleXMLRPCServer.register_instance(instance, allow_dotted_names=False)

Register an object which is used to expose method names which have not been registered using register_function(). If *instance* contains a _dispatch() method, it is called with the requested method name and the parameters from the request. Its API is def _dispatch(self, method, params) (note that params does not represent a variable argument list). If it calls an underlying function to perform its task, that function is called as func(*params), expanding the parameter list. The return value from _dispatch() is returned to the client as the result. If *instance* does not have a _dispatch() method, it is searched for an attribute matching the name of the requested method.

If the optional allow_dotted_names argument is true and the instance does not have a _dispatch() method, then if the requested method name contains periods, each component of the
method name is searched for individually, with the effect that a simple hierarchical search is performed. The value found from this search is then called with the parameters from the request, and the return value is passed back to the client.

**Warning:** Enabling the *allow_dotted_names* option allows intruders to access your module’s global variables and may allow intruders to execute arbitrary code on your machine. Only use this option on a secure, closed network.

SimpleXMLRPCServer.*register_introspection_functions*()  
Registers the XML-RPC introspection functions `system.listMethods`, `system.methodHelp` and `system.methodSignature`.

SimpleXMLRPCServer.*register_multicall_functions*()  
Registers the XML-RPC multicall function `system.multicall`.

SimpleXMLRPCRequestHandler.*rpc_paths*  
An attribute value that must be a tuple listing valid path portions of the URL for receiving XML-RPC requests. Requests posted to other paths will result in a 404 “no such page” HTTP error. If this tuple is empty, all paths will be considered valid. The default value is `('/', '/RPC2')`.

**21.27.1.1. SimpleXMLRPCServer Example**

Server code:

```python
from xmlrpc.server import SimpleXMLRPCServer
from xmlrpc.server import SimpleXMLRPCRequestHandler
```
The following client code will call the methods made available by the preceding server:

```python
import xmlrpc.client

s = xmlrpc.client.ServerProxy('http://localhost:8000')
print(s.pow(2, 3))  # Returns 2**3 = 8
```
print(s.add(2,3)) # Returns 5
print(s.mul(5,2)) # Returns 5*2 = 10

# Print list of available methods
print(s.system.listMethods())

The following example included in the Lib/xmlrpc/server.py module shows a server allowing dotted names and registering a multicall function.

**Warning:** Enabling the *allow_dotted_names* option allows intruders to access your module's global variables and may allow intruders to execute arbitrary code on your machine. Only use this example only within a secure, closed network.

```python
import datetime

class ExampleService:
    def getData(self):
        return '42'

class currentTime:
    @staticmethod
    def getCurrentTime():
        return datetime.datetime.now()

server = SimpleXMLRPCServer(("localhost", 8000))
server.register_function(pow)
server.register_function(lambda x,y: x+y, 'add')
server.register_instance(ExampleService(), allow_dot)
server.register_multicall_functions()
print('Serving XML-RPC on localhost port 8000')
try:
    server.serve_forever()
```
except KeyboardInterrupt:
    print("Keyboard interrupt received, exiting.")
server.server_close()
sys.exit(0)

This ExampleService demo can be invoked from the command line:

```
python -m xmlrpc.server
```

The client that interacts with the above server is included in `Lib/xmlrpc/client.py`:

```python
server = ServerProxy("http://localhost:8000")

try:
    print(server.currentTime.getCurrentTime())
except Error as v:
    print("ERROR", v)

multi = MultiCall(server)
multi.getData()
multi.pow(2, 9)
multi.add(1, 2)

try:
    for response in multi():
        print(response)
except Error as v:
    print("ERROR", v)
```

This client which interacts with the demo XMLRPC server can be invoked as:

```
python -m xmlrpc.client
```
21.27.2. CGIXMLRPCRequestHandler

The CGIXMLRPCRequestHandler class can be used to handle XML-RPC requests sent to Python CGI scripts.

CGIXMLRPCRequestHandler.register_function(function, name=None)

Register a function that can respond to XML-RPC requests. If *name* is given, it will be the method name associated with function, otherwise *function.__name__* will be used. *name* can be either a normal or Unicode string, and may contain characters not legal in Python identifiers, including the period character.

CGIXMLRPCRequestHandler.register_instance(instance)

Register an object which is used to expose method names which have not been registered using register_function(). If instance contains a _dispatch() method, it is called with the requested method name and the parameters from the request; the return value is returned to the client as the result. If instance does not have a _dispatch() method, it is searched for an attribute matching the name of the requested method; if the requested method name contains periods, each component of the method name is searched for individually, with the effect that a simple hierarchical search is performed. The value found from this search is then called with the parameters from the request, and the return value is passed back to the client.

CGIXMLRPCRequestHandler.register_introspection_functions

Register the XML-RPC introspection functions system.listMethods, system.methodHelp and system.methodSignature.
CGIXMLRPCRequestHandler.register_multicall_function
Register the XML-RPC multicall function system.multicall.

CGIXMLRPCRequestHandler.handle_request(request_text=None)
Handle a XML-RPC request. If request_text is given, it should be the POST data provided by the HTTP server, otherwise the contents of stdin will be used.

Example:

```python
class MyFuncs:
    def mul(self, x, y):
        return x * y

handler = CGIXMLRPCRequestHandler()
handler.register_function(pow)
handler.register_function(lambda x,y: x+y, 'add')
handler.register_introspection_functions()
handler.register_instance(MyFuncs())
handler.handle_request()
```
21.27.3. Documenting XMLRPC server

These classes extend the above classes to serve HTML documentation in response to HTTP GET requests. Servers can either be free standing, using `DocXMLRPCServer`, or embedded in a CGI environment, using `DocCGIXMLRPCRequestHandler`.

```python
class xmlrpc.server.DocXMLRPCServer(addr, requestHandler=DocXMLRPCRequestHandler, logRequests=True, allow_none=False, encoding=None, bind_and_activate=True, use_builtin_types=True)
```

Create a new server instance. All parameters have the same meaning as for `SimpleXMLRPCServer`; `requestHandler` defaults to `DocXMLRPCRequestHandler`.

*Changed in version 3.3:* The `use_builtin_types` flag was added.

```python
class xmlrpc.server.DocCGIXMLRPCRequestHandler
```

Create a new instance to handle XML-RPC requests in a CGI environment.

```python
class xmlrpc.server.DocXMLRPCRequestHandler
```

Create a new request handler instance. This request handler supports XML-RPC POST requests, documentation GET requests, and modifies logging so that the `logRequests` parameter to the `DocXMLRPCServer` constructor parameter is honored.
21.27.4. DocXMLRPCServer Objects

The `DocXMLRPCServer` class is derived from `SimpleXMLRPCServer` and provides a means of creating self-documenting, stand alone XML-RPC servers. HTTP POST requests are handled as XML-RPC method calls. HTTP GET requests are handled by generating pydoc-style HTML documentation. This allows a server to provide its own web-based documentation.

`DocXMLRPCServer.set_server_title(server_title)`

Set the title used in the generated HTML documentation. This title will be used inside the HTML “title” element.

`DocXMLRPCServer.set_server_name(server_name)`

Set the name used in the generated HTML documentation. This name will appear at the top of the generated documentation inside a “h1” element.

`DocXMLRPCServer.set_server_documentation(server_doc)`

Set the description used in the generated HTML documentation. This description will appear as a paragraph, below the server name, in the documentation.
21.27.5. DocCGIXMLRPCRequestHandler

The DocCGIXMLRPCRequestHandler class is derived from CGIXMLRPCRequestHandler and provides a means of creating self-documenting, XML-RPC CGI scripts. HTTP POST requests are handled as XML-RPC method calls. HTTP GET requests are handled by generating pydoc-style HTML documentation. This allows a server to provide its own web-based documentation.

DocCGIXMLRPCRequestHandler.set_server_title(server_title)
Set the title used in the generated HTML documentation. This title will be used inside the HTML “title” element.

DocCGIXMLRPCRequestHandler.set_server_name(server_name)
Set the name used in the generated HTML documentation. This name will appear at the top of the generated documentation inside a “h1” element.

DocCGIXMLRPCRequestHandler.set_server_documentation()
Set the description used in the generated HTML documentation. This description will appear as a paragraph, below the server name, in the documentation.
21.28. ipaddress — IPv4/IPv6 manipulation library

Source code: Lib/ipaddress.py

`ipaddress` provides the capabilities to create, manipulate and operate on IPv4 and IPv6 addresses and networks.

The functions and classes in this module make it straightforward to handle various tasks related to IP addresses, including checking whether or not two hosts are on the same subnet, iterating over all hosts in a particular subnet, checking whether or not a string represents a valid IP address or network definition, and so on.

This is the full module API reference—for an overview and introduction, see An introduction to the ipaddress module.

*New in version 3.3.*
21.28.1. Convenience factory functions

The `ipaddress` module provides factory functions to conveniently create IP addresses, networks and interfaces:

`ipaddress.ip_address(address)`

Return an `IPv4Address` or `IPv6Address` object depending on the IP address passed as argument. Either IPv4 or IPv6 addresses may be supplied; integers less than $2^{32}$ will be considered to be IPv4 by default. A `ValueError` is raised if `address` does not represent a valid IPv4 or IPv6 address.

```python
>>> ipaddress.ip_address('192.168.0.1')
IPv4Address('192.168.0.1')
>>> ipaddress.ip_address('2001:db8::')
IPv6Address('2001:db8::')
```

`ipaddress.ip_network(address, strict=True)`

Return an `IPv4Network` or `IPv6Network` object depending on the IP address passed as argument. `address` is a string or integer representing the IP network. Either IPv4 or IPv6 networks may be supplied; integers less than $2^{32}$ will be considered to be IPv4 by default. `strict` is passed to `IPv4Network` or `IPv6Network` constructor. A `ValueError` is raised if `address` does not represent a valid IPv4 or IPv6 address, or if the network has host bits set.

```python
>>> ipaddress.ip_network('192.168.0.0/28')
IPv4Network('192.168.0.0/28')
```

`ipaddress.ip_interface(address)`

Return an `IPv4Interface` or `IPv6Interface` object depending
on the IP address passed as argument. *address* is a string or integer representing the IP address. Either IPv4 or IPv6 addresses may be supplied; integers less than 2**32 will be considered to be IPv4 by default. A *ValueError* is raised if *address* does not represent a valid IPv4 or IPv6 address.

One downside of these convenience functions is that the need to handle both IPv4 and IPv6 formats means that error messages provide minimal information on the precise error, as the functions don't know whether the IPv4 or IPv6 format was intended. More detailed error reporting can be obtained by calling the appropriate version specific class constructors directly.
21.28.2. IP Addresses

21.28.2.1. Address objects

The IPv4Address and IPv6Address objects share a lot of common attributes. Some attributes that are only meaningful for IPv6 addresses are also implemented by IPv4Address objects, in order to make it easier to write code that handles both IP versions correctly.

```python
class ipaddress.IPv4Address(address)
    Construct an IPv4 address. An AddressValueError is raised if address is not a valid IPv4 address.
```

The following constitutes a valid IPv4 address:

1. A string in decimal-dot notation, consisting of four decimal integers in the inclusive range 0-255, separated by dots (e.g. 192.168.0.1). Each integer represents an octet (byte) in the address. Leading zeroes are tolerated only for values less than 8 (as there is no ambiguity between the decimal and octal interpretations of such strings).
2. An integer that fits into 32 bits.
3. An integer packed into a bytes object of length 4 (most significant octet first).

```python
>>> ipaddress.IPv4Address('192.168.0.1')
IPv4Address('192.168.0.1')
>>> ipaddress.IPv4Address(3232235521)
IPv4Address('192.168.0.1')
>>> ipaddress.IPv4Address(b'\xC0\xA8\x00\x01')
IPv4Address('192.168.0.1')
```
The appropriate version number: 4 for IPv4, 6 for IPv6.

**max_prefixlen**

The total number of bits in the address representation for this version: 32 for IPv4, 128 for IPv6.

The prefix defines the number of leading bits in an address that are compared to determine whether or not an address is part of a network.

**compressed**

**exploded**

The string representation in dotted decimal notation. Leading zeroes are never included in the representation.

As IPv4 does not define a shorthand notation for addresses with octets set to zero, these two attributes are always the same as `str(addr)` for IPv4 addresses. Exposing these attributes makes it easier to write display code that can handle both IPv4 and IPv6 addresses.

**packed**

The binary representation of this address - a `bytes` object of the appropriate length (most significant octet first). This is 4 bytes for IPv4 and 16 bytes for IPv6.

**reverse_pointer**

The name of the reverse DNS PTR record for the IP address, e.g.:

```python
>>> ipaddress.ip_address("127.0.0.1").reverse_pointer
'1.0.0.127.in-addr.arpa'
>>> ipaddress.ip_address("2001:db8::1").reverse_pointer
'1::1.in-addr.arpa'
```
This is the name that could be used for performing a PTR lookup, not the resolved hostname itself.

_New in version 3.5._

**is_multicast**
True if the address is reserved for multicast use. See [RFC 3171](https://tools.ietf.org/html/rfc3171) (for IPv4) or [RFC 2373](https://tools.ietf.org/html/rfc2373) (for IPv6).

**is_private**
True if the address is allocated for private networks. See [iana-ipv4-special-registry](https://www.iana.org/assignments/ipv4-special-registry) (for IPv4) or [iana-ipv6-special-registry](https://www.iana.org/assignments/ipv6-special-registry) (for IPv6).

**is_global**
True if the address is allocated for public networks. See [iana-ipv4-special-registry](https://www.iana.org/assignments/ipv4-special-registry) (for IPv4) or [iana-ipv6-special-registry](https://www.iana.org/assignments/ipv6-special-registry) (for IPv6).

_New in version 3.4._

**is_unspecified**

**is_reserved**
True if the address is otherwise IETF reserved.

**is_loopback**
True if this is a loopback address. See [RFC 3330](https://tools.ietf.org/html/rfc3330) (for IPv4) or [RFC 2373](https://tools.ietf.org/html/rfc2373) (for IPv6).
is_link_local

True if the address is reserved for link-local usage. See RFC 3927.

class ipaddress.IPv6Address(address)

Construct an IPv6 address. An AddressValueError is raised if address is not a valid IPv6 address.

The following constitutes a valid IPv6 address:

1. A string consisting of eight groups of four hexadecimal digits, each group representing 16 bits. The groups are separated by colons. This describes an exploded (longhand) notation. The string can also be compressed (shorthand notation) by various means. See RFC 4291 for details. For example, "0000:0000:0000:0000:0000:0abc:0007:0def" can be compressed to "::abc:7:def".
2. An integer that fits into 128 bits.
3. An integer packed into a bytes object of length 16, big-endian.

>>> ipaddress.IPv6Address('2001:db8::1000')
IPv6Address('2001:db8::1000')

compressed

The short form of the address representation, with leading zeroes in groups omitted and the longest sequence of groups consisting entirely of zeroes collapsed to a single empty group.

This is also the value returned by str(addr) for IPv6 addresses.

e xpl o ded

The long form of the address representation, with all leading
For the following attributes, see the corresponding documentation of the IPv4Address class:

- packed
- reverse_pointer
- version
- max_prefixlen
- is_multicast
- is_private
- is_global
- is_unspecified
- is_reserved
- is_loopback
- is_link_local
  
  New in version 3.4: is_global

- is_site_local
  
  True if the address is reserved for site-local usage. Note that the site-local address space has been deprecated by RFC 3879. Use is_private to test if this address is in the space of unique local addresses as defined by RFC 4193.

- ipv4_mapped
  
  For addresses that appear to be IPv4 mapped addresses (starting with ::FFFF/96), this property will report the
embedded IPv4 address. For any other address, this property will be None.

**sixtofour**
For addresses that appear to be 6to4 addresses (starting with 2002::/16) as defined by RFC 3056, this property will report the embedded IPv4 address. For any other address, this property will be None.

**teredo**
For addresses that appear to be Teredo addresses (starting with 2001::/32) as defined by RFC 4380, this property will report the embedded (server, client) IP address pair. For any other address, this property will be None.

### 21.28.2.2. Conversion to Strings and Integers

To interoperate with networking interfaces such as the socket module, addresses must be converted to strings or integers. This is handled using the `str()` and `int()` built-in functions:

```
>>> str(ipaddress.IPv4Address('192.168.0.1'))
'192.168.0.1'
>>> int(ipaddress.IPv4Address('192.168.0.1'))
3232235521
>>> str(ipaddress.IPv6Address('::1'))
'::1'
>>> int(ipaddress.IPv6Address('::1'))
1
```

### 21.28.2.3. Operators
Address objects support some operators. Unless stated otherwise, operators can only be applied between compatible objects (i.e. IPv4 with IPv4, IPv6 with IPv6).

21.28.2.3.1. Comparison operators

Address objects can be compared with the usual set of comparison operators. Some examples:

```python
>>> IPv4Address('127.0.0.2') > IPv4Address('127.0.0.1')
True
>>> IPv4Address('127.0.0.2') == IPv4Address('127.0.0.1')
False
>>> IPv4Address('127.0.0.2') != IPv4Address('127.0.0.1')
True
```

21.28.2.3.2. Arithmetic operators

Integers can be added to or subtracted from address objects. Some examples:

```python
>>> IPv4Address('127.0.0.2') + 3
IPv4Address('127.0.0.5')
>>> IPv4Address('127.0.0.2') - 3
IPv4Address('126.255.255.255')
>>> IPv4Address('255.255.255.255') + 1
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ipaddress.AddressValueError: 4294967296 (>= 2**32)
```

21.28.3. IP Network definitions

The IPv4Network and IPv6Network objects provide a mechanism for defining and inspecting IP network definitions. A network definition consists of a mask and a network address, and as such defines a range of IP addresses that equal the network address when masked (binary AND) with the mask. For example, a network definition with the mask 255.255.255.0 and the network address 192.168.1.0 consists of IP addresses in the inclusive range 192.168.1.0 to 192.168.1.255.

21.28.3.1. Prefix, net mask and host mask

There are several equivalent ways to specify IP network masks. A prefix /<nbits> is a notation that denotes how many high-order bits are set in the network mask. A net mask is an IP address with some number of high-order bits set. Thus the prefix /24 is equivalent to the net mask 255.255.255.0 in IPv4, or ffff:ff00:: in IPv6. In addition, a host mask is the logical inverse of a net mask, and is sometimes used (for example in Cisco access control lists) to denote a network mask. The host mask equivalent to /24 in IPv4 is 0.0.0.255.

21.28.3.2. Network objects

All attributes implemented by address objects are implemented by network objects as well. In addition, network objects implement additional attributes. All of these are common between IPv4Network and IPv6Network, so to avoid duplication they are only documented for IPv4Network.
class `ipaddress.IPv4Network(address, strict=True)`

Construct an IPv4 network definition. `address` can be one of the following:

1. A string consisting of an IP address and an optional mask, separated by a slash (/). The IP address is the network address, and the mask can be either a single number, which means it's a *prefix*, or a string representation of an IPv4 address. If it’s the latter, the mask is interpreted as a *net mask* if it starts with a non-zero field, or as a *host mask* if it starts with a zero field. If no mask is provided, it’s considered to be /32.

   For example, the following `address` specifications are equivalent:
   
   192.168.1.0/24, 192.168.1.0/255.255.255.0 and 192.168.1.0/0.0.0.255.

2. An integer that fits into 32 bits. This is equivalent to a single-address network, with the network address being `address` and the mask being /32.

3. An integer packed into a `bytes` object of length 4, big-endian. The interpretation is similar to an integer `address`.

4. A two-tuple of an address description and a netmask, where the address description is either a string, a 32-bits integer, a 4-bytes packed integer, or an existing IPv4Address object; and the netmask is either an integer representing the prefix length (e.g. 24) or a string representing the prefix mask (e.g. 255.255.255.0).

An `AddressValueError` is raised if `address` is not a valid IPv4
address. A `NetmaskValueError` is raised if the mask is not valid for an IPv4 address.

If `strict` is True and host bits are set in the supplied address, then `ValueError` is raised. Otherwise, the host bits are masked out to determine the appropriate network address.

Unless stated otherwise, all network methods accepting other network/address objects will raise `TypeError` if the argument’s IP version is incompatible to `self`

*Changed in version 3.5:* Added the two-tuple form for the `address` constructor parameter.

**version**

**max_prefixlen**

Refer to the corresponding attribute documentation in `IPv4Address`

**is_multicast**

**is_private**

**is_unspecified**

**is_reserved**

**is_loopback**

**is_link_local**

These attributes are true for the network as a whole if they are true for both the network address and the broadcast address

**network_address**

The network address for the network. The network address and
the prefix length together uniquely define a network.

**broadcast_address**
The broadcast address for the network. Packets sent to the broadcast address should be received by every host on the network.

**hostmask**
The host mask, as a string.

**with_prefixlen**
**compressed**
**exploded**
A string representation of the network, with the mask in prefix notation.

with_prefixlen and compressed are always the same as str(network). exploded uses the exploded form the network address.

**with_netmask**
A string representation of the network, with the mask in net mask notation.

**with_hostmask**
A string representation of the network, with the mask in host mask notation.

**num_addresses**
The total number of addresses in the network.

**prefixlen**
Length of the network prefix, in bits.

hosts()
Returns an iterator over the usable hosts in the network. The usable hosts are all the IP addresses that belong to the network, except the network address itself and the network broadcast address.

```python
>>> list(ip_network('192.0.2.0/29').hosts())
[IPv4Address('192.0.2.1'), IPv4Address('192.0.2.2'), IPv4Address('192.0.2.3'), IPv4Address('192.0.2.4'), IPv4Address('192.0.2.5'), IPv4Address('192.0.2.6')]
```

overlaps(other)
True if this network is partly or wholly contained in other or other is wholly contained in this network.

address_exclude(network)
Computes the network definitions resulting from removing the given network from this one. Returns an iterator of network objects. Raises ValueError if network is not completely contained in this network.

```python
>>> n1 = ip_network('192.0.2.0/28')
>>> n2 = ip_network('192.0.2.1/32')
>>> list(n1.address_exclude(n2))
[IPv4Network('192.0.2.8/29'), IPv4Network('192.0.2.4/30'), IPv4Network('192.0.2.2/31'), IPv4Network('192.0.2.0/32')]
```

subnets(prefixlen_diff=1, new_prefix=None)
The subnets that join to make the current network definition, depending on the argument values. prefixlen_diff is the amount
our prefix length should be increased by. \textit{new\_prefix} is the desired new prefix of the subnets; it must be larger than our prefix. One and only one of \textit{prefixlen\_diff} and \textit{new\_prefix} must be set. Returns an iterator of network objects.

\begin{verbatim}
>>> list(ip_network('192.0.2.0/24').subnets())
[IPv4Network('192.0.2.0/25'), IPv4Network('192.0.2.128/25')]

>>> list(ip_network('192.0.2.0/24').subnets(prefixlen_diff=1, new_prefix=None))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
    raise ValueError('new prefix must be longer than the prefix length used to create this network')
ValueError: new prefix must be longer

>>> list(ip_network('192.0.2.0/24').subnets(prefixlen_diff=1, new_prefix='192.0.2.0/25'))
[IPv4Network('192.0.2.0/25'), IPv4Network('192.0.2.128/25')]
\end{verbatim}

\textbf{supernet}(prefixlen\_diff=1, new\_prefix=None)

The supernet containing this network definition, depending on the argument values. \textit{prefixlen\_diff} is the amount our prefix length should be decreased by. \textit{new\_prefix} is the desired new prefix of the supernet; it must be smaller than our prefix. One and only one of \textit{prefixlen\_diff} and \textit{new\_prefix} must be set. Returns a single network object.

\begin{verbatim}
>>> ip_network('192.0.2.0/24').supernet()
IPv4Network('192.0.2.0/23')

>>> ip_network('192.0.2.0/24').supernet(prefixlen_diff=1)
IPv4Network('192.0.0.0/22')

>>> ip_network('192.0.2.0/24').supernet(new_prefix='192.0.0.0/22')
IPv4Network('192.0.2.0/25')
\end{verbatim}
**IPv4Network('192.0.0.0/20')**

**compare_networks(other)**

Compare this network to other. In this comparison only the network addresses are considered; host bits aren’t. Returns either -1, 0 or 1.

```python
>>> ip_network('192.0.2.1/32').compare_networks(ip_network('192.0.2.1/32')) -1
>>> ip_network('192.0.2.1/32').compare_networks(ip_network('192.0.2.1/32')) 1
>>> ip_network('192.0.2.1/32').compare_networks(ip_network('192.0.2.1/32')) 0
```

**class ipaddress.IPv6Network(address, strict=True)**

Construct an IPv6 network definition. address can be one of the following:

1. A string consisting of an IP address and an optional mask, separated by a slash (/). The IP address is the network address, and the mask can be either a single number, which means it's a prefix, or a string representation of an IPv6 address. If it's the latter, the mask is interpreted as a net mask. If no mask is provided, it's considered to be /128.

   For example, the following address specifications are equivalent: 2001:db00::0/24 and 2001:db00::0/ffff:ff00:..

2. An integer that fits into 128 bits. This is equivalent to a single-address network, with the network address being address and the mask being /128.
3. An integer packed into a bytes object of length 16, big-endian. The interpretation is similar to an integer address.

4. A two-tuple of an address description and a netmask, where the address description is either a string, a 128-bits integer, a 16-bytes packed integer, or an existing IPv4Address object; and the netmask is an integer representing the prefix length.

An AddressValueError is raised if address is not a valid IPv6 address. A NetmaskValueError is raised if the mask is not valid for an IPv6 address.

If strict is True and host bits are set in the supplied address, then ValueError is raised. Otherwise, the host bits are masked out to determine the appropriate network address.

*Changed in version 3.5:* Added the two-tuple form for the address constructor parameter.

version
max_prefixlen
is_multicast
is_private
is_unspecified
is_reserved
is_loopback
is_link_local
network_address
broadcast_address
hostmask
with_prefixlen
compressed
exploded
with_netmask
with_hostmask
num_addresses
prefixlen
hosts()
overlaps(other)
address_exclude(network)
subnets(prefixlen_diff=1, new_prefix=None)
supernet(prefixlen_diff=1, new_prefix=None)
compare_networks(other)
    Refer to the corresponding attribute documentation in IPv4Network

is_site_local
    These attribute is true for the network as a whole if it is true for both the network address and the broadcast address

21.28.3.3. Operators
Network objects support some operators. Unless stated otherwise, operators can only be applied between compatible objects (i.e. IPv4 with IPv4, IPv6 with IPv6).

**21.28.3.3.1. Logical operators**

Network objects can be compared with the usual set of logical operators, similarly to address objects.

**21.28.3.3.2. Iteration**

Network objects can be iterated to list all the addresses belonging to the network. For iteration, all hosts are returned, including unusable hosts (for usable hosts, use the `hosts()` method). An example:

```python
>>> for addr in IPv4Network('192.0.2.0/28'):
...   addr
...  IPv4Address('192.0.2.0')
  IPv4Address('192.0.2.1')
  IPv4Address('192.0.2.2')
  IPv4Address('192.0.2.3')
  IPv4Address('192.0.2.4')
  IPv4Address('192.0.2.5')
  IPv4Address('192.0.2.6')
  IPv4Address('192.0.2.7')
  IPv4Address('192.0.2.8')
  IPv4Address('192.0.2.9')
  IPv4Address('192.0.2.10')
  IPv4Address('192.0.2.11')
  IPv4Address('192.0.2.12')
  IPv4Address('192.0.2.13')
  IPv4Address('192.0.2.14')
  IPv4Address('192.0.2.15')
```
21.28.3.3.3. Networks as containers of addresses

Network objects can act as containers of addresses. Some examples:

```python
>>> IPv4Network('192.0.2.0/28')[0]
IPv4Address('192.0.2.0')
>>> IPv4Network('192.0.2.0/28')[15]
IPv4Address('192.0.2.15')
>>> IPv4Address('192.0.2.6') in IPv4Network('192.0.2.0/28')
True
>>> IPv4Address('192.0.3.6') in IPv4Network('192.0.2.0/28')
False
```
21.28.4. Interface objects

```python
class ipaddress.IPv4Interface(address)
Construct an IPv4 interface. The meaning of address is as in the
constructor of IPv4Network, except that arbitrary host addresses
are always accepted.

IPv4Interface is a subclass of IPv4Address, so it inherits all
the attributes from that class. In addition, the following attributes
are available:

ip
The address (IPv4Address) without network information.

```  
```python
>>> interface = IPv4Interface('192.0.2.5/24')
>>> interface.ip
IPv4Address('192.0.2.5')
```

network
The network (IPv4Network) this interface belongs to.

```python
>>> interface = IPv4Interface('192.0.2.5/24')
>>> interface.network
IPv4Network('192.0.2.0/24')
```

with_prefixlen
A string representation of the interface with the mask in prefix
notation.

```python
>>> interface = IPv4Interface('192.0.2.5/24')
>>> interface.with_prefixlen
'192.0.2.5/24'
```
**with_netmask**

A string representation of the interface with the network as a net mask.

```
>>> interface = IPv4Interface('192.0.2.5/24')
>>> interface.with_netmask
'192.0.2.5/255.255.255.0'
```

**with_hostmask**

A string representation of the interface with the network as a host mask.

```
>>> interface = IPv4Interface('192.0.2.5/24')
>>> interface.with_hostmask
'192.0.2.5/0.0.0.255'
```

class `ipaddress.IPV6Interface(address)`

Construct an IPv6 interface. The meaning of `address` is as in the constructor of `IPv6Network`, except that arbitrary host addresses are always accepted.

`IPv6Interface` is a subclass of `IPv6Address`, so it inherits all the attributes from that class. In addition, the following attributes are available:

- `ip`
- `network`
- `with_prefixlen`
- `with_netmask`
- `with_hostmask`

Refer to the corresponding attribute documentation in
IPv4Interface.
21.28.5. Other Module Level Functions

The module also provides the following module level functions:

\[\text{ipaddress.v4\_int\_to\_packed(address)}\]

Represent an address as 4 packed bytes in network (big-endian) order. \(\text{address}\) is an integer representation of an IPv4 IP address. A \text{ValueError} is raised if the integer is negative or too large to be an IPv4 IP address.

\[
\begin{align*}
\text{>>> ipaddress.ip\_address(3221225985)} & \quad \text{IPv4Address('192.0.2.1')} \\
\text{>>> ipaddress.v4\_int\_to\_packed(3221225985)} & \quad \text{b'\xc0\x00\x02\x01'}
\end{align*}
\]

\[\text{ipaddress.v6\_int\_to\_packed(address)}\]

Represent an address as 16 packed bytes in network (big-endian) order. \(\text{address}\) is an integer representation of an IPv6 IP address. A \text{ValueError} is raised if the integer is negative or too large to be an IPv6 IP address.

\[\text{ipaddress.summarize\_address\_range(first, last)}\]

Return an iterator of the summarized network range given the first and last IP addresses. \(\text{first}\) is the first \text{IPv4Address} or \text{IPv6Address} in the range and \(\text{last}\) is the last \text{IPv4Address} or \text{IPv6Address} in the range. A \text{TypeError} is raised if \(\text{first}\) or \(\text{last}\) are not IP addresses or are not of the same version. A \text{ValueError} is raised if \(\text{last}\) is not greater than \(\text{first}\) or if \(\text{first}\) address version is not 4 or 6.

\[
\begin{align*}
\text{>>> [ipaddr for ipaddr in ipaddress.summarize_add... ipaddress.IPv4Address('192.0.2.0')},
\end{align*}
\]
ipaddress.collapse_addresses(addresses)

Return an iterator of the collapsed IPv4Network or IPv6Network objects. addresses is an iterator of IPv4Network or IPv6Network objects. A TypeError is raised if addresses contains mixed version objects.

>>> [ipaddr for ipaddr in ...
ipaddress.collapse_addresses([ipaddress.IPv4Network('192.0.2.128/25')])]
[IPv4Network('192.0.2.0/24')]

ipaddress.get_mixed_type_key(obj)

Return a key suitable for sorting between networks and addresses. Address and Network objects are not sortable by default; they're fundamentally different, so the expression:

IPv4Address('192.0.2.0') <= IPv4Network('192.0.2.0')

doesn't make sense. There are some times however, where you may wish to have ipaddress sort these anyway. If you need to do this, you can use this function as the key argument to sorted().

obj is either a network or address object.
21.28.6. Custom Exceptions

To support more specific error reporting from class constructors, the module defines the following exceptions:

exception ipaddress.AddressValueError(ValorError)

  Any value error related to the address.

exception ipaddress.NetmaskValueError(ValorError)

  Any value error related to the netmask.
22. Multimedia Services

The modules described in this chapter implement various algorithms or interfaces that are mainly useful for multimedia applications. They are available at the discretion of the installation. Here’s an overview:

- **22.1. audioop** — Manipulate raw audio data
- **22.2. aifc** — Read and write AIFF and AIFC files
- **22.3. sunau** — Read and write Sun AU files
  - 22.3.1. AU_read Objects
  - 22.3.2. AU_write Objects
- **22.4. wave** — Read and write WAV files
  - 22.4.1. Wave_read Objects
  - 22.4.2. Wave_write Objects
- **22.5. chunk** — Read IFF chunked data
- **22.6. colorsys** — Conversions between color systems
- **22.7. imghdr** — Determine the type of an image
- **22.8. sndhdr** — Determine type of sound file
- **22.9. ossaudiodev** — Access to OSS-compatible audio devices
  - 22.9.1. Audio Device Objects
  - 22.9.2. Mixer Device Objects
22.1. audioop — Manipulate raw audio data

The audioop module contains some useful operations on sound fragments. It operates on sound fragments consisting of signed integer samples 8, 16, 24 or 32 bits wide, stored in bytes-like objects. All scalar items are integers, unless specified otherwise.

*Changed in version 3.4:* Support for 24-bit samples was added. All functions now accept any bytes-like object. String input now results in an immediate error.

This module provides support for a-LAW, u-LAW and Intel/DVI ADPCM encodings.

A few of the more complicated operations only take 16-bit samples, otherwise the sample size (in bytes) is always a parameter of the operation.

The module defines the following variables and functions:

*exception* audioop.error

This exception is raised on all errors, such as unknown number of bytes per sample, etc.

audioop.add(fragment1, fragment2, width)

Return a fragment which is the addition of the two samples passed as parameters. width is the sample width in bytes, either 1, 2, 3 or 4. Both fragments should have the same length. Samples are truncated in case of overflow.
audioop.adpcm2lin(adpcmfragment, width, state)
Decide an Intel/DVI ADPCM coded fragment to a linear fragment. See the description of lin2adpcm() for details on ADPCM coding. Return a tuple (sample, newstate) where the sample has the width specified in width.

audioop.alaw2lin(fragment, width)
Convert sound fragments in a-LAW encoding to linearly encoded sound fragments. a-LAW encoding always uses 8 bits samples, so width refers only to the sample width of the output fragment here.

audioop.avg(fragment, width)
Return the average over all samples in the fragment.

audioop.avgpp(fragment, width)
Return the average peak-peak value over all samples in the fragment. No filtering is done, so the usefulness of this routine is questionable.

audioop.bias(fragment, width, bias)
Return a fragment that is the original fragment with a bias added to each sample. Samples wrap around in case of overflow.

audioop.byteswap(fragment, width)
“Byteswap” all samples in a fragment and returns the modified fragment. Converts big-endian samples to little-endian and vice versa.

New in version 3.4.

audioop.cross(fragment, width)
Return the number of zero crossings in the fragment passed as an argument.
audioop.**findfactor**(fragment, reference)

Return a factor \( F \) such that \( \text{rms}(\text{add}(\text{fragment}, \text{mul}(\text{reference}, -F))) \) is minimal, i.e., return the factor with which you should multiply \text{reference} to make it match as well as possible to \text{fragment}. The fragments should both contain 2-byte samples.

The time taken by this routine is proportional to \text{len(fragment)}.

audioop.**findfit**(fragment, reference)

Try to match \text{reference} as well as possible to a portion of \text{fragment} (which should be the longer fragment). This is (conceptually) done by taking slices out of \text{fragment}, using **findfactor()** to compute the best match, and minimizing the result. The fragments should both contain 2-byte samples. Return a tuple \((\text{offset}, \text{factor})\) where \text{offset} is the (integer) offset into \text{fragment} where the optimal match started and \text{factor} is the (floating-point) factor as per **findfactor()**.

audioop.**findmax**(fragment, length)

Search \text{fragment} for a slice of length \text{length} samples (not bytes!) with maximum energy, i.e., return \( i \) for which \( \text{rms}(\text{fragment}[i*2:(i+\text{length})*2]) \) is maximal. The fragments should both contain 2-byte samples.

The routine takes time proportional to \text{len(fragment)}.

audioop.**getsample**(fragment, width, index)

Return the value of sample \text{index} from the fragment.

audioop.**lin2adpcm**(fragment, width, state)
Convert samples to 4 bit Intel/DVI ADPCM encoding. ADPCM coding is an adaptive coding scheme, whereby each 4 bit number is the difference between one sample and the next, divided by a (varying) step. The Intel/DVI ADPCM algorithm has been selected for use by the IMA, so it may well become a standard.

`state` is a tuple containing the state of the coder. The coder returns a tuple `(adpcmfrag, newstate)`, and the `newstate` should be passed to the next call of `lin2adpcm()`. In the initial call, None can be passed as the state. `adpcmfrag` is the ADPCM coded fragment packed 2 4-bit values per byte.

**audioop.**lin2alaw(*fragment, width*)

Convert samples in the audio fragment to a-LAW encoding and return this as a bytes object. a-LAW is an audio encoding format whereby you get a dynamic range of about 13 bits using only 8 bit samples. It is used by the Sun audio hardware, among others.

**audioop.**lin2lin(*fragment, width, newwidth*)

Convert samples between 1-, 2-, 3- and 4-byte formats.

**Note:** In some audio formats, such as .WAV files, 16, 24 and 32 bit samples are signed, but 8 bit samples are unsigned. So when converting to 8 bit wide samples for these formats, you need to also add 128 to the result:

```python
new_frames = audioop.lin2lin(frames, old_width,
new_frames = audioop.bias(new_frames, 1, 128)
```

The same, in reverse, has to be applied when converting from 8 to 16, 24 or 32 bit width samples.
audioop.\texttt{lin2ulaw}(\texttt{fragment, width})

Convert samples in the audio fragment to u-LAW encoding and return this as a bytes object. u-LAW is an audio encoding format whereby you get a dynamic range of about 14 bits using only 8 bit samples. It is used by the Sun audio hardware, among others.

audioop.\texttt{max}(\texttt{fragment, width})

Return the maximum of the \textit{absolute value} of all samples in a fragment.

audioop.\texttt{maxpp}(\texttt{fragment, width})

Return the maximum peak-peak value in the sound fragment.

audioop.\texttt{minmax}(\texttt{fragment, width})

Return a tuple consisting of the minimum and maximum values of all samples in the sound fragment.

audioop.\texttt{mul}(\texttt{fragment, width, factor})

Return a fragment that has all samples in the original fragment multiplied by the floating-point value \textit{factor}. Samples are truncated in case of overflow.

audioop.\texttt{ratecv}(\texttt{fragment, width, nchannels, inrate, outrate, state[, weightA[, weightB]]})

Convert the frame rate of the input fragment.

\textit{state} is a tuple containing the state of the converter. The converter returns a tuple (newfragment, newstate), and \textit{newstate} should be passed to the next call of \texttt{ratecv()}. The initial call should pass None as the state.

The \textit{weightA} and \textit{weightB} arguments are parameters for a simple
digital filter and default to 1 and 0 respectively.

audioop.reverse(fragment, width)
Reverse the samples in a fragment and returns the modified fragment.

audioop.rms(fragment, width)
Return the root-mean-square of the fragment, i.e. \( \sqrt{\text{sum}(S_i^2)/n} \).

This is a measure of the power in an audio signal.

audioop.tomono(fragment, width, ifactor, rfactor)
Convert a stereo fragment to a mono fragment. The left channel is multiplied by \( ifactor \) and the right channel by \( rfactor \) before adding the two channels to give a mono signal.

audioop.tostereo(fragment, width, ifactor, rfactor)
Generate a stereo fragment from a mono fragment. Each pair of samples in the stereo fragment are computed from the mono sample, whereby left channel samples are multiplied by \( ifactor \) and right channel samples by \( rfactor \).

audioop.ulaw2lin(fragment, width)
Convert sound fragments in u-LAW encoding to linearly encoded sound fragments. u-LAW encoding always uses 8 bits samples, so \( width \) refers only to the sample width of the output fragment here.

Note that operations such as \texttt{mul()} or \texttt{max()} make no distinction between mono and stereo fragments, i.e. all samples are treated equal. If this is a problem the stereo fragment should be split into two mono fragments first and recombined later. Here is an example of how to do that:
def mul_stereo(sample, width, lfactor, rfactor):
    lsample = audioop.tomono(sample, width, 1, 0)
    rsample = audioop.tomono(sample, width, 0, 1)
    lsample = audioop.mul(lsample, width, lfactor)
    rsample = audioop.mul(rsample, width, rfactor)
    lsample = audioop.tostereo(lsample, width, 1, 0)
    rsample = audioop.tostereo(rsample, width, 0, 1)
    return audioop.add(lsample, rsample, width)

If you use the ADPCM coder to build network packets and you want
your protocol to be stateless (i.e. to be able to tolerate packet loss)
you should not only transmit the data but also the state. Note that you
should send the initial state (the one you passed to lin2adpcm())
along to the decoder, not the final state (as returned by the coder). If
you want to use struct.Struct to store the state in binary you can
code the first element (the predicted value) in 16 bits and the second
(the delta index) in 8.

The ADPCM coders have never been tried against other ADPCM
coders, only against themselves. It could well be that I misinterpreted
the standards in which case they will not be interoperable with the
respective standards.

The find*() routines might look a bit funny at first sight. They are
primarily meant to do echo cancellation. A reasonably fast way to do
this is to pick the most energetic piece of the output sample, locate
that in the input sample and subtract the whole output sample from the
input sample:

def echocancel(outputdata, inputdata):
    pos = audioop.findmax(outputdata, 800)  # one
gen_test = outputdata[pos*2:]
in_test = inputdata[pos*2:]

ipos, factor = audioop.findfit(in_test, out_test)
# Optional (for better cancellation):
# factor = audioop.findfactor(in_test[ipos*2:ipos*2+len(out_test)],
# out_test)
prefill = '\0'*(pos+ipos)*2
postfill = '\0'*(len(inputdata)-len(prefill)-len(outputdata) + len(prefill))
outputdata = prefill + audioop.mul(outputdata, 2,
return audioop.add(inputdata, outputdata, 2)
22.2. aifc — Read and write AIFF and AIFC files

Source code: Lib/aifc.py

This module provides support for reading and writing AIFF and AIFF-C files. AIFF is Audio Interchange File Format, a format for storing digital audio samples in a file. AIFF-C is a newer version of the format that includes the ability to compress the audio data.

Note: Some operations may only work under IRIX; these will raise ImportError when attempting to import the c1 module, which is only available on IRIX.

Audio files have a number of parameters that describe the audio data. The sampling rate or frame rate is the number of times per second the sound is sampled. The number of channels indicate if the audio is mono, stereo, or quadro. Each frame consists of one sample per channel. The sample size is the size in bytes of each sample. Thus a frame consists of nchannels * samplesize bytes, and a second's worth of audio consists of nchannels * samplesize * framerate bytes.

For example, CD quality audio has a sample size of two bytes (16 bits), uses two channels (stereo) and has a frame rate of 44,100 frames/second. This gives a frame size of 4 bytes (2*2), and a second's worth occupies 2*2*44100 bytes (176,400 bytes).

Module aifc defines the following function:
aifc.open(file, mode=None)

Open an AIFF or AIFF-C file and return an object instance with methods that are described below. The argument file is either a string naming a file or a file object. mode must be 'r' or 'rb' when the file must be opened for reading, or 'w' or 'wb' when the file must be opened for writing. If omitted, file.mode is used if it exists, otherwise 'rb' is used. When used for writing, the file object should be seekable, unless you know ahead of time how many samples you are going to write in total and use writeframesraw() and setnframes(). The open() function may be used in a with statement. When the with block completes, the close() method is called.

Changed in version 3.4: Support for the with statement was added.

Objects returned by open() when a file is opened for reading have the following methods:

aifc.getnchannels()

Return the number of audio channels (1 for mono, 2 for stereo).

aifc.getsampwidth()

Return the size in bytes of individual samples.

aifc.getframerate()

Return the sampling rate (number of audio frames per second).

aifc.getnframes()

Return the number of audio frames in the file.

aifc.getcomptype()
Return a bytes array of length 4 describing the type of compression used in the audio file. For AIFF files, the returned value is b'NONE'.

aifc.getcompname()
Return a bytes array convertible to a human-readable description of the type of compression used in the audio file. For AIFF files, the returned value is b'not compressed'.

aifc.getparams()
Returns a namedtuple() (nchannels, sampwidth, framerate, nframes, comptype, compname), equivalent to output of the get*() methods.

aifc.getmarkers()
Return a list of markers in the audio file. A marker consists of a tuple of three elements. The first is the mark ID (an integer), the second is the mark position in frames from the beginning of the data (an integer), the third is the name of the mark (a string).

aifc.getmark(id)
Return the tuple as described in getmarkers() for the mark with the given id.

aifc.readframes(nframes)
Read and return the next nframes frames from the audio file. The returned data is a string containing for each frame the uncompressed samples of all channels.

aifc.rewind()
Rewind the read pointer. The next readframes() will start from the beginning.
aifc.setpos(pos)
    Seek to the specified frame number.

aifc.tell()
    Return the current frame number.

aifc.close()
    Close the AIFF file. After calling this method, the object can no
    longer be used.

Objects returned by open() when a file is opened for writing have all
the above methods, except for readframes() and setpos(). In
addition the following methods exist. The get*() methods can only
be called after the corresponding set*() methods have been called.
Before the first writeframes() or writeframesraw(), all
parameters except for the number of frames must be filled in.

aifc.aiff()
    Create an AIFF file. The default is that an AIFF-C file is created,
    unless the name of the file ends in '.aiff' in which case the
default is an AIFF file.

aifc.aifc()
    Create an AIFF-C file. The default is that an AIFF-C file is created,
    unless the name of the file ends in '.aiff' in which case the
default is an AIFF file.

aifc.setnchannels(nchannels)
    Specify the number of channels in the audio file.

aifc.setsampwidth(width)
    Specify the size in bytes of audio samples.
aifc.setframerate(rate)
   Specify the sampling frequency in frames per second.

aifc.setnframes(nframes)
   Specify the number of frames that are to be written to the audio file. If this parameter is not set, or not set correctly, the file needs to support seeking.

aifc.setcomptype(type, name)
   Specify the compression type. If not specified, the audio data will not be compressed. In AIFF files, compression is not possible. The name parameter should be a human-readable description of the compression type as a bytes array, the type parameter should be a bytes array of length 4. Currently the following compression types are supported: b'NONE', b'ULAW', b'ALAW', b'G722'.

aifc.setparams(nchannels, sampwidth, framerate, comptype, compname)
   Set all the above parameters at once. The argument is a tuple consisting of the various parameters. This means that it is possible to use the result of a getparams() call as argument to setparams().

aifc.setmark(id, pos, name)
   Add a mark with the given id (larger than 0), and the given name at the given position. This method can be called at any time before close().

aifc.tell()
   Return the current write position in the output file. Useful in combination with setmark().
aifc.writeframes(data)
  Write data to the output file. This method can only be called after
  the audio file parameters have been set.

  Changed in version 3.4: Any bytes-like object is now accepted.

aifc.writeframesraw(data)
  Like writeframes(), except that the header of the audio file is
  not updated.

  Changed in version 3.4: Any bytes-like object is now accepted.

aifc.close()
  Close the AIFF file. The header of the file is updated to reflect the
  actual size of the audio data. After calling this method, the object
  can no longer be used.
22.3. sunau — Read and write Sun AU files

Source code: Lib/sunau.py

The sunau module provides a convenient interface to the Sun AU sound format. Note that this module is interface-compatible with the modules aifc and wave.

An audio file consists of a header followed by the data. The fields of the header are:

<table>
<thead>
<tr>
<th>Field</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>magic word</td>
<td>The four bytes . snd.</td>
</tr>
<tr>
<td>header size</td>
<td>Size of the header, including info, in bytes.</td>
</tr>
<tr>
<td>data size</td>
<td>Physical size of the data, in bytes.</td>
</tr>
<tr>
<td>encoding</td>
<td>Indicates how the audio samples are encoded.</td>
</tr>
<tr>
<td>sample rate</td>
<td>The sampling rate.</td>
</tr>
<tr>
<td># of channels</td>
<td>The number of channels in the samples.</td>
</tr>
<tr>
<td>info</td>
<td>ASCII string giving a description of the audio file (padded with null bytes).</td>
</tr>
</tbody>
</table>

Apart from the info field, all header fields are 4 bytes in size. They are all 32-bit unsigned integers encoded in big-endian byte order.

The sunau module defines the following functions:

sunau. open(file, mode)
If `file` is a string, open the file by that name, otherwise treat it as a seekable file-like object. `mode` can be any of

'`r`'
Read only mode.

'`w`'
Write only mode.

Note that it does not allow read/write files.

A `mode` of 'r' returns an AU_read object, while a `mode` of 'w' or 'wb' returns an AU_write object.

sunau.openfp(file, mode)
A synonym for `open()`, maintained for backwards compatibility.

The `sunau` module defines the following exception:

`exception sunau.Error`
An error raised when something is impossible because of Sun AU specs or implementation deficiency.

The `sunau` module defines the following data items:

sunau.AUDIO_FILE_MAGIC
An integer every valid Sun AU file begins with, stored in big-endian form. This is the string `.snd` interpreted as an integer.

sunau.AUDIO_FILE_ENCODING_MULAW_8
sunau.AUDIO_FILE_ENCODING_LINEAR_8
sunau.AUDIO_FILE_ENCODING_LINEAR_16
sunau.AUDIO_FILE_ENCODING_LINEAR_24
sunau.AUDIO_FILE_ENCODING_LINEAR_32
sunau.AUDIO_FILE_ENCODING_ALAW_8
Values of the encoding field from the AU header which are supported by this module.

sunau.\texttt{AUDIO\_FILE\_ENCODING\_FLOAT}

sunau.\texttt{AUDIO\_FILE\_ENCODING\_DOUBLE}

sunau.\texttt{AUDIO\_FILE\_ENCODING\_ADPCM\_G721}

sunau.\texttt{AUDIO\_FILE\_ENCODING\_ADPCM\_G722}

sunau.\texttt{AUDIO\_FILE\_ENCODING\_ADPCM\_G723\_3}

sunau.\texttt{AUDIO\_FILE\_ENCODING\_ADPCM\_G723\_5}

Additional known values of the encoding field from the AU header, but which are not supported by this module.
22.3.1. AU_read Objects

AU_read objects, as returned by `open()` above, have the following methods:

**AU_read.close()**
Close the stream, and make the instance unusable. (This is called automatically on deletion.)

**AU_read.getnchannels()**
Returns number of audio channels (1 for mono, 2 for stereo).

**AU_read.getsampwidth()**
Returns sample width in bytes.

**AU_read.getframerate()**
Returns sampling frequency.

**AU_read.getnframes()**
Returns number of audio frames.

**AU_read.getcomptype()**
Returns compression type. Supported compression types are 'ULAW', 'ALAW' and 'NONE'.

**AU_read.getcomppname()**
Human-readable version of `getcomptype()`. The supported types have the respective names 'CCITT G.711 u-law', 'CCITT G.711 A-law' and 'not compressed'.

**AU_read.getparams()**
Returns a `namedtuple()` (nchannels, sampwidth,
framerate, nframes, comtype, compname), equivalent to output of the get*( ) methods.

**AU_read.readframes(n)**
Reads and returns at most n frames of audio, as a string of bytes. The data will be returned in linear format. If the original data is in u-LAW format, it will be converted.

**AU_read.rewind()**
Rewind the file pointer to the beginning of the audio stream.

The following two methods define a term “position” which is compatible between them, and is otherwise implementation dependent.

**AU_read.setpos(pos)**
Set the file pointer to the specified position. Only values returned from tell( ) should be used for pos.

**AU_read.tell()**
Return current file pointer position. Note that the returned value has nothing to do with the actual position in the file.

The following two functions are defined for compatibility with the aifc, and don’t do anything interesting.

**AU_read.getmarkers()**
Returns None.

**AU_read.getmark(id)**
Raise an error.
22.3.2. AU_write Objects

AU_write objects, as returned by open() above, have the following methods:

\texttt{AU\_write.setnchannels(n)}
Set the number of channels.

\texttt{AU\_write.setsampwidth(n)}
Set the sample width (in bytes.)

\textit{Changed in version 3.4:} Added support for 24-bit samples.

\texttt{AU\_write.setframerate(n)}
Set the frame rate.

\texttt{AU\_write.setnframes(n)}
Set the number of frames. This can be later changed, when and if more frames are written.

\texttt{AU\_write.setcomptype(type, name)}
Set the compression type and description. Only 'NONE' and 'ULAW' are supported on output.

\texttt{AU\_write.setparams(tuple)}
The \textit{tuple} should be (nchannels, sampwidth, framerate, nframes, comptype, compname), with values valid for the set*() methods. Set all parameters.

\texttt{AU\_write.tell()}
Return current position in the file, with the same disclaimer for the \texttt{AU\_read.tell()} and \texttt{AU\_read.setpos()} methods.
AU_write.writeframesraw(data)
Write audio frames, without correcting nframes.

Changed in version 3.4: Any bytes-like object is now accepted.

AU_write.writeframes(data)
Write audio frames and make sure nframes is correct.

Changed in version 3.4: Any bytes-like object is now accepted.

AU_write.close()
Make sure nframes is correct, and close the file.

This method is called upon deletion.

Note that it is invalid to set any parameters after calling writeframes() or writeframesraw().
22.4. `wave` — Read and write WAV files

**Source code:** Lib/wave.py

The `wave` module provides a convenient interface to the WAV sound format. It does not support compression/decompression, but it does support mono/stereo.

The `wave` module defines the following function and exception:

```python
wave.open(file, mode=None)
```

If `file` is a string, open the file by that name, otherwise treat it as a file-like object. `mode` can be:

- `'rb'`
  
  Read only mode.

- `'wb'`
  
  Write only mode.

Note that it does not allow read/write WAV files.

A `mode` of `'rb'` returns a `Wave_read` object, while a `mode` of `'wb'` returns a `Wave_write` object. If `mode` is omitted and a file-like object is passed as `file`, `file.mode` is used as the default value for `mode`.

If you pass in a file-like object, the `wave` object will not close it when its `close()` method is called; it is the caller’s responsibility to close the file object.
The open() function may be used in a with statement. When the with block completes, the Wave_read.close() or Wave_write.close() method is called.

*Changed in version 3.4:* Added support for unseekable files.

wave.openfp(file, mode)

A synonym for open(), maintained for backwards compatibility.

exception wave.Error

An error raised when something is impossible because it violates the WAV specification or hits an implementation deficiency.
22.4.1. Wave_read Objects

Wave_read objects, as returned by open(), have the following methods:

Wave_read.close()
   Close the stream if it was opened by wave, and make the instance unusable. This is called automatically on object collection.

Wave_read.getnchannels()
   Returns number of audio channels (1 for mono, 2 for stereo).

Wave_read.getsampwidth()
   Returns sample width in bytes.

Wave_read.getframerate()
   Returns sampling frequency.

Wave_read.getnframes()
   Returns number of audio frames.

Wave_read.getcomptype()
   Returns compression type ('NONE' is the only supported type).

Wave_read.getcompname()
   Human-readable version of getcomptype(). Usually 'not compressed' parallels 'NONE'.

Wave_read.getparams()
   Returns a namedtuple() (nchannels, sampwidth, framerate, nframes, comptype, compname), equivalent to
output of the get*() methods.

Wave_read.readframes(n)
  Reads and returns at most n frames of audio, as a string of bytes.

Wave_read.rewind()
  Rewind the file pointer to the beginning of the audio stream.

The following two methods are defined for compatibility with the aifc module, and don’t do anything interesting.

Wave_read.getmarkers()
  Returns None.

Wave_read.getmark(id)
  Raise an error.

The following two methods define a term “position” which is compatible between them, and is otherwise implementation dependent.

Wave_read.setpos(pos)
  Set the file pointer to the specified position.

Wave_read.tell()
  Return current file pointer position.
22.4.2. Wave_write Objects

For seekable output streams, the wave header will automatically be updated to reflect the number of frames actually written. For unseekable streams, the nframes value must be accurate when the first frame data is written. An accurate nframes value can be achieved either by calling setnframes() or setparams() with the number of frames that will be written before close() is called and then using writeframesraw() to write the frame data, or by calling writeframes() with all of the frame data to be written. In the latter case writeframes() will calculate the number of frames in the data and set nframes accordingly before writing the frame data.

Wave_write objects, as returned by open(), have the following methods:

*Changed in version 3.4:* Added support for unseekable files.

Wave_write.close()

Make sure nframes is correct, and close the file if it was opened by wave. This method is called upon object collection. It will raise an exception if the output stream is not seekable and nframes does not match the number of frames actually written.

Wave_write.setnchannels(n)

Set the number of channels.

Wave_write.setsampwidth(n)

Set the sample width to n bytes.

Wave_write.setframerate(n)
Set the frame rate to \( n \).

*Changed in version 3.2:* A non-integral input to this method is rounded to the nearest integer.

**Wave_write.setnframes(\( n \))**
Set the number of frames to \( n \). This will be changed later if the number of frames actually written is different (this update attempt will raise an error if the output stream is not seekable).

**Wave_write.setcomptype(type, name)**
Set the compression type and description. At the moment, only compression type NONE is supported, meaning no compression.

**Wave_write.setparams(tuple)**
The tuple should be (nchannels, sampwidth, framerate, nframes, comptype, compname), with values valid for the set*() methods. Sets all parameters.

**Wave_write.tell()**
Return current position in the file, with the same disclaimer for the Wave_read.tell() and Wave_read.setpos() methods.

**Wave_write.writeframesraw(data)**
Write audio frames, without correcting nframes.

*Changed in version 3.4:* Any bytes-like object is now accepted.

**Wave_write.writeframes(data)**
Write audio frames and make sure nframes is correct. It will raise an error if the output stream is not seekable and the total number of frames that have been written after data has been written does not match the previously set value for nframes.
Changed in version 3.4: Any bytes-like object is now accepted.

Note that it is invalid to set any parameters after calling `writeframes()` or `writeframesraw()`, and any attempt to do so will raise `wave.Error`.
22.5. **chunk — Read IFF chunked data**

This module provides an interface for reading files that use EA IFF 85 chunks. [1] This format is used in at least the Audio Interchange File Format (AIFF/AIFF-C) and the Real Media File Format (RMFF). The WAVE audio file format is closely related and can also be read using this module.

A chunk has the following structure:

<table>
<thead>
<tr>
<th>Offset</th>
<th>Length</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4</td>
<td>Chunk ID</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Size of chunk in big-endian byte order, not including the header</td>
</tr>
<tr>
<td>8</td>
<td>(n)</td>
<td>Data bytes, where (n) is the size given in the preceding field</td>
</tr>
<tr>
<td>8 + (n)</td>
<td>0 or 1</td>
<td>Pad byte needed if (n) is odd and chunk alignment is used</td>
</tr>
</tbody>
</table>

The ID is a 4-byte string which identifies the type of chunk.

The size field (a 32-bit value, encoded using big-endian byte order) gives the size of the chunk data, not including the 8-byte header.

Usually an IFF-type file consists of one or more chunks. The proposed usage of the **Chunk** class defined here is to instantiate an instance at the start of each chunk and read from the instance until it reaches the end, after which a new instance can be instantiated. At the end of the file, creating a new instance will fail with an **EOFError** exception.
**class** chunk.

**Chunk(file, align=True, bigendian=True, inclheader=False)**

Class which represents a chunk. The *file* argument is expected to be a file-like object. An instance of this class is specifically allowed. The only method that is needed is `read()`. If the methods `seek()` and `tell()` are present and don’t raise an exception, they are also used. If these methods are present and raise an exception, they are expected to not have altered the object. If the optional argument *align* is true, chunks are assumed to be aligned on 2-byte boundaries. If *align* is false, no alignment is assumed. The default value is true. If the optional argument *bigendian* is false, the chunk size is assumed to be in little-endian order. This is needed for WAVE audio files. The default value is true. If the optional argument *inclheader* is true, the size given in the chunk header includes the size of the header. The default value is false.

A **Chunk** object supports the following methods:

**getname()**

Returns the name (ID) of the chunk. This is the first 4 bytes of the chunk.

**getsize()**

Returns the size of the chunk.

**close()**

Close and skip to the end of the chunk. This does not close the underlying file.

The remaining methods will raise **OSError** if called after the **close()** method has been called. Before Python 3.3, they used to raise **IOError**, now an alias of **OSError**.
**isatty()**

Returns False.

**seek(pos, whence=0)**

Set the chunk's current position. The *whence* argument is optional and defaults to 0 (absolute file positioning); other values are 1 (seek relative to the current position) and 2 (seek relative to the file's end). There is no return value. If the underlying file does not allow seek, only forward seeks are allowed.

**tell()**

Return the current position into the chunk.

**read(size=-1)**

Read at most size bytes from the chunk (less if the read hits the end of the chunk before obtaining size bytes). If the *size* argument is negative or omitted, read all data until the end of the chunk. An empty bytes object is returned when the end of the chunk is encountered immediately.

**skip()**

Skip to the end of the chunk. All further calls to *read()* for the chunk will return b' '. If you are not interested in the contents of the chunk, this method should be called so that the file points to the start of the next chunk.

**Footnotes**

22.6. `colorsys` — Conversions between color systems

**Source code:** Lib/colorsys.py

The `colorsys` module defines bidirectional conversions of color values between colors expressed in the RGB (Red Green Blue) color space used in computer monitors and three other coordinate systems: YIQ, HLS (Hue Lightness Saturation) and HSV (Hue Saturation Value). Coordinates in all of these color spaces are floating point values. In the YIQ space, the Y coordinate is between 0 and 1, but the I and Q coordinates can be positive or negative. In all other spaces, the coordinates are all between 0 and 1.

**See also:** More information about color spaces can be found at [http://www.poynton.com/ColorFAQ.html](http://www.poynton.com/ColorFAQ.html) and [http://www.cambridgeincolour.com/tutorials/color-spaces.htm](http://www.cambridgeincolour.com/tutorials/color-spaces.htm).

The `colorsys` module defines the following functions:

- `colorsys.rgb_to_yiq(r, g, b)`
  Convert the color from RGB coordinates to YIQ coordinates.

- `colorsys.yiq_to_rgb(y, i, q)`
  Convert the color from YIQ coordinates to RGB coordinates.

- `colorsys.rgb_to_hls(r, g, b)`
  Convert the color from RGB coordinates to HLS coordinates.

- `colorsys.hls_to_rgb(h, l, s)`
Convert the color from HLS coordinates to RGB coordinates.

```
colorsys.rgb_to_hsv(r, g, b)
```

Convert the color from RGB coordinates to HSV coordinates.

```
colorsys.hsv_to_rgb(h, s, v)
```

Convert the color from HSV coordinates to RGB coordinates.

Example:

```
>>> import colorsys
>>> colorsys.rgb_to_hsv(0.2, 0.4, 0.4)
(0.5, 0.5, 0.4)
>>> colorsys.hsv_to_rgb(0.5, 0.5, 0.4)
(0.2, 0.4, 0.4)
```
22.7. **imghdr** — Determine the type of an image

**Source code:** Lib/imghdr.py

The `imghdr` module determines the type of image contained in a file or byte stream.

The `imghdr` module defines the following function:

```
imghdr.what(filename, h=None)
```

Tests the image data contained in the file named by `filename`, and returns a string describing the image type. If optional `h` is provided, the `filename` is ignored and `h` is assumed to contain the byte stream to test.

The following image types are recognized, as listed below with the return value from `what()`:

<table>
<thead>
<tr>
<th>Value</th>
<th>Image format</th>
</tr>
</thead>
<tbody>
<tr>
<td>'rgb'</td>
<td>SGI ImgLib Files</td>
</tr>
<tr>
<td>'gif'</td>
<td>GIF 87a and 89a Files</td>
</tr>
<tr>
<td>'pnm'</td>
<td>Portable Bitmap Files</td>
</tr>
<tr>
<td>'pgm'</td>
<td>Portable Graymap Files</td>
</tr>
<tr>
<td>'ppm'</td>
<td>Portable Pixmap Files</td>
</tr>
<tr>
<td>'tiff'</td>
<td>TIFF Files</td>
</tr>
<tr>
<td>'rast'</td>
<td>SunRaster Files</td>
</tr>
<tr>
<td></td>
<td>Description</td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>'xbm'</td>
<td>X Bitmap Files</td>
</tr>
<tr>
<td>'jpeg'</td>
<td>JPEG data in JFIF or Exif formats</td>
</tr>
<tr>
<td>'bmp'</td>
<td>BMP files</td>
</tr>
<tr>
<td>'png'</td>
<td>Portable Network Graphics</td>
</tr>
<tr>
<td>'webp'</td>
<td>WebP files</td>
</tr>
<tr>
<td>'exr'</td>
<td>OpenEXR Files</td>
</tr>
</tbody>
</table>

New in version 3.5: The exr and webp formats were added.

You can extend the list of file types `imghdr` can recognize by appending to this variable:

`imghdr.tests`

A list of functions performing the individual tests. Each function takes two arguments: the byte-stream and an open file-like object. When `what()` is called with a byte-stream, the file-like object will be None.

The test function should return a string describing the image type if the test succeeded, or None if it failed.

Example:

```
>>> import imghdr
>>> imghdr.what('bass.gif')
'gif'
```
Last updated on Dec 06, 2015. Found a bug?
Created using Sphinx 1.3.1.
22.8. sndhdr — Determine type of sound file

Source code: Lib/sndhdr.py

The sndhdr provides utility functions which attempt to determine the type of sound data which is in a file. When these functions are able to determine what type of sound data is stored in a file, they return a namedtuple(), containing five attributes: (filetype, framerate, nchannels, nframes, sampwidth). The value for type indicates the data type and will be one of the strings 'aifc', 'aiff', 'au', 'hcom', 'sndr', 'sndt', 'voc', 'wav', '8svx', 'sb', 'ub', or 'ul'. The sampling rate will be either the actual value or 0 if unknown or difficult to decode. Similarly, channels will be either the number of channels or 0 if it cannot be determined or if the value is difficult to decode. The value for frames will be either the number of frames or -1. The last item in the tuple, bits_per_sample, will either be the sample size in bits or 'A' for A-LAW or 'U' for u-LAW.

sndhdr.what(filename)

Determines the type of sound data stored in the file filename using whathdr(). If it succeeds, returns a namedtuple as described above, otherwise None is returned.

Changed in version 3.5: Result changed from a tuple to a namedtuple.

sndhdr.whathdr(filename)

Determines the type of sound data stored in a file based on the file
header. The name of the file is given by *filename*. This function returns a namedtuple as described above on success, or None.

*Changed in version 3.5:* Result changed from a tuple to a namedtuple.
22.9. ossaudiodev — Access to OSS-compatible audio devices

This module allows you to access the OSS (Open Sound System) audio interface. OSS is available for a wide range of open-source and commercial Unices, and is the standard audio interface for Linux and recent versions of FreeBSD.

Changed in version 3.3: Operations in this module now raise OSError where IOError was raised.

See also:

Open Sound System Programmer's Guide
the official documentation for the OSS C API

The module defines a large number of constants supplied by the OSS device driver; see <sys/soundcard.h> on either Linux or FreeBSD for a listing.

ossaudiodev defines the following variables and functions:

exception ossaudiodev.OSSAudioError

This exception is raised on certain errors. The argument is a string describing what went wrong.

(If ossaudiodev receives an error from a system call such as open(), write(), or ioctl(), it raises OSError. Errors detected directly by ossaudiodev result in OSSAudioError.)

(For backwards compatibility, the exception class is also available
ossaudiodev.error.

**ossaudiodev.open**(mode)

**ossaudiodev.open**(device, mode)

Open an audio device and return an OSS audio device object. This object supports many file-like methods, such as read(), write(), and fileno() (although there are subtle differences between conventional Unix read/write semantics and those of OSS audio devices). It also supports a number of audio-specific methods; see below for the complete list of methods.

*device* is the audio device filename to use. If it is not specified, this module first looks in the environment variable AUDIODEV for a device to use. If not found, it falls back to /dev/dsp.

*mode* is one of 'r' for read-only (record) access, 'w' for write-only (playback) access and 'rw' for both. Since many sound cards only allow one process to have the recorder or player open at a time, it is a good idea to open the device only for the activity needed. Further, some sound cards are half-duplex: they can be opened for reading or writing, but not both at once.

Note the unusual calling syntax: the first argument is optional, and the second is required. This is a historical artifact for compatibility with the older linuxaudiodev module which ossaudiodev supersedes.

ossaudiodev.openmixer([device])

Open a mixer device and return an OSS mixer device object. *device* is the mixer device filename to use. If it is not specified, this module first looks in the environment variable MIXERDEV for a device to use. If not found, it falls back to /dev/mixer.
22.9.1. Audio Device Objects

Before you can write to or read from an audio device, you must call three methods in the correct order:

1. `setfmt()` to set the output format
2. `channels()` to set the number of channels
3. `speed()` to set the sample rate

Alternately, you can use the `setparameters()` method to set all three audio parameters at once. This is more convenient, but may not be as flexible in all cases.

The audio device objects returned by `open()` define the following methods and (read-only) attributes:

`oss_audio_device.close()`

Explicitly close the audio device. When you are done writing to or reading from an audio device, you should explicitly close it. A closed device cannot be used again.

`oss_audio_device.fileno()`

Return the file descriptor associated with the device.

`oss_audio_device.read(size)`

Read `size` bytes from the audio input and return them as a Python string. Unlike most Unix device drivers, OSS audio devices in blocking mode (the default) will block `read()` until the entire requested amount of data is available.

`oss_audio_device.write(data)`

Write a bytes-like object `data` to the audio device and return the
number of bytes written. If the audio device is in blocking mode (the default), the entire data is always written (again, this is different from usual Unix device semantics). If the device is in non-blocking mode, some data may not be written — see `writeall()`.

`oss_audio_device.writeall(data)`

Write a bytes-like object `data` to the audio device: waits until the audio device is able to accept data, writes as much data as it will accept, and repeats until `data` has been completely written. If the device is in blocking mode (the default), this has the same effect as `write()`; `writeall()` is only useful in non-blocking mode. Has no return value, since the amount of data written is always equal to the amount of data supplied.

*Changed in version 3.2:* Audio device objects also support the context management protocol, i.e. they can be used in a `with` statement.

The following methods each map to exactly one `ioctl()` system call. The correspondence is obvious: for example, `setfmt()` corresponds to the `SNDCTL_DSP_SETFMT` ioctl, and `sync()` to `SNDCTL_DSP_SYNC` (this can be useful when consulting the OSS documentation). If the underlying `ioctl()` fails, they all raise `OSError`.

`oss_audio_device.nonblock()`

Put the device into non-blocking mode. Once in non-blocking mode, there is no way to return it to blocking mode.

`oss_audio_device.getfmts()`

Return a bitmask of the audio output formats supported by the soundcard. Some of the formats supported by OSS are:
<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFMT_MU_LAW</td>
<td>a logarithmic encoding (used by Sun .au files and /dev/audio)</td>
</tr>
<tr>
<td>AFMT_A_LAW</td>
<td>a logarithmic encoding</td>
</tr>
<tr>
<td>AFMT.IMA.ADPCM</td>
<td>a 4:1 compressed format defined by the Interactive Multimedia Association</td>
</tr>
<tr>
<td>AFMT_U8</td>
<td>Unsigned, 8-bit audio</td>
</tr>
<tr>
<td>AFMT.S16.LE</td>
<td>Signed, 16-bit audio, little-endian byte order (as used by Intel processors)</td>
</tr>
<tr>
<td>AFMT.S16.BE</td>
<td>Signed, 16-bit audio, big-endian byte order (as used by 68k, PowerPC, Sparc)</td>
</tr>
<tr>
<td>AFMT_S8</td>
<td>Signed, 8 bit audio</td>
</tr>
<tr>
<td>AFMT.U16.LE</td>
<td>Unsigned, 16-bit little-endian audio</td>
</tr>
<tr>
<td>AFMT.U16.BE</td>
<td>Unsigned, 16-bit big-endian audio</td>
</tr>
</tbody>
</table>

Consult the OSS documentation for a full list of audio formats, and note that most devices support only a subset of these formats. Some older devices only support AFMT_U8; the most common format used today is AFMT_S16_LE.

**oss_audio_device.setfmt(format)**

Try to set the current audio format to *format*—see *getfmts()* for a list. Returns the audio format that the device was set to, which may not be the requested format. May also be used to return the current audio format—do this by passing an “audio format” of AFMT_QUERY.

**oss_audio_device.channels(nchannels)**

Set the number of output channels to *nchannels*. A value of 1 indicates monophonic sound, 2 stereophonic. Some devices may
have more than 2 channels, and some high-end devices may not support mono. Returns the number of channels the device was set to.

**oss_audio_device.speed(samplerate)**

Try to set the audio sampling rate to *samplerate* samples per second. Returns the rate actually set. Most sound devices don’t support arbitrary sampling rates. Common rates are:

<table>
<thead>
<tr>
<th>Rate</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8000</td>
<td>default rate for /dev/audio</td>
</tr>
<tr>
<td>11025</td>
<td>speech recording</td>
</tr>
<tr>
<td>22050</td>
<td></td>
</tr>
<tr>
<td>44100</td>
<td>CD quality audio (at 16 bits/sample and 2 channels)</td>
</tr>
<tr>
<td>96000</td>
<td>DVD quality audio (at 24 bits/sample)</td>
</tr>
</tbody>
</table>

**oss_audio_device.sync()**

Wait until the sound device has played every byte in its buffer. (This happens implicitly when the device is closed.) The OSS documentation recommends closing and re-opening the device rather than using `sync()`.

**oss_audio_device.reset()**

Immediately stop playing or recording and return the device to a state where it can accept commands. The OSS documentation recommends closing and re-opening the device after calling `reset()`.

**oss_audio_device.post()**

Tell the driver that there is likely to be a pause in the output,
making it possible for the device to handle the pause more intelligently. You might use this after playing a spot sound effect, before waiting for user input, or before doing disk I/O.

The following convenience methods combine several ioctl's, or one ioctl and some simple calculations.

oss_audio_device.setparameters(format, nchannels, samplerate[, strict=False])
Set the key audio sampling parameters—sample format, number of channels, and sampling rate—in one method call. format, nchannels, and samplerate should be as specified in the setfmt(), channels(), and speed() methods. If strict is true, setparameters() checks to see if each parameter was actually set to the requested value, and raises OSSAudioError if not. Returns a tuple (format, nchannels, samplerate) indicating the parameter values that were actually set by the device driver (i.e., the same as the return values of setfmt(), channels(), and speed()).

For example,

```
(fmt, channels, rate) = dsp.setparameters(fmt, channels, samplerate)
```

is equivalent to

```
fmt = dsp.setfmt(fmt)
channels = dsp.channels(channels)
rate = dsp.rate(rate)
```

oss_audio_device.bufsize()
Returns the size of the hardware buffer, in samples.
oss_audio_device.\textbf{obufcount}()
   Returns the number of samples that are in the hardware buffer yet to be played.

oss_audio_device.\textbf{obuffree}()
   Returns the number of samples that could be queued into the hardware buffer to be played without blocking.

Audio device objects also support several read-only attributes:

oss_audio_device.\textbf{closed}
   Boolean indicating whether the device has been closed.

oss_audio_device.\textbf{name}
   String containing the name of the device file.

oss_audio_device.\textbf{mode}
   The I/O mode for the file, either "r", "rw", or "w".
22.9.2. Mixer Device Objects

The mixer object provides two file-like methods:

oss_mixer_device.close()

This method closes the open mixer device file. Any further attempts to use the mixer after this file is closed will raise an OSError.

oss_mixer_device.fileno()

Returns the file handle number of the open mixer device file.

Changed in version 3.2: Mixer objects also support the context management protocol.

The remaining methods are specific to audio mixing:

oss_mixer_device.controls()

This method returns a bitmask specifying the available mixer controls ("Control" being a specific mixable "channel", such as SOUND_MIXER_PCM or SOUND_MIXER_SYNTH). This bitmask indicates a subset of all available mixer controls—the SOUND_MIXER_* constants defined at module level. To determine if, for example, the current mixer object supports a PCM mixer, use the following Python code:

```python
mixer=ossaudiodev.openmixer()
if mixer.controls() & (1 << ossaudiodev.SOUND_MIX
    # PCM is supported
    ... code ...
```

For most purposes, the SOUND_MIXER_VOLUME (master volume) and SOUND_MIXER_PCM controls should suffice—but code that
uses the mixer should be flexible when it comes to choosing mixer controls. On the Gravis Ultrasound, for example, SOUND_MIXER_VOLUME does not exist.

oss_mixer_device.stereocontrols()
Returns a bitmask indicating stereo mixer controls. If a bit is set, the corresponding control is stereo; if it is unset, the control is either monophonic or not supported by the mixer (use in combination with controls() to determine which).

See the code example for the controls() function for an example of getting data from a bitmask.

oss_mixer_device.reccontrols()
Returns a bitmask specifying the mixer controls that may be used to record. See the code example for controls() for an example of reading from a bitmask.

oss_mixer_device.get(control)
Returns the volume of a given mixer control. The returned volume is a 2-tuple (left_volume, right_volume). Volumes are specified as numbers from 0 (silent) to 100 (full volume). If the control is monophonic, a 2-tuple is still returned, but both volumes are the same.

Raises OSSAudioError if an invalid control is specified, or OSError if an unsupported control is specified.

oss_mixer_device.set(control, (left, right))
Sets the volume for a given mixer control to (left, right). left and right must be ints and between 0 (silent) and 100 (full volume). On success, the new volume is returned as a 2-tuple.
Note that this may not be exactly the same as the volume specified, because of the limited resolution of some soundcard's mixers.

Raises **OSSAudioError** if an invalid mixer control was specified, or if the specified volumes were out-of-range.

**oss_mixer_device.get_recsrc()**

This method returns a bitmask indicating which control(s) are currently being used as a recording source.

**oss_mixer_device.set_recsrc(bitmask)**

Call this function to specify a recording source. Returns a bitmask indicating the new recording source (or sources) if successful; raises **OSError** if an invalid source was specified. To set the current recording source to the microphone input:

```python
mixer.setrecesrc (1 << ossaudiodev.SOUND_MIXER_MIC)
```
23. Internationalization

The modules described in this chapter help you write software that is independent of language and locale by providing mechanisms for selecting a language to be used in program messages or by tailoring output to match local conventions.

The list of modules described in this chapter is:

- **23.1. gettext — Multilingual internationalization services**
  - 23.1.1. GNU gettext API
  - 23.1.2. Class-based API
    - 23.1.2.1. The NullTranslations class
    - 23.1.2.2. The GNUTranslations class
    - 23.1.2.3. Solaris message catalog support
    - 23.1.2.4. The Catalog constructor
  - 23.1.3. Internationalizing your programs and modules
    - 23.1.3.1. Localizing your module
    - 23.1.3.2. Localizing your application
    - 23.1.3.3. Changing languages on the fly
    - 23.1.3.4. Deferred translations
  - 23.1.4. Acknowledgements

- **23.2. locale — Internationalization services**
  - 23.2.1. Background, details, hints, tips and caveats
  - 23.2.2. For extension writers and programs that embed Python
  - 23.2.3. Access to message catalogs
23.1. gettext — Multilingual internationalization services

Source code: Lib/gettext.py

The gettext module provides internationalization (I18N) and localization (L10N) services for your Python modules and applications. It supports both the GNU gettext message catalog API and a higher level, class-based API that may be more appropriate for Python files. The interface described below allows you to write your module and application messages in one natural language, and provide a catalog of translated messages for running under different natural languages.

Some hints on localizing your Python modules and applications are also given.
23.1.1. GNU gettext API

The gettext module defines the following API, which is very similar to the GNU gettext API. If you use this API you will affect the translation of your entire application globally. Often this is what you want if your application is monolingual, with the choice of language dependent on the locale of your user. If you are localizing a Python module, or if your application needs to switch languages on the fly, you probably want to use the class-based API instead.

`gettext.bindtextdomain(domain, localedir=None)`

Bind the `domain` to the locale directory `localedir`. More concretely, `gettext` will look for binary `.mo` files for the given domain using the path (on Unix):
```
localedir/language/LC_MESSAGES/domain.mo
```
where `languages` is searched for in the environment variables `LANGUAGE`, `LC_ALL`, `LC_MESSAGES`, and `LANG` respectively.

If `localedir` is omitted or `None`, then the current binding for `domain` is returned. [1]

`gettext.bind_textdomain_codeset(domain, codeset=None)`

Bind the `domain` to `codeset`, changing the encoding of strings returned by the `gettext()` family of functions. If `codeset` is omitted, then the current binding is returned.

`gettext.textdomain(domain=None)`

Change or query the current global domain. If `domain` is `None`, then the current global domain is returned, otherwise the global domain is set to `domain`, which is returned.
**gettext.gettext(message)**

Return the localized translation of `message`, based on the current global domain, language, and locale directory. This function is usually aliased as `_()` in the local namespace (see examples below).

**gettext.lgettext(message)**

Equivalent to `gettext()`, but the translation is returned in the preferred system encoding, if no other encoding was explicitly set with `bind_textdomain_codeset()`.

**gettext.dgettext(domain, message)**

Like `gettext()`, but look the message up in the specified `domain`.

**gettext.ldgettext(domain, message)**

Equivalent to `dgettext()`, but the translation is returned in the preferred system encoding, if no other encoding was explicitly set with `bind_textdomain_codeset()`.

**gettext.ngettext(singular, plural, n)**

Like `gettext()`, but consider plural forms. If a translation is found, apply the plural formula to `n`, and return the resulting message (some languages have more than two plural forms). If no translation is found, return `singular` if `n` is 1; return `plural` otherwise.

The Plural formula is taken from the catalog header. It is a C or Python expression that has a free variable `n`; the expression evaluates to the index of the plural in the catalog. See the [GNU gettext documentation](https://www.gnu.org/software/gettext/manual/html_node/) for the precise syntax to be used in `.po` files and the formulas for a variety of languages.

**gettext.lngettext(singular, plural, n)**
Equivalent to `ngettext()`, but the translation is returned in the preferred system encoding, if no other encoding was explicitly set with `bind_textdomain_codeset()`.

```python
import gettext
gettext.bindtextdomain('myapplication', '/path/to/my
gettext.textdomain('myapplication')
_ = gettextgettext
# ...
print(_('This is a translatable string.'))
```

`gettext.dngettext(domain, singular, plural, n)`

Like `ngettext()`, but look the message up in the specified `domain`.

`gettext.ldngettext(domain, singular, plural, n)`

Equivalent to `dngettext()`, but the translation is returned in the preferred system encoding, if no other encoding was explicitly set with `bind_textdomain_codeset()`.

Note that GNU `gettext` also defines a `dcgettext()` method, but this was deemed not useful and so it is currently unimplemented.

Here's an example of typical usage for this API:
23.1.2. Class-based API

The class-based API of the gettext module gives you more flexibility and greater convenience than the GNU gettext API. It is the recommended way of localizing your Python applications and modules. gettext defines a “translations” class which implements the parsing of GNU .mo format files, and has methods for returning strings. Instances of this “translations” class can also install themselves in the built-in namespace as the function _().

`gettext.find(domain, localedir=None, languages=None, all=False)`

This function implements the standard .mo file search algorithm. It takes a domain, identical to what textdomain() takes. Optional localedir is as in bindtextdomain() Optional languages is a list of strings, where each string is a language code.

If localedir is not given, then the default system locale directory is used. [2] If languages is not given, then the following environment variables are searched: LANGUAGE, LC_ALL, LC_MESSAGES, and LANG. The first one returning a non-empty value is used for the languages variable. The environment variables should contain a colon separated list of languages, which will be split on the colon to produce the expected list of language code strings.

find() then expands and normalizes the languages, and then iterates through them, searching for an existing file built of these components:

`localedir/language/LC_MESSAGES/domain.mo`
The first such file name that exists is returned by `find()`. If no such file is found, then `None` is returned. If `all` is given, it returns a list of all file names, in the order in which they appear in the languages list or the environment variables.

```python
gettext.translation(domain, localedir=None, languages=None, class_=None, fallback=False, codeset=None)
```

Return a `Translations` instance based on the `domain`, `localedir`, and `languages`, which are first passed to `find()` to get a list of the associated `.mo` file paths. Instances with identical `.mo` file names are cached. The actual class instantiated is either `class_` if provided, otherwise `GNUTranslations`. The class's constructor must take a single `file object` argument. If provided, `codeset` will change the charset used to encode translated strings in the `gettext()` and `lngettext()` methods.

If multiple files are found, later files are used as fallbacks for earlier ones. To allow setting the fallback, `copy.copy()` is used to clone each translation object from the cache; the actual instance data is still shared with the cache.

If no `.mo` file is found, this function raises `OSError` if `fallback` is false (which is the default), and returns a `NullTranslations` instance if `fallback` is true.

*Changed in version 3.3:* `IOError` used to be raised instead of `OSError`.

```python
gettext.install(domain, localedir=None, codeset=None, names=None)
```

This installs the function `_( )` in Python's builtins namespace, based on `domain`, `localedir`, and `codeset` which are passed to the
function translation().

For the names parameter, please see the description of the translation object's install() method.

As seen below, you usually mark the strings in your application that are candidates for translation, by wrapping them in a call to the _() function, like this:

```
print(_('This string will be translated.'))
```

For convenience, you want the _() function to be installed in Python's builtins namespace, so it is easily accessible in all modules of your application.

23.1.2.1. The NullTranslations class

Translation classes are what actually implement the translation of original source file message strings to translated message strings. The base class used by all translation classes is NullTranslations; this provides the basic interface you can use to write your own specialized translation classes. Here are the methods of NullTranslations:

class gettext.NullTranslations(fp=None)

Takes an optional file object fp, which is ignored by the base class. Initializes “protected” instance variables _info and _charset which are set by derived classes, as well as _fallback, which is set through add_fallback(). It then calls self._parse(fp) if fp is not None.

_parse(fp)

No-op’d in the base class, this method takes file object fp, and
reads the data from the file, initializing its message catalog. If you have an unsupported message catalog file format, you should override this method to parse your format.

**add_fallback(fallback)**

Add *fallback* as the fallback object for the current translation object. A translation object should consult the fallback if it cannot provide a translation for a given message.

**gettext(message)**

If a fallback has been set, forward `gettext()` to the fallback. Otherwise, return the translated message. Overridden in derived classes.

**lgettext(message)**

If a fallback has been set, forward `lgettext()` to the fallback. Otherwise, return the translated message. Overridden in derived classes.

**ngettext(singular, plural, n)**

If a fallback has been set, forward `ngettext()` to the fallback. Otherwise, return the translated message. Overridden in derived classes.

**lngettext(singular, plural, n)**

If a fallback has been set, forward `lngettext()` to the fallback. Otherwise, return the translated message. Overridden in derived classes.

**info()**

Return the “protected” `_info` variable.
charset()
Return the “protected” _charset variable, which is the encoding of the message catalog file.

output_charset()
Return the “protected” _output_charset variable, which defines the encoding used to return translated messages in lgettext() and lngettext().

set_output_charset(charset)
Change the “protected” _output_charset variable, which defines the encoding used to return translated messages.

install(names=None)
This method installs self.gettext() into the built-in namespace, binding it to _.

If the names parameter is given, it must be a sequence containing the names of functions you want to install in the builtin namespace in addition to _. Supported names are 'gettext' (bound to self.gettext()), 'ngettext' (bound to self.ngettext()), 'lgettext' and 'lngettext'.

Note that this is only one way, albeit the most convenient way, to make the _() function available to your application. Because it affects the entire application globally, and specifically the built-in namespace, localized modules should never install _. Instead, they should use this code to make _() available to their module:

```python
import gettext
```
This puts `_()` only in the module's global namespace and so only affects calls within this module.

### 23.1.2.2. The GNUTranslations class

The `gettext` module provides one additional class derived from `NullTranslations`: `GNUTranslations`. This class overrides `_parse()` to enable reading GNU `gettext` format `.mo` files in both big-endian and little-endian format.

`GNUTranslations` parses optional meta-data out of the translation catalog. It is convention with GNU `gettext` to include meta-data as the translation for the empty string. This meta-data is in RFC 822-style key: value pairs, and should contain the `Project-Id-Version` key. If the key `Content-Type` is found, then the charset property is used to initialize the “protected” `_charset` instance variable, defaulting to `None` if not found. If the charset encoding is specified, then all message ids and message strings read from the catalog are converted to Unicode using this encoding, else ASCII encoding is assumed.

Since message ids are read as Unicode strings too, all `*gettext()` methods will assume message ids as Unicode strings, not byte strings.

The entire set of key/value pairs are placed into a dictionary and set as the “protected” `_info` instance variable.

If the `.mo` file's magic number is invalid, the major version number is unexpected, or if other problems occur while reading the file,
instantiating a GNUTranslations class can raise OSError.

The following methods are overridden from the base class implementation:

**GNUTranslations.gettext**(message)

Look up the *message* id in the catalog and return the corresponding message string, as a Unicode string. If there is no entry in the catalog for the *message* id, and a fallback has been set, the look up is forwarded to the fallback's gettext() method. Otherwise, the *message* id is returned.

**GNUTranslations.lgettext**(message)

Equivalent to gettext(), but the translation is returned as a bytestring encoded in the selected output charset, or in the preferred system encoding if no encoding was explicitly set with set_output_charset().

**GNUTranslations.ngettext**(singular, plural, n)

Do a plural-forms lookup of a message id. *singular* is used as the message id for purposes of lookup in the catalog, while *n* is used to determine which plural form to use. The returned message string is a Unicode string.

If the message id is not found in the catalog, and a fallback is specified, the request is forwarded to the fallback’s ngettext() method. Otherwise, when *n* is 1 *singular* is returned, and *plural* is returned in all other cases.

Here is an example:

```python
n = len(os.listdir('.'))
cat = GNUTranslations(somefile)
```
message = cat.ngettext(
'There is %(num)d file in this directory',
'There are %(num)d files in this directory',
n) % {'num': n}

GNUTranslations.\texttt{lngettext}(\textit{singular}, \textit{plural}, \textit{n})
Equivalent to \texttt{gettext()}, but the translation is returned as a bytestring encoded in the selected output charset, or in the preferred system encoding if no encoding was explicitly set with set_output_charset().

23.1.2.3. Solaris message catalog support

The Solaris operating system defines its own binary .mo file format, but since no documentation can be found on this format, it is not supported at this time.

23.1.2.4. The Catalog constructor

GNOME uses a version of the \texttt{gettext} module by James Henstridge, but this version has a slightly different API. Its documented usage was:

\begin{verbatim}
import gettext
cat = gettext.Catalog(domain, localedir)
_ = cat.gettext
print(_('hello world'))
\end{verbatim}

For compatibility with this older module, the function Catalog() is an alias for the translation() function described above.

One difference between this module and Henstridge’s: his catalog objects supported access through a mapping API, but this appears to
be unused and so is not currently supported.
23.1.3. Internationalizing your programs and modules

Internationalization (I18N) refers to the operation by which a program is made aware of multiple languages. Localization (L10N) refers to the adaptation of your program, once internationalized, to the local language and cultural habits. In order to provide multilingual messages for your Python programs, you need to take the following steps:

1. prepare your program or module by specially marking translatable strings
2. run a suite of tools over your marked files to generate raw messages catalogs
3. create language specific translations of the message catalogs
4. use the gettext module so that message strings are properly translated

In order to prepare your code for I18N, you need to look at all the strings in your files. Any string that needs to be translated should be marked by wrapping it in `_('...')` — that is, a call to the function `_()`. For example:

```python
filename = 'mylog.txt'
message = _('writing a log message')
fp = open(filename, 'w')
fp.write(message)
fp.close()
```

In this example, the string 'writing a log message' is marked as a candidate for translation, while the strings 'mylog.txt' and 'w' are not.
There are a few tools to extract the strings meant for translation. The original GNU gettext only supported C or C++ source code but its extended version xgettext scans code written in a number of languages, including Python, to find strings marked as translatable. Babel is a Python internationalization library that includes a pybabel script to extract and compile message catalogs. François Pinard's program called xpot does a similar job and is available as part of his po-utils package.

(Python also includes pure-Python versions of these programs, called pygettext.py and msgfmt.py; some Python distributions will install them for you. pygettext.py is similar to xgettext, but only understands Python source code and cannot handle other programming languages such as C or C++. pygettext.py supports a command-line interface similar to xgettext; for details on its use, run pygettext.py --help. msgfmt.py is binary compatible with GNU msgfmt. With these two programs, you may not need the GNU gettext package to internationalize your Python applications.)

xgettext, pygettext, and similar tools generate .po files that are message catalogs. They are structured human-readable files that contain every marked string in the source code, along with a placeholder for the translated versions of these strings.

Copies of these .po files are then handed over to the individual human translators who write translations for every supported natural language. They send back the completed language-specific versions as a <language-name>.po file that's compiled into a machine-readable .mo binary catalog file using the msgfmt program. The .mo files are used by the gettext module for the actual translation processing at run-time.
How you use the gettext module in your code depends on whether you are internationalizing a single module or your entire application. The next two sections will discuss each case.

### 23.1.3.1. Localizing your module

If you are localizing your module, you must take care not to make global changes, e.g. to the built-in namespace. You should not use the GNU gettext API but instead the class-based API.

Let's say your module is called “spam” and the module's various natural language translation .mo files reside in /usr/share/locale in GNU gettext format. Here's what you would put at the top of your module:

```python
import gettext
t = gettext.translation('spam', '/usr/share/locale')
_ = t.lgettext
```

### 23.1.3.2. Localizing your application

If you are localizing your application, you can install the _( ) function globally into the built-in namespace, usually in the main driver file of your application. This will let all your application-specific files just use _( '...' ) without having to explicitly install it in each file.

In the simple case then, you need only add the following bit of code to the main driver file of your application:

```python
import gettext
ggettext.install('myapplication')
```
If you need to set the locale directory, you can pass it into the `install()` function:

```python
import gettext
gettext.install('myapplication', '/usr/share/locale')
```

### 23.1.3.3. Changing languages on the fly

If your program needs to support many languages at the same time, you may want to create multiple translation instances and then switch between them explicitly, like so:

```python
import gettext

lang1 = gettext.translation('myapplication', language='en')
lang2 = gettext.translation('myapplication', language='fr')
lang3 = gettext.translation('myapplication', language='es')

# start by using language1
lang1.install()

# ... time goes by, user selects language 2
lang2.install()

# ... more time goes by, user selects language 3
lang3.install()
```

### 23.1.3.4. Deferred translations

In most coding situations, strings are translated where they are coded. Occasionally however, you need to mark strings for translation, but defer actual translation until later. A classic example is:
animals = ['mollusk',
            'albatross',
            'rat',
            'penguin',
            'python',
          ]

# ...
for a in animals:
    print(a)

Here, you want to mark the strings in the animals list as being translatable, but you don’t actually want to translate them until they are printed.

Here is one way you can handle this situation:

def _(message):  return message

animals = [_( exceed'),
            _( 'albatross'),
            _( 'rat'),
            _( 'penguin'),
            _( 'python'),
          ]

del _

# ...
for a in animals:
    print(_(a))

This works because the dummy definition of _() simply returns the string unchanged. And this dummy definition will temporarily override any definition of _() in the built-in namespace (until the del command). Take care, though if you have a previous definition of _() in the local namespace.
Note that the second use of \_() will not identify “a” as being translatable to the \gettext program, because the parameter is not a string literal.

Another way to handle this is with the following example:

```python
def N_(message): return message

animals = [N_('mollusk'),
           N_('albatross'),
           N_('rat'),
           N_('penguin'),
           N_('python'),  ]

# ...
for a in animals:
    print(_(a))
```

In this case, you are marking translatable strings with the function \N_(), which won’t conflict with any definition of \_(). However, you will need to teach your message extraction program to look for translatable strings marked with \N_(). \xgettext, \pygettext, pybabel extract, and \xpot all support this through the use of the -k command-line switch. The choice of \N_() here is totally arbitrary; it could just as easily have been MarkThisStringForTranslation().
23.1.4. Acknowledgements

The following people contributed code, feedback, design suggestions, previous implementations, and valuable experience to the creation of this module:

- Peter Funk
- James Henstridge
- Juan David Ibáñez Palomar
- Marc-André Lemburg
- Martin von Löwis
- François Pinard
- Barry Warsaw
- Gustavo Niemeyer

Footnotes

The default locale directory is system dependent; for example, on RedHat Linux it is /usr/share/locale, but on Solaris it is /usr/lib/locale. The gettext module does not try to support these system dependent defaults; instead its default is sys.prefix/share/locale. For this reason, it is always best to call bindtextdomain() with an explicit absolute path at the start of your application.

[1] The default locale directory is system dependent; for example, on RedHat Linux it is /usr/share/locale, but on Solaris it is /usr/lib/locale. The gettext module does not try to support these system dependent defaults; instead its default is sys.prefix/share/locale. For this reason, it is always best to call bindtextdomain() with an explicit absolute path at the start of your application.

[2] See the footnote for bindtextdomain() above.
23.2. locale — Internationalization services

The `locale` module opens access to the POSIX locale database and functionality. The POSIX locale mechanism allows programmers to deal with certain cultural issues in an application, without requiring the programmer to know all the specifics of each country where the software is executed.

The `locale` module is implemented on top of the `_locale` module, which in turn uses an ANSI C locale implementation if available.

The `locale` module defines the following exception and functions:

`exception locale.Error`
Exception raised when the locale passed to `setlocale()` is not recognized.

`locale.setlocale(category, locale=None)`
If `locale` is given and not None, `setlocale()` modifies the locale setting for the `category`. The available categories are listed in the data description below. `locale` may be a string, or an iterable of two strings (language code and encoding). If it's an iterable, it's converted to a locale name using the locale aliasing engine. An empty string specifies the user’s default settings. If the modification of the locale fails, the exception `Error` is raised. If successful, the new locale setting is returned.

If `locale` is omitted or None, the current setting for `category` is returned.
**setlocale()** is not thread-safe on most systems. Applications typically start with a call of

```python
import locale
locale.setlocale(locale.LC_ALL, '')
```

This sets the locale for all categories to the user’s default setting (typically specified in the LANG environment variable). If the locale is not changed thereafter, using multithreading should not cause problems.

**locale.localeconv()**

Returns the database of the local conventions as a dictionary. This dictionary has the following strings as keys:

<table>
<thead>
<tr>
<th>Category</th>
<th>Key</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LC_NUMERIC</strong></td>
<td>'decimal_point'</td>
<td>Decimal point character.</td>
</tr>
<tr>
<td></td>
<td>'grouping'</td>
<td>Sequence of numbers specifying which relative positions the 'thousands_sep' is expected. If the sequence terminates with a character, the last group size is repeatedly used.</td>
</tr>
<tr>
<td></td>
<td>'thousands_sep'</td>
<td>Character used further grouping is performed.</td>
</tr>
</tbody>
</table>

```
<table>
<thead>
<tr>
<th><strong>LC_MONETARY</strong></th>
<th>'int_curr_symbol'</th>
<th>International currency symbol.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>'currency_symbol'</td>
<td>Local currency symbol.</td>
</tr>
<tr>
<td></td>
<td>'p_cs_precedes/n_cs_precedes'</td>
<td>Whether currency symbol precedes the value (for positive resp. negative values).</td>
</tr>
<tr>
<td></td>
<td>'p_sep_by_space/n_sep_by_space'</td>
<td>Whether currency symbol is separated from the value (for positive resp. negative values).</td>
</tr>
<tr>
<td></td>
<td>'mon_decimal_point'</td>
<td>Decimal point used for monetary values.</td>
</tr>
<tr>
<td></td>
<td>'frac_digits'</td>
<td>Number of fractional digits used in local formatting of monetary values.</td>
</tr>
<tr>
<td></td>
<td>'int_frac_digits'</td>
<td>Number of fractional digits used in international formatting of monetary values.</td>
</tr>
<tr>
<td></td>
<td>'mon_thousands_sep'</td>
<td>Group separator used for monetary values.</td>
</tr>
<tr>
<td></td>
<td>'mon_grouping'</td>
<td>Equivalent to 'grouping' for monetary values.</td>
</tr>
</tbody>
</table>
The `positive_sign` symbol is used to annotate a positive monetary value.

The `negative_sign` symbol is used to annotate a negative monetary value.

The `p_sign_posn/n_sign_posn` value specifies the position of the sign (for positive resp. negative values), see below.

All numeric values can be set to `CHAR_MAX` to indicate that there is no value specified in this locale.

The possible values for 'p_sign_posn' and 'n_sign_posn' are given below.

<table>
<thead>
<tr>
<th>Value</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Currency and value are surrounded by parentheses.</td>
</tr>
<tr>
<td>1</td>
<td>The sign should precede the value and currency symbol.</td>
</tr>
<tr>
<td>2</td>
<td>The sign should follow the value and currency symbol.</td>
</tr>
<tr>
<td>3</td>
<td>The sign should immediately precede the value.</td>
</tr>
<tr>
<td>4</td>
<td>The sign should immediately follow the value.</td>
</tr>
<tr>
<td><code>CHAR_MAX</code></td>
<td>Nothing is specified in this locale.</td>
</tr>
</tbody>
</table>

`locale.nl_langinfo(option)`

Return some locale-specific information as a string. This function is not available on all systems, and the set of possible options might
also vary across platforms. The possible argument values are
numbers, for which symbolic constants are available in the locale
module.

The `nl_langinfo()` function accepts one of the following keys. Most
descriptions are taken from the corresponding description in
the GNU C library.

**locale.CODSET**
Get a string with the name of the character encoding used in
the selected locale.

**locale.D_T_FMT**
Get a string that can be used as a format string for
`time.strftime()` to represent date and time in a locale-
specific way.

**locale.D_FMT**
Get a string that can be used as a format string for
`time.strftime()` to represent a date in a locale-specific
way.

**locale.T_FMT**
Get a string that can be used as a format string for
`time.strftime()` to represent a time in a locale-specific
way.

**locale.T_FMT_AMPM**
Get a format string for `time.strftime()` to represent time in
the am/pm format.

**DAY_1 ... DAY_7**
Get the name of the n-th day of the week.
Note: This follows the US convention of DAY_1 being Sunday, not the international convention (ISO 8601) that Monday is the first day of the week.

**ABDAY_1 . . . ABDAY_7**
Get the abbreviated name of the n-th day of the week.

**MON_1 . . . MON_12**
Get the name of the n-th month.

**ABMON_1 . . . ABMON_12**
Get the abbreviated name of the n-th month.

**locale.RADIXCHAR**
Get the radix character (decimal dot, decimal comma, etc.).

**locale.THOUSEP**
Get the separator character for thousands (groups of three digits).

**locale.YESEXPR**
Get a regular expression that can be used with the regex function to recognize a positive response to a yes/no question.

Note: The expression is in the syntax suitable for the `regex()` function from the C library, which might differ from the syntax used in `re`.

**locale.NOEXPR**
Get a regular expression that can be used with the `regex(3)` function to recognize a negative response to a yes/no question.

**locale.CRNCYSTR**
Get the currency symbol, preceded by “-” if the symbol should appear before the value, “+” if the symbol should appear after the value, or “.” if the symbol should replace the radix character.

`locale.ERA`

Get a string that represents the era used in the current locale.

Most locales do not define this value. An example of a locale which does define this value is the Japanese one. In Japan, the traditional representation of dates includes the name of the era corresponding to the then-emperor’s reign.

Normally it should not be necessary to use this value directly. Specifying the E modifier in their format strings causes the `time.strftime()` function to use this information. The format of the returned string is not specified, and therefore you should not assume knowledge of it on different systems.

`locale.ERA_D_T_FMT`

Get a format string for `time.strftime()` to represent date and time in a locale-specific era-based way.

`locale.ERA_D_FMT`

Get a format string for `time.strftime()` to represent a date in a locale-specific era-based way.

`locale.ERA_T_FMT`

Get a format string for `time.strftime()` to represent a time in a locale-specific era-based way.

`locale.ALT_DIGITS`

Get a representation of up to 100 values used to represent the values 0 to 99.
locale.getdefaultlocale([envvars])

Tries to determine the default locale settings and returns them as a tuple of the form (language code, encoding).

According to POSIX, a program which has not called setlocale(LC_ALL, '') runs using the portable 'C' locale. Calling setlocale(LC_ALL, '') lets it use the default locale as defined by the LANG variable. Since we do not want to interfere with the current locale setting we thus emulate the behavior in the way described above.

To maintain compatibility with other platforms, not only the LANG variable is tested, but a list of variables given as envvars parameter. The first found to be defined will be used. envvars defaults to the search path used in GNU gettext; it must always contain the variable name 'LANG'. The GNU gettext search path contains 'LC_ALL', 'LC_CTYPE', 'LANG' and 'LANGUAGE', in that order.

Except for the code 'C', the language code corresponds to RFC 1766. language code and encoding may be None if their values cannot be determined.

locale.getlocale(category=LC_CTYPE)

Returns the current setting for the given locale category as sequence containing language code, encoding. category may be one of the LC_* values except LC_ALL. It defaults to LC_CTYPE.

Except for the code 'C', the language code corresponds to RFC 1766. language code and encoding may be None if their values cannot be determined.
locale.getpreferredencoding(do_setlocale=True)

Return the encoding used for text data, according to user preferences. User preferences are expressed differently on different systems, and might not be available programmatically on some systems, so this function only returns a guess.

On some systems, it is necessary to invoke setlocale() to obtain the user preferences, so this function is not thread-safe. If invoking setlocale is not necessary or desired, do_setlocale should be set to False.

locale.normalize(localename)

Returns a normalized locale code for the given locale name. The returned locale code is formatted for use with setlocale(). If normalization fails, the original name is returned unchanged.

If the given encoding is not known, the function defaults to the default encoding for the locale code just like setlocale().

locale.resetlocale(category=LC_ALL)

Sets the locale for category to the default setting.

The default setting is determined by calling getdefaultlocale(). category defaults to LC_ALL.

locale.strcoll(string1, string2)

Compares two strings according to the current LC_COLLATE setting. As any other compare function, returns a negative, or a positive value, or 0, depending on whether string1 collates before or after string2 or is equal to it.

locale.strxfrm(string)
Transforms a string to one that can be used in locale-aware comparisons. For example, `strxfrm(s1) < strxfrm(s2)` is equivalent to `strcoll(s1, s2) < 0`. This function can be used when the same string is compared repeatedly, e.g. when collating a sequence of strings.

`locale.format(format, val, grouping=False, monetary=False)`

Formats a number `val` according to the current `LC_NUMERIC` setting. The format follows the conventions of the `%` operator. For floating point values, the decimal point is modified if appropriate. If `grouping` is true, also takes the grouping into account.

If `monetary` is true, the conversion uses monetary thousands separator and grouping strings.

Please note that this function will only work for exactly one `%char` specifier. For whole format strings, use `format_string()`.

`locale.format_string(format, val, grouping=False)`

Processes formatting specifiers as in `format % val`, but takes the current locale settings into account.

`locale.currency(val, symbol=True, grouping=False, international=False)`

Formats a number `val` according to the current `LC_MONETARY` settings.

The returned string includes the currency symbol if `symbol` is true, which is the default. If `grouping` is true (which is not the default), grouping is done with the value. If `international` is true (which is not the default), the international currency symbol is used.

Note that this function will not work with the ‘C’ locale, so you have
to set a locale via `setlocale()` first.

`locale.str(float)`
Forms a floating point number using the same format as the built-in function `str(float)`, but takes the decimal point into account.

`locale.delocalize(string)`
Converts a string into a normalized number string, following the `LC_NUMERIC` settings.

*New in version 3.5.*

`locale.atof(string)`
Converts a string to a floating point number, following the `LC_NUMERIC` settings.

`locale.atoi(string)`
Converts a string to an integer, following the `LC_NUMERIC` conventions.

`locale.LC_CTYPE`
Locale category for the character type functions. Depending on the settings of this category, the functions of module `string` dealing with case change their behaviour.

`locale.LC_COLLATE`
Locale category for sorting strings. The functions `strcoll()` and `strxfrm()` of the `locale` module are affected.

`locale.LC_TIME`
Locale category for the formatting of time. The function `time.strftime()` follows these conventions.
locale.LC_MONETARY
Locate category for formatting of monetary values. The available options are available from the `localeconv()` function.

locale.LC_MESSAGES
Locale category for message display. Python currently does not support application specific locale-aware messages. Messages displayed by the operating system, like those returned by `os.strerror()` might be affected by this category.

locale.LC_NUMERIC
Locale category for formatting numbers. The functions `format()`, `atoi()`, `atof()` and `str()` of the `locale` module are affected by that category. All other numeric formatting operations are not affected.

locale.LC_ALL
Combination of all locale settings. If this flag is used when the locale is changed, setting the locale for all categories is attempted. If that fails for any category, no category is changed at all. When the locale is retrieved using this flag, a string indicating the setting for all categories is returned. This string can be later used to restore the settings.

locale.CHAR_MAX
This is a symbolic constant used for different values returned by `localeconv()`.

Example:

```python
>>> import locale
>>> loc = locale.getlocale() # get current locale
# use German locale; name might vary with platform
```
>>> locale.setlocale(locale.LC_ALL, 'de_DE')
>>> locale.strcoll('f\xe4n', 'foo')  # compare a string containing an umlaut
>>> locale.setlocale(locale.LC_ALL, '')  # use user's preferred locale
>>> locale.setlocale(locale.LC_ALL, 'C')  # use default (C) locale
>>> locale.setlocale(locale.LC_ALL, loc)  # restore saved locale
23.2.1. Background, details, hints, tips and caveats

The C standard defines the locale as a program-wide property that may be relatively expensive to change. On top of that, some implementation are broken in such a way that frequent locale changes may cause core dumps. This makes the locale somewhat painful to use correctly.

Initially, when a program is started, the locale is the C locale, no matter what the user’s preferred locale is. There is one exception: the LC_CTYPE category is changed at startup to set the current locale encoding to the user’s preferred locale encoding. The program must explicitly say that it wants the user’s preferred locale settings for other categories by calling setlocale(LC_ALL, '').

It is generally a bad idea to call setlocale() in some library routine, since as a side effect it affects the entire program. Saving and restoring it is almost as bad: it is expensive and affects other threads that happen to run before the settings have been restored.

If, when coding a module for general use, you need a locale independent version of an operation that is affected by the locale (such as certain formats used with time.strftime()), you will have to find a way to do it without using the standard library routine. Even better is convincing yourself that using locale settings is okay. Only as a last resort should you document that your module is not compatible with non-C locale settings.

The only way to perform numeric operations according to the locale is to use the special functions defined by this module: atof(), atoi(),
There is no way to perform case conversions and character classifications according to the locale. For (Unicode) text strings these are done according to the character value only, while for byte strings, the conversions and classifications are done according to the ASCII value of the byte, and bytes whose high bit is set (i.e., non-ASCII bytes) are never converted or considered part of a character class such as letter or whitespace.
23.2.2. For extension writers and programs that embed Python

Extension modules should never call `setlocale()`, except to find out what the current locale is. But since the return value can only be used portably to restore it, that is not very useful (except perhaps to find out whether or not the locale is C).

When Python code uses the `locale` module to change the locale, this also affects the embedding application. If the embedding application doesn’t want this to happen, it should remove the `_locale` extension module (which does all the work) from the table of built-in modules in the `config.c` file, and make sure that the `_locale` module is not accessible as a shared library.
23.2.3. Access to message catalogs

The locale module exposes the C library's gettext interface on systems that provide this interface. It consists of the functions gettext(), dgettext(), dcgettext(), textdomain(), bindtextdomain(), and bind_textdomain_codeset(). These are similar to the same functions in the gettext module, but use the C library's binary format for message catalogs, and the C library's search algorithms for locating message catalogs.

Python applications should normally find no need to invoke these functions, and should use gettext instead. A known exception to this rule are applications that link with additional C libraries which internally invoke gettext() or dcgettext(). For these applications, it may be necessary to bind the text domain, so that the libraries can properly locate their message catalogs.
24. Program Frameworks

The modules described in this chapter are frameworks that will largely dictate the structure of your program. Currently the modules described here are all oriented toward writing command-line interfaces.

The full list of modules described in this chapter is:

- **24.1. turtle — Turtle graphics**
  - 24.1.1. Introduction
  - 24.1.2. Overview of available Turtle and Screen methods
    - 24.1.2.1. Turtle methods
    - 24.1.2.2. Methods of TurtleScreen/Screen
  - 24.1.3. Methods of RawTurtle/Turtle and corresponding functions
    - 24.1.3.1. Turtle motion
    - 24.1.3.2. Tell Turtle's state
    - 24.1.3.3. Settings for measurement
    - 24.1.3.4. Pen control
      - 24.1.3.4.1. Drawing state
      - 24.1.3.4.2. Color control
      - 24.1.3.4.3. Filling
      - 24.1.3.4.4. More drawing control
    - 24.1.3.5. Turtle state
      - 24.1.3.5.1. Visibility
      - 24.1.3.5.2. Appearance
    - 24.1.3.6. Using events
    - 24.1.3.7. Special Turtle methods
    - 24.1.3.8. Compound shapes
  - 24.1.4. Methods of TurtleScreen/Screen and corresponding functions
    - 24.1.4.1. Window control
    - 24.1.4.2. Animation control
24.1.4.3. Using screen events
24.1.4.4. Input methods
24.1.4.5. Settings and special methods
24.1.4.6. Methods specific to Screen, not inherited from TurtleScreen
  24.1.5. Public classes
  24.1.6. Help and configuration
    24.1.6.1. How to use help
    24.1.6.2. Translation of docstrings into different languages
    24.1.6.3. How to configure Screen and Turtles
  24.1.7. turtle_demo — Demo scripts
  24.1.8. Changes since Python 2.6
  24.1.9. Changes since Python 3.0

- 24.2. cmd — Support for line-oriented command interpreters
  - 24.2.1. Cmd Objects
  - 24.2.2. Cmd Example

- 24.3. shlex — Simple lexical analysis
  - 24.3.1. shlex Objects
  - 24.3.2. Parsing Rules
24.1. *turtle* — Turtle graphics
24.1.1. Introduction

Turtle graphics is a popular way for introducing programming to kids. It was part of the original Logo programming language developed by Wally Feurzig and Seymour Papert in 1966.

Imagine a robotic turtle starting at (0, 0) in the x-y plane. After an `import turtle`, give it the command `turtle.forward(15)`, and it moves (on-screen!) 15 pixels in the direction it is facing, drawing a line as it moves. Give it the command `turtle.right(25)`, and it rotates in-place 25 degrees clockwise.

By combining together these and similar commands, intricate shapes and pictures can easily be drawn.

The `turtle` module is an extended reimplementation of the same-named module from the Python standard distribution up to version Python 2.5.

It tries to keep the merits of the old turtle module and to be (nearly) 100% compatible with it. This means in the first place to enable the learning programmer to use all the commands, classes and methods interactively when using the module from within IDLE run with the -n switch.

The turtle module provides turtle graphics primitives, in both object-
oriented and procedure-oriented ways. Because it uses tkinter for the underlying graphics, it needs a version of Python installed with Tk support.

The object-oriented interface uses essentially two+two classes:

1. The TurtleScreen class defines graphics windows as a playground for the drawing turtles. Its constructor needs a tkinter.Canvas or a ScrolledCanvas as argument. It should be used when turtle is used as part of some application.

   The function Screen() returns a singleton object of a TurtleScreen subclass. This function should be used when turtle is used as a standalone tool for doing graphics. As a singleton object, inheriting from its class is not possible.

   All methods of TurtleScreen/Screen also exist as functions, i.e. as part of the procedure-oriented interface.

2. RawTurtle (alias: RawPen) defines Turtle objects which draw on a TurtleScreen. Its constructor needs a Canvas, ScrolledCanvas or TurtleScreen as argument, so the RawTurtle objects know where to draw.

   Derived from RawTurtle is the subclass Turtle (alias: Pen), which draws on “the” Screen instance which is automatically created, if not already present.

   All methods of RawTurtle/Turtle also exist as functions, i.e. part of the procedure-oriented interface.
The procedural interface provides functions which are derived from the methods of the classes `Screen` and `Turtle`. They have the same names as the corresponding methods. A screen object is automatically created whenever a function derived from a Screen method is called. An (unnamed) turtle object is automatically created whenever any of the functions derived from a Turtle method is called.

To use multiple turtles on a screen one has to use the object-oriented interface.

**Note:** In the following documentation the argument list for functions is given. Methods, of course, have the additional first argument `self` which is omitted here.
24.1.2. Overview of available Turtle and Screen methods

24.1.2.1. Turtle methods

Turtle motion
  Move and draw

  \texttt{forward()} | \texttt{fd()}
  \texttt{backward()} | \texttt{bk() | back()}
  \texttt{right()} | \texttt{rt()}
  \texttt{left()} | \texttt{lt()}
  \texttt{goto()} | \texttt{setpos()} | \texttt{setposition()}
  \texttt{setx()}
  \texttt{sety()}
  \texttt{setheading()} | \texttt{seth()}
  \texttt{home()}
  \texttt{circle()}
  \texttt{dot()}
  \texttt{stamp()}
  \texttt{clearstamp()}
  \texttt{clearstamps()}
  \texttt{undo()}
  \texttt{speed()}

Tell Turtle's state

  \texttt{position()} | \texttt{pos()}
  \texttt{towards()}
  \texttt{xcor()}
  \texttt{ycor()}
  \texttt{heading()}
  \texttt{distance()}
Setting and measurement

\begin{verbatim}
  degrees()
  radians()
\end{verbatim}

Pen control

Drawing state

\begin{verbatim}
  pendown() | pd() | down()
  penup()  | pu()  | up()
  pensize() | width()
  pen()
  isdown()
\end{verbatim}

Color control

\begin{verbatim}
  color()
  pencolor()
  fillcolor()
\end{verbatim}

Filling

\begin{verbatim}
  filling()
  begin_fill()
  end_fill()
\end{verbatim}

More drawing control

\begin{verbatim}
  reset()
  clear()
  write()
\end{verbatim}

Turtle state

Visibility

\begin{verbatim}
  showturtle() | st()
\end{verbatim}
hideturtle() | ht() 
isvisible() 

Appearance 

shape() 
resizemode() 
shapesize() | turtlesize() 
shearfactor() 
settiltangle() 
tiltangle() 
tilt() 
shapetransform() 
get_shapepoly() 

Using events 

onclick() 
onrelease() 
ondrag() 

Special Turtle methods 

begin_poly() 
end_poly() 
get_poly() 
clone() 
getturtle() | getpen() 
getscreenshot() 
setundobuffer() 
undobufferentries() 

24.1.2.2. Methods of TurtleScreen/Screen 

Window control
bgcolor()
bgpic()
clear()|clearscreen()
reset()|resetscreen()
screensize()
setworldcoordinates()

Animation control

delay()
tracer()
update()

Using screen events

listen()
onkey()|onkeyrelease()
onkeypress()
onclick()|onscreenclick()
ontimer()
mainloop()|done()

Settings and special methods

mode()
colormode()
getcanvas()
getshapes()
register_shape()|addshape()
turtles()
window_height()
window_width()

Input methods

textinput()
numinput()

Methods specific to Screen

bye()
exitonclick()
setup()
title()
24.1.3. Methods of RawTurtle/Turtle and corresponding functions

Most of the examples in this section refer to a Turtle instance called turtle.

24.1.3.1. Turtle motion

turtle.\texttt{forward}(distance)
turtle.\texttt{fd}(distance)

<table>
<thead>
<tr>
<th>Parameters:</th>
<th>distance – a number (integer or float)</th>
</tr>
</thead>
</table>

Move the turtle forward by the specified distance, in the direction the turtle is headed.

```python
>>> turtle.position()
(0.00, 0.00)
>>> turtle.forward(25)
>>> turtle.position()
(25.00, 0.00)
>>> turtle.forward(-75)
>>> turtle.position()
(-50.00, 0.00)
```

turtle.\texttt{back}(distance)
turtle.\texttt{bk}(distance)
turtle.\texttt{backward}(distance)

<table>
<thead>
<tr>
<th>Parameters:</th>
<th>distance – a number</th>
</tr>
</thead>
</table>

Move the turtle backward by distance, opposite to the direction the turtle is headed. Do not change the turtle's heading.
```python
>>> turtle.position()
(0.00,0.00)
>>> turtle.backward(30)
>>> turtle.position()
(-30.00,0.00)
```

turtle.right\(\text{angle}\)
turtle.rt\(\text{angle}\)

**Parameters:**  
\textbf{angle} – a number (integer or float)

Turn turtle right by \textit{angle} units. (Units are by default degrees, but can be set via the \texttt{degrees()} and \texttt{radians()} functions.) Angle orientation depends on the turtle mode, see \texttt{mode()}.  

```python
>>> turtle.heading()
22.0
>>> turtle.right(45)
>>> turtle.heading()
337.0
```

turtle.left\(\text{angle}\)
turtle.lt\(\text{angle}\)

**Parameters:**  
\textbf{angle} – a number (integer or float)

Turn turtle left by \textit{angle} units. (Units are by default degrees, but can be set via the \texttt{degrees()} and \texttt{radians()} functions.) Angle orientation depends on the turtle mode, see \texttt{mode()}.  

```python
>>> turtle.heading()
22.0
>>> turtle.left(45)
>>> turtle.heading()
67.0
```
turtle.goto(x, y=None)
turtle.setpos(x, y=None)
turtle.setPosition(x, y=None)

Parameters:
- x – a number or a pair/vector of numbers
- y – a number or None

If y is None, x must be a pair of coordinates or a Vec2D (e.g. as returned by pos()).

Move turtle to an absolute position. If the pen is down, draw line. Do not change the turtle's orientation.

```python
>>> tp = turtle.pos()
>>> tp
(0.00, 0.00)
>>> turtle.setpos(60, 30)
>>> turtle.pos()
(60.00, 30.00)
>>> turtle.setpos((20, 80))
>>> turtle.pos()
(20.00, 80.00)
>>> turtle.setpos(tp)
>>> turtle.pos()
(0.00, 0.00)
```

turtle.setx(x)

Parameters:
- x – a number (integer or float)

Set the turtle's first coordinate to x, leave second coordinate unchanged.

```python
>>> turtle.position()
(0.00, 240.00)
>>> turtle.setx(10)
```
turtle.sety(y)

Parameters:  
- **y** – a number (integer or float)

Set the turtle’s second coordinate to \( y \), leave first coordinate unchanged.

```
>>> turtle.position()
(10.00,240.00)
>>> turtle.sety(10)
>>> turtle.position()
(0.00,340.00)
```

turtle.setheading(to_angle)
turtle.seth(to_angle)

Parameters:  
- **to_angle** – a number (integer or float)

Set the orientation of the turtle to \( to\_angle \). Here are some common directions in degrees:

<table>
<thead>
<tr>
<th>standard mode</th>
<th>logo mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - east</td>
<td>0 - north</td>
</tr>
<tr>
<td>90 - north</td>
<td>90 - east</td>
</tr>
<tr>
<td>180 - west</td>
<td>180 - south</td>
</tr>
<tr>
<td>270 - south</td>
<td>270 - west</td>
</tr>
</tbody>
</table>

```
>>> turtle.setheading(90)
>>> turtle.heading()
90.0
```
turtle.home()

Move turtle to the origin – coordinates (0, 0) – and set its heading to its start-orientation (which depends on the mode, see `mode()`).

```python
>>> turtle.heading()
90.0
>>> turtle.position()
(0.00, -10.00)
>>> turtle.home()
>>> turtle.position()
(0.00, 0.00)
>>> turtle.heading()
0.0
```

turtle.circle(radius, extent=None, steps=None)

Parameters:
- `radius` – a number
- `extent` – a number (or None)
- `steps` – an integer (or None)

Draw a circle with given `radius`. The center is `radius` units left of the turtle; `extent` – an angle – determines which part of the circle is drawn. If `extent` is not given, draw the entire circle. If `extent` is not a full circle, one endpoint of the arc is the current pen position. Draw the arc in counterclockwise direction if `radius` is positive, otherwise in clockwise direction. Finally the direction of the turtle is changed by the amount of `extent`.

As the circle is approximated by an inscribed regular polygon, `steps` determines the number of steps to use. If not given, it will be calculated automatically. May be used to draw regular polygons.

```python
>>> turtle.home()
>>> turtle.position()
```
turtle.**heading**()
0.0

turtle.**circle**(50)

turtle.**position**()
(-0.00,0.00)

turtle.**heading**()
0.0

turtle.**circle**(120, 180)  # draw a semicircle

turtle.**position**()
(0.00,240.00)

turtle.**heading**()
180.0

turtle.**dot**(*size=None, *color*)

**Parameters:**

- **size** – an integer $\geq 1$ (if given)
- **color** – a colorstring or a numeric color tuple

Draw a circular dot with diameter **size**, using **color**. If **size** is not given, the maximum of pensize+4 and 2*pensize* is used.

turtle.**home**()

turtle.**dot**()

turtle.**fd**(50); turtle.**dot**(20, "blue"); turtle

turtle.**position**()
(100.00,-0.00)

turtle.**heading**()
0.0

turtle.**stamp**()

Stamp a copy of the turtle shape onto the canvas at the current turtle position. Return a stamp_id for that stamp, which can be used to delete it by calling clearstamp(stamp_id).
turtle.color("blue")
turtle.stamp()
turtle.fd(50)

turtle.clearstamp(stampid)

Parameters:

- **stampid** – an integer, must be return value of previous `stamp()` call

Delete stamp with given `stampid`.

turtle.clearstamps(n=None)

Parameters:

- **n** – an integer (or None)

Delete all or first/last n of turtle’s stamps. If n is None, delete all stamps, if n > 0 delete first n stamps, else if n < 0 delete last n stamps.

```python
>>> for i in range(8):
...     turtle.stamp(); turtle.fd(30)
13
14
15
16
```
turtle.clearstamps(2)
turtle.clearstamps(-2)
turtle.clearstamps()

turtle.undo()
Undo (repeatedly) the last turtle action(s). Number of available undo actions is determined by the size of the undobuffer.

for i in range(4):
    ... turtle.fd(50); turtle.lt(80)

for i in range(8):
    ... turtle.undo()

turtle.speed(speed=None)

Parameters:

| speed | an integer in the range 0..10 or a speedstring (see below) |

Set the turtle's speed to an integer value in the range 0..10. If no argument is given, return current speed.

If input is a number greater than 10 or smaller than 0.5, speed is set to 0. Speedstrings are mapped to speed values as follows:

- “fastest”: 0
- “fast”: 10
- “normal”: 6
- “slow”: 3
- “slowest”: 1

Speeds from 1 to 10 enforce increasingly faster animation of line
drawing and turtle turning.

Attention: \textit{speed} = 0 means that \textit{no} animation takes place. forward/back makes turtle jump and likewise left/right make the turtle turn instantly.

\begin{verbatim}
>>> turtle.speed()
3
>>> turtle.speed('normal')
>>> turtle.speed()
6
>>> turtle.speed(9)
>>> turtle.speed()
9
\end{verbatim}

24.1.3.2. Tell Turtle's state

turtle.\underline{position}()
turtle.\underline{pos}()

Return the turtle's current location (x,y) (as a \texttt{Vec2D} vector).

\begin{verbatim}
>>> turtle.pos()
(440.00,-0.00)
\end{verbatim}

turtle.\underline{towards}(x, y=None)

\begin{tabular}{|l|}
\hline
\textbf{Parameters:} & \textbullet\ x – a number or a pair/vector of numbers or a turtle instance \\
& \textbullet\ y – a number if \textit{x} is a number, else None \\
\hline
\end{tabular}

Return the angle between the line from turtle position to position specified by (x,y), the vector or the other turtle. This depends on the turtle's start orientation which depends on the mode - “standard”/"world" or “logo”).
turtle.goto(10, 10)
turtle.towards(0, 0)
225.0

turtle.xcor()
Return the turtle's x coordinate.

>>> turtle.home()
>>> turtle.left(50)
>>> turtle.forward(100)
>>> turtle.pos()
(64.28, 76.60)
>>> print(round(turtle.xcor(), 5))
64.27876

turtle.ycor()
Return the turtle's y coordinate.

>>> turtle.home()
>>> turtle.left(60)
>>> turtle.forward(100)
>>> print(turtle.pos())
(50.00, 86.60)
>>> print(round(turtle.ycor(), 5))
86.60254

turtle.heading()
Return the turtle's current heading (value depends on the turtle mode, see mode()).

>>> turtle.home()
>>> turtle.left(67)
>>> turtle.heading()
67.0
turtle.distance(x, y=None)

<table>
<thead>
<tr>
<th>Parameters:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• x – a number or a pair/vector of numbers or a turtle instance</td>
<td></td>
</tr>
<tr>
<td>• y – a number if x is a number, else None</td>
<td></td>
</tr>
</tbody>
</table>

Return the distance from the turtle to (x,y), the given vector, or the given other turtle, in turtle step units.

```python
>>> turtle.home()
>>> turtle.distance(30,40)
50.0
>>> turtle.distance((30,40))
50.0
>>> joe = Turtle()
>>> joe.forward(77)
>>> turtle.distance(joe)
77.0
```

24.1.3.3. Settings for measurement

turtle.degrees(fullcircle=360.0)

<table>
<thead>
<tr>
<th>Parameters:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>fullcircle – a number</td>
<td></td>
</tr>
</tbody>
</table>

Set angle measurement units, i.e. set number of “degrees” for a full circle. Default value is 360 degrees.

```python
>>> turtle.home()
>>> turtle.left(90)
>>> turtle.heading()
90.0
```

Change angle measurement unit to grad (also known grade, or gradian and equals 1/100-th of the right

```python
>>> turtle.degrees(400.0)
```
turtle.**radians**()

Set the angle measurement units to radians. Equivalent to degrees(2*\(\text{math.pi}\)).

```python
>>> turtle.home()
>>> turtle.left(90)
>>> turtle.heading()
90.0
>>> turtle.radians()
>>> turtle.heading()
1.5707963267948966
```

24.1.3.4. Pen control

24.1.3.4.1. Drawing state

turtle.**pendown**()
turtle.**pd**()
turtle.**down**()

Pull the pen down – drawing when moving.

turtle.**penup**()
turtle.**pu**()
turtle.**up**()

Pull the pen up – no drawing when moving.

turtle.**pensize**(width=None)
turtle.width(width=None)

**Parameters:**
- **width** – a positive number

Set the line thickness to `width` or return it. If resizemode is set to “auto” and turtleshape is a polygon, that polygon is drawn with the same line thickness. If no argument is given, the current pensize is returned.

```python
>>> turtle.pensize()
1
>>> turtle.pensize(10)  # from here on lines of # from here on lines of
```

turtle.pen(pen=None, **pendict)

**Parameters:**
- **pen** – a dictionary with some or all of the below listed keys
- **pendict** – one or more keyword-arguments with the below listed keys as keywords

Return or set the pen’s attributes in a “pen-dictionary” with the following key/value pairs:

- “shown”: True/False
- “pendown”: True/False
- “pencolor”: color-string or color-tuple
- “fillcolor”: color-string or color-tuple
- “pensize”: positive number
- “speed”: number in range 0..10
- “resizemode”: “auto” or “user” or “noresize”
- “stretchfactor”: (positive number, positive number)
- “outline”: positive number
- “tilt”: number

This dictionary can be used as argument for a subsequent call to
pen() to restore the former pen-state. Moreover one or more of these attributes can be provided as keyword-arguments. This can be used to set several pen attributes in one statement.

```python
>>> turtle.pen(fillcolor="black", pencolor="red",
>>> sorted(turtle.pen().items())
[('fillcolor', 'black'), ('outline', 1), ('pencol ('pendown', True), ('pensize', 10), ('resizemode ('shearfactor', 0.0), ('shown', True), ('speed', ('stretchfactor', (1.0, 1.0)), ('tilt', 0.0)]
```

```python
>>> penstate=turtle.pen()
>>> turtle.color("yellow", ")
>>> turtle.penup()
>>> sorted(turtle.pen().items())[3]
[('fillcolor', ''), ('outline', 1), ('pencolor',
```

```python
turtle.isdown()
Return True if pen is down, False if it's up.

```python
>>> turtle.penup()
>>> turtle.isdown()
False
>>> turtle.pendown()
>>> turtle.isdown()
True
```

24.1.3.4.2. Color control

turtle.pencolor(*args)
Return or set the pencolor.
Four input formats are allowed:

`pencolor()`
Return the current pencolor as color specification string or as a tuple (see example). May be used as input to another color/pencolor/fillcolor call.

`pencolor(colorstring)`
Set pencolor to `colorstring`, which is a Tk color specification string, such as "red", "yellow", or "#33cc8c".

`pencolor((r, g, b))`
Set pencolor to the RGB color represented by the tuple of `r`, `g`, and `b`. Each of `r`, `g`, and `b` must be in the range 0..colormode, where colormode is either 1.0 or 255 (see `colormode()`).

`pencolor(r, g, b)`
Set pencolor to the RGB color represented by `r`, `g`, and `b`. Each of `r`, `g`, and `b` must be in the range 0..colormode.

If turtleshape is a polygon, the outline of that polygon is drawn with the newly set pencolor.

```python
>>> colormode()
1.0
>>> turtle.pencolor()
'red'
>>> turtle.pencolor("brown")
>>> turtle.pencolor()
'brown'
>>> tup = (0.2, 0.8, 0.55)
>>> turtle.pencolor(tup)
>>> turtle.pencolor()
(0.2, 0.8, 0.5490196078431373)
>>> colormode(255)
>>> turtle.pencolor()
(51.0, 204.0, 140.0)
```
turtle.pencolor('violet')
>>> turtle.pencolor()
(50.0, 193.0, 143.0)

turtle.fillcolor(*args)
Return or set the fillcolor.

Four input formats are allowed:

fillcolor()
    Return the current fillcolor as color specification string, possibly in tuple format (see example). May be used as input to another color/pencolor/fillcolor call.

fillcolor(colorstring)
    Set fillcolor to colorstring, which is a Tk color specification string, such as "red", "yellow", or "#33cc8c".

fillcolor((r, g, b))
    Set fillcolor to the RGB color represented by the tuple of r, g, and b. Each of r, g, and b must be in the range 0..colormode, where colormode is either 1.0 or 255 (see colormode()).

fillcolor(r, g, b)
    Set fillcolor to the RGB color represented by r, g, and b. Each of r, g, and b must be in the range 0..colormode.

If turtleshape is a polygon, the interior of that polygon is drawn with the newly set fillcolor.

>>> turtle.fillcolor("violet")
>>> turtle.fillcolor()
'violet'
>>> col = turtle.pencolor()
>>> col
(50.0, 193.0, 143.0)
turtle.fillcolor(col)
>>> turtle.fillcolor()
(50.0, 193.0, 143.0)
>>> turtle.fillcolor('#ffffff')
>>> turtle.fillcolor()
(255.0, 255.0, 255.0)

turtle.color(*args)
Return or set pencolor and fillcolor.

Several input formats are allowed. They use 0 to 3 arguments as follows:

color()
Return the current pencolor and the current fillcolor as a pair of color specification strings or tuples as returned by pencolor() and fillcolor().

color(colorstring), color((r,g,b)), color(r,g,b)
Inputs as in pencolor(), set both, fillcolor and pencolor, to the given value.

color(colorstring1, colorstring2), color((r1,g1,b1), (r2,g2,b2))
Equivalent to pencolor(colorstring1) and fillcolor(colorstring2) and analogously if the other input format is used.

If turtleshape is a polygon, outline and interior of that polygon is drawn with the newly set colors.

>>> turtle.color("red", "green")
>>> turtle.color()
('red', 'green')
>>> color("#285078", "#a0c8f0")
See also: Screen method `colormode()`.

24.1.3.4.3. Filling

`turtle.filling()`

Return fillstate (True if filling, False else).

```python
turtle.begin_fill()
>>> if turtle.filling():
...    turtle.pensize(5)
...    else:
...    turtle.pensize(3)
```  

`turtle.begin_fill()`

To be called just before drawing a shape to be filled.

`turtle.end_fill()`

Fill the shape drawn after the last call to `begin_fill()`.

```python
turtle.color("black", "red")
turtle.begin_fill()
turtle.circle(80)
turtle.end_fill()
```  

24.1.3.4.4. More drawing control

`turtle.reset()`

Delete the turtle's drawings from the screen, re-center the turtle and set variables to the default values.
turtle.goto(0,-22)
turtle.left(100)
turtle.position()
(0.00,-22.00)
turtle.heading()
100.0
turtle.reset()
turtle.position()
(0.00,0.00)
turtle.heading()
0.0
turtle.clear()

Delete the turtle's drawings from the screen. Do not move turtle. State and position of the turtle as well as drawings of other turtles are not affected.

turtle.write(arg, move=False, align="left", font=("Arial", 8, "normal"))

Parameters:
- **arg** – object to be written to the TurtleScreen
- **move** – True/False
- **align** – one of the strings “left”, “center” or right"
- **font** – a triple (fontname, fontsize, fonttype)

Write text - the string representation of *arg* - at the current turtle position according to *align* (“left”, “center” or right”) and with the given font. If *move* is true, the pen is moved to the bottom-right corner of the text. By default, *move* is False.

>>> turtle.write("Home = ", True, align="center")
>>> turtle.write((0,0), True)
24.1.3.5. Turtle state

24.1.3.5.1. Visibility

```python
turtle.hideturtle()
turtle.ht()
```

Make the turtle invisible. It’s a good idea to do this while you’re in the middle of doing some complex drawing, because hiding the turtle speeds up the drawing observably.

```python
turtle.hideturtle()
```

```python
turtle.showturtle()
turtle.st()
```

Make the turtle visible.

```python
turtle.showturtle()
```

```python
turtle.isvisible()
```

Return True if the Turtle is shown, False if it’s hidden.

```python
turtle.isvisible()
turtle.hideturtle()
turtle.isvisible()
False
turtle.showturtle()
turtle.isvisible()
True
```

24.1.3.5.2. Appearance

```python
turtle.shape(name=None)
```

**Parameters:** `name` – a string which is a valid shapename
Set turtle shape to shape with given name or, if name is not given, return name of current shape. Shape with name must exist in the TurtleScreen’s shape dictionary. Initially there are the following polygon shapes: “arrow”, “turtle”, “circle”, “square”, “triangle”, “classic”. To learn about how to deal with shapes see Screen method register_shape().

```python
>>> turtle.shape()
'classic'
>>> turtle.shape("turtle")
>>> turtle.shape()
'turtle'
```

turtle.resizemode(rmode=None)

| Parameters: | rmode – one of the strings “auto”, “user”, “noresize” |

Set resizemode to one of the values: “auto”, “user”, “noresize”. If rmode is not given, return current resizemode. Different resizemodes have the following effects:

- “auto”: adapts the appearance of the turtle corresponding to the value of pensize.
- “user”: adapts the appearance of the turtle according to the values of stretchfactor and outlinewidth (outline), which are set by shapesize().
- “noresize”: no adaption of the turtle’s appearance takes place.

resizemode(“user”) is called by shapesize() when used with arguments.

```python
>>> turtle.resizemode()
'noresize'
>>> turtle.resizemode("auto")
```
turtle.shapesize(stretch_wid=None, stretch_len=None, outline=None)
turtle.turtlesize(stretch_wid=None, stretch_len=None, outline=None)

Parameters:
- stretch_wid – positive number
- stretch_len – positive number
- outline – positive number

Return or set the pen's attributes x/y-stretchfactors and/or outline. Set resizemode to “user”. If and only if resizemode is set to “user”, the turtle will be displayed stretched according to its stretchfactors: stretch_wid is stretchfactor perpendicular to its orientation, stretch_len is stretchfactor in direction of its orientation, outline determines the width of the shape's outline.

turtle.shearfactor(shear=None)

Parameters: shear – number (optional)

Set or return the current shearfactor. Shear the turtleshape according to the given shearfactor shear, which is the tangent of
the shear angle. Do not change the turtle's heading (direction of movement). If shear is not given: return the current shearfactor, i.e. the tangent of the shear angle, by which lines parallel to the heading of the turtle are sheared.

```python
>>> turtle.shape("circle")
>>> turtle.shapesize(5,2)
>>> turtle.shearfactor(0.5)
>>> turtle.shearfactor()
0.5
```

turtle.tilt(angle)

**Parameters:**  
angle – a number

Rotate the turtleshape by angle from its current tilt-angle, but do not change the turtle's heading (direction of movement).

```python
>>> turtle.reset()
>>> turtle.shape("circle")
>>> turtle.shapesize(5,2)
>>> turtle.tilt(30)
>>> turtle.fd(50)
>>> turtle.tilt(30)
>>> turtle.fd(50)
```

turtle.settiltangle(angle)

**Parameters:**  
angle – a number

Rotate the turtleshape to point in the direction specified by angle, regardless of its current tilt-angle. Do not change the turtle's heading (direction of movement).

```python
>>> turtle.reset()
>>> turtle.shape("circle")
```
```python
>>> turtle.shapesize(5, 2)
>>> turtle.settiltangle(45)
>>> turtle.fd(50)
>>> turtle.settiltangle(-45)
>>> turtle.fd(50)
```

*Deprecated since version 3.1.*

**turtle.tiltangle**(angle=None)

<table>
<thead>
<tr>
<th>Parameters:</th>
<th>angle – a number (optional)</th>
</tr>
</thead>
</table>

Set or return the current tilt-angle. If angle is given, rotate the turtleshape to point in the direction specified by angle, regardless of its current tilt-angle. Do *not* change the turtle’s heading (direction of movement). If angle is not given: return the current tilt-angle, i.e. the angle between the orientation of the turtleshape and the heading of the turtle (its direction of movement).

```python
>>> turtle.reset()
>>> turtle.shape("circle")
>>> turtle.shapesize(5, 2)
>>> turtle.tilt(45)
>>> turtle.tiltangle()
45.0
```

**turtle.shapetransform**(t11=None, t12=None, t21=None, t22=None)

<table>
<thead>
<tr>
<th>Parameters:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• t11 – a number (optional)</td>
</tr>
<tr>
<td>• t12 – a number (optional)</td>
</tr>
<tr>
<td>• t21 – a number (optional)</td>
</tr>
<tr>
<td>• t22 – a number (optional)</td>
</tr>
</tbody>
</table>

Set or return the current transformation matrix of the turtleshape.
If none of the matrix elements are given, return the transformation matrix as a tuple of 4 elements. Otherwise set the given elements and transform the turtleshape according to the matrix consisting of first row t11, t12 and second row t21, 22. The determinant $t_{11} \times t_{22} - t_{12} \times t_{21}$ must not be zero, otherwise an error is raised. Modify stretchfactor, shearfactor and tiltangle according to the given matrix.

```python
>>> turtle = Turtle()
>>> turtle.shape("square")
>>> turtle.shapesize(4,2)
>>> turtle.shearfactor(-0.5)
>>> turtle.shapetransform()
(4.0, -1.0, 0.0, 2.0)
```

turtle.get_shapepoly()

Return the current shape polygon as tuple of coordinate pairs. This can be used to define a new shape or components of a compound shape.

```python
>>> turtle.shape("square")
>>> turtle.shapetransform(4, -1, 0, 2)
>>> turtle.get_shapepoly()
((50, -20), (30, 20), (-50, 20), (-30, -20))
```

24.1.3.6. Using events

turtle.onclick(fun, btn=1, add=None)

- **fun** – a function with two arguments which will be called with the coordinates of the clicked point on the canvas
- **num** – number of the mouse-button, defaults
to 1 (left mouse button)

- **add** – True or False – if True, a new binding will be added, otherwise it will replace a former binding

Bind *fun* to mouse-click events on this turtle. If *fun* is None, existing bindings are removed. Example for the anonymous turtle, i.e. the procedural way:

```python
>>> def turn(x, y):
...     left(180)
...
>>> onclick(turn)  # Now clicking into the turtle
>>> onclick(None)  # event-binding will be removed
```

```python
turtle.onrelease(*fun*, *btn=1*, *add=None*)
```

**Parameters:**

- **fun** – a function with two arguments which will be called with the coordinates of the clicked point on the canvas
- **num** – number of the mouse-button, defaults to 1 (left mouse button)
- **add** – True or False – if True, a new binding will be added, otherwise it will replace a former binding

Bind *fun* to mouse-button-release events on this turtle. If *fun* is None, existing bindings are removed.

```python
>>> class MyTurtle(Turtle):
...     def glow(self, x, y):
...         self.fillcolor("red")
...     def unglow(self, x, y):
...         self.fillcolor("")
```
turtle.ondrag(fun, btn=1, add=None)

Parameters:
- **fun** – a function with two arguments which will be called with the coordinates of the clicked point on the canvas
- **num** – number of the mouse-button, defaults to 1 (left mouse button)
- **add** – True or False – if True, a new binding will be added, otherwise it will replace a former binding

Bind *fun* to mouse-move events on this turtle. If *fun* is None, existing bindings are removed.

Remark: Every sequence of mouse-move-events on a turtle is preceded by a mouse-click event on that turtle.

```python
>>> turtle.ondrag(turtle.goto)
```

Subsequently, clicking and dragging the Turtle will move it across the screen thereby producing handdrawings (if pen is down).

### 24.1.3.7. Special Turtle methods

**turtle.begin_poly()**

Start recording the vertices of a polygon. Current turtle position is first vertex of polygon.

**turtle.end_poly()**
Stop recording the vertices of a polygon. Current turtle position is last vertex of polygon. This will be connected with the first vertex.

turtle.get_poly()
Return the last recorded polygon.

```python
>>> turtle.home()
>>> turtle.begin_poly()
>>> turtle.fd(100)
>>> turtle.left(20)
>>> turtle.fd(30)
>>> turtle.left(60)
>>> turtle.fd(50)
>>> turtle.end_poly()
>>> p = turtle.get_poly()
>>> register_shape("myFavouriteShape", p)
```

turtle.clone()
Create and return a clone of the turtle with same position, heading and turtle properties.

```python
>>> mick = Turtle()
>>> joe = mick.clone()
```

turtle.getturtle()
turtle.getpen()
Return the Turtle object itself. Only reasonable use: as a function to return the “anonymous turtle”:

```python
>>> pet = getturtle()
>>> pet.fd(50)
>>> pet
<turtle.Turtle object at 0x...>
```
turtle.getscreen()

Return the TurtleScreen object the turtle is drawing on. TurtleScreen methods can then be called for that object.

```python
>>> ts = turtle.getscreen()
>>> ts
<turtle._Screen object at 0x...>
>>> ts.bgcolor("pink")
```

turtle.setundobuffer(size)

Parameters:  

- **size** – an integer or None

Set or disable undobuffer. If size is an integer an empty undobuffer of given size is installed. size gives the maximum number of turtle actions that can be undone by the undo() method/function. If size is None, the undobuffer is disabled.

```python
>>> turtle.setundobuffer(42)
```

turtle.undobufferentries()

Return number of entries in the undobuffer.

```python
>>> while undobufferentries():
...     undo()
```

24.1.3.8. Compound shapes

To use compound turtle shapes, which consist of several polygons of different color, you must use the helper class Shape explicitly as described below:

1. Create an empty Shape object of type “compound”.
2. Add as many components to this object as desired, using the `addcomponent()` method.

For example:

```python
>>> s = Shape("compound")
>>> poly1 = ((0,0),(10,-5),(0,10),(-10,-5))
>>> s.addcomponent(poly1, "red", "blue")
>>> poly2 = ((0,0),(10,-5),(-10,-5))
>>> s.addcomponent(poly2, "blue", "red")
```

3. Now add the Shape to the Screen’s shapelist and use it:

```python
>>> register_shape("myshape", s)
>>> shape("myshape")
```

**Note:** The `Shape` class is used internally by the `register_shape()` method in different ways. The application programmer has to deal with the Shape class only when using compound shapes like shown above!
24.1.4. Methods of TurtleScreen/Screen and corresponding functions

Most of the examples in this section refer to a TurtleScreen instance called screen.

24.1.4.1. Window control

turtle.bgcolor(*args)

| Parameters: | **args** – a color string or three numbers in the range 0..colormode or a 3-tuple of such numbers |

Set or return background color of the TurtleScreen.

```python
>>> screen.bgcolor("orange")
'orange'
>>> screen.bgcolor()
>>> screen.bgcolor("#800080")
>>> screen.bgcolor()
(128.0, 0.0, 128.0)
```

turtle.bgpic(picname=None)

| Parameters: | **picname** – a string, name of a gif-file or "nopic", or None |

Set background image or return name of current background image. If **picname** is a filename, set the corresponding image as background. If **picname** is "nopic", delete background image, if present. If **picname** is None, return the filename of the current background image.
turtle.**clear**()

turtle.**clearscreen**()

Delete all drawings and all turtles from the TurtleScreen. Reset the newly empty TurtleScreen to its initial state: white background, no background image, no event bindings and tracing on.

**Note:** This TurtleScreen method is available as a global function only under the name clearscreen. The global function clear is a different one derived from the Turtle method clear.

turtle.**reset**()

turtle.**resetscreen**()

Reset all Turtles on the Screen to their initial state.

**Note:** This TurtleScreen method is available as a global function only under the name resetscreen. The global function reset is another one derived from the Turtle method reset.

turtle.**screensize**(*canvwidth=None, canvheight=None, bg=None*)

**Parameters:**

- **canvwidth** – positive integer, new width of canvas in pixels
- **canvheight** – positive integer, new height of canvas in pixels
- **bg** – colorstring or color-tuple, new background color
If no arguments are given, return current (canvaswidth, canvashight). Else resize the canvas the turtles are drawing on. Do not alter the drawing window. To observe hidden parts of the canvas, use the scrollbars. With this method, one can make visible those parts of a drawing which were outside the canvas before.

```python
>>> screen.screensize()
(400, 300)
>>> screen.screensize(2000, 1500)
>>> screen.screensize()
(2000, 1500)
```

e.g. to search for an erroneously escaped turtle ;-)

turtle.setworldcoordinates(llx, lly, urx, ury)

**Parameters:**
- **llx** – a number, x-coordinate of lower left corner of canvas
- **lly** – a number, y-coordinate of lower left corner of canvas
- **urx** – a number, x-coordinate of upper right corner of canvas
- **ury** – a number, y-coordinate of upper right corner of canvas

Set up user-defined coordinate system and switch to mode “world” if necessary. This performs a `screen.reset()`. If mode “world” is already active, all drawings are redrawn according to the new coordinates.

**ATTENTION:** in user-defined coordinate systems angles may appear distorted.
24.1.4.2. Animation control

turtle.\texttt{delay}(\texttt{delay} = \texttt{None})

<table>
<thead>
<tr>
<th>Parameters:</th>
<th>\texttt{delay} – positive integer</th>
</tr>
</thead>
</table>

Set or return the drawing \texttt{delay} in milliseconds. (This is approximately the time interval between two consecutive canvas updates.) The longer the drawing delay, the slower the animation.

Optional argument:

```python
>>> screen.delay()
10
>>> screen.delay(5)
>>> screen.delay()
5
```

turtle.\texttt{tracer}(\texttt{n} = \texttt{None}, \texttt{delay} = \texttt{None})

| Parameters: | • \texttt{n} – nonnegative integer  
• \texttt{delay} – nonnegative integer |
|-------------|-----------------------------------|

Turn turtle animation on/off and set delay for update drawings. If \texttt{n} is given, only each n-th regular screen update is really performed. (Can be used to accelerate the drawing of complex graphics.) When called without arguments, returns the currently stored value.
of n. Second argument sets delay value (see \texttt{delay()}).

\begin{verbatim}
>>> screen.tracer(8, 25)
>>> dist = 2
>>> for i in range(200):
...     fd(dist)
...     rt(90)
>>> dist += 2
\end{verbatim}

\texttt{turtle.update()}

Perform a TurtleScreen update. To be used when tracer is turned off.

See also the RawTurtle/Turtle method \texttt{speed()}. 

\subsection*{24.1.4.3. Using screen events}

\texttt{turtle.listen}(\texttt{xdummy=None, ydummy=None})

Set focus on TurtleScreen (in order to collect key-events). Dummy arguments are provided in order to be able to pass \texttt{listen()} to the onclick method.

\texttt{turtle.onkey}(\texttt{fun, key})
\texttt{turtle.onkeyrelease}(\texttt{fun, key})

\begin{table}[h]
\begin{tabular}{|l|}
\hline
\textbf{Parameters:} & \begin{itemize}
\item \texttt{fun} – a function with no arguments or None
\item \texttt{key} – a string: key (e.g. “a”) or key-symbol (e.g. “space”)
\end{itemize}
\hline
\end{tabular}
\end{table}

Bind \texttt{fun} to key-release event of key. If \texttt{fun} is None, event bindings are removed. Remark: in order to be able to register key-events, TurtleScreen must have the focus. (See method \texttt{listen()}. )
```python
>>> def f():
...    fd(50)
...    lt(60)
...
>>> screen.onkey(f, "Up")
>>> screen.listen()
```

**turtle.onkeypress**(*fun*, *key=None*)

<table>
<thead>
<tr>
<th>Parameters</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>fun</strong></td>
<td>a function with no arguments or None</td>
<td></td>
</tr>
<tr>
<td><strong>key</strong></td>
<td>a string: key (e.g. “a”) or key-symbol (e.g. “space”)</td>
<td></td>
</tr>
</tbody>
</table>

Bind *fun* to key-press event of key if key is given, or to any key-press-event if no key is given. Remark: in order to be able to register key-events, TurtleScreen must have focus. (See method *listen()*.)

```python
>>> def f():
...    fd(50)
...    lt(60)
...
>>> screen.onkey(f, "Up")
>>> screen.listen()
```

**turtle.onclick**(*fun*, *btn=1, add=None*)

**turtle.onscreenclick**(*fun*, *btn=1, add=None*)

<table>
<thead>
<tr>
<th>Parameters</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>fun</strong></td>
<td>a function with two arguments which will be called with the coordinates of the clicked point on the canvas</td>
<td></td>
</tr>
<tr>
<td><strong>num</strong></td>
<td>number of the mouse-button, defaults to 1 (left mouse button)</td>
<td></td>
</tr>
<tr>
<td><strong>add</strong></td>
<td>True or False – if True, a new binding will be added, otherwise it will replace a former binding</td>
<td></td>
</tr>
</tbody>
</table>
Bind `fun` to mouse-click events on this screen. If `fun` is None, existing bindings are removed.

Example for a TurtleScreen instance named `screen` and a Turtle instance named `turtle`:

```python
>>> screen.onclick(turtle.goto)  # Subsequently clicking into the TurtleScreen will make the turtle move to the clicked point.
>>> screen.onclick(None)  # remove event binding again
```

**Note:** This TurtleScreen method is available as a global function only under the name `onscreenclick`. The global function `onclick` is another one derived from the Turtle method `onclick`.

`turtle.ontimer(fun, t=0)`

**Parameters:**
- `fun` – a function with no arguments
- `t` – a number $\geq 0$

Install a timer that calls `fun` after `t` milliseconds.

```python
>>> running = True
>>> def f():
...    if running:
...        fd(50)
...        lt(60)
...        screen.ontimer(f, 250)
>>> f()  # makes the turtle march around
>>> running = False
```

`turtle.mainloop()`

`turtle.done()`
Starts event loop - calling Tkinter’s mainloop function. Must be the last statement in a turtle graphics program. Must *not* be used if a script is run from within IDLE in -n mode (No subprocess) - for interactive use of turtle graphics.

```python
>>> screen.mainloop()
```

### 24.1.4.4. Input methods

**turtle.textinput**(title, prompt)

<table>
<thead>
<tr>
<th>Parameters:</th>
</tr>
</thead>
<tbody>
<tr>
<td>title – string</td>
</tr>
<tr>
<td>prompt – string</td>
</tr>
</tbody>
</table>

Pop up a dialog window for input of a string. Parameter title is the title of the dialog window, prompt is a text mostly describing what information to input. Return the string input. If the dialog is canceled, return None.

```python
>>> screen.textinput("NIM", "Name of first player:")
```

**turtle.numinput**(title, prompt, default=None, minval=None, maxval=None)

<table>
<thead>
<tr>
<th>Parameters:</th>
</tr>
</thead>
<tbody>
<tr>
<td>title – string</td>
</tr>
<tr>
<td>prompt – string</td>
</tr>
<tr>
<td>default – number (optional)</td>
</tr>
<tr>
<td>minval – number (optional)</td>
</tr>
<tr>
<td>maxval – number (optional)</td>
</tr>
</tbody>
</table>

Pop up a dialog window for input of a number. title is the title of the dialog window, prompt is a text mostly describing what numerical information to input. default: default value, minval: minimum value
for input, maxval: maximum value for input The number input must be in the range minval .. maxval if these are given. If not, a hint is issued and the dialog remains open for correction. Return the number input. If the dialog is canceled, return None.

```python
>>> screen.numinput("Poker", "Your stakes:", 1000
```

24.1.4.5. Settings and special methods

turtle.**mode**(mode=None)

**Parameters:**

mode – one of the strings “standard”, “logo” or “world”

Set turtle mode (“standard”, “logo” or “world”) and perform reset. If mode is not given, current mode is returned.

Mode “standard” is compatible with old turtle. Mode “logo” is compatible with most Logo turtle graphics. Mode “world” uses user-defined “world coordinates”. **Attention:** in this mode angles appear distorted if x/y unit-ratio doesn’t equal 1.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Initial turtle heading</th>
<th>positive angles</th>
</tr>
</thead>
<tbody>
<tr>
<td>“standard”</td>
<td>to the right (east)</td>
<td>counterclockwise</td>
</tr>
<tr>
<td>“logo”</td>
<td>upward (north)</td>
<td>clockwise</td>
</tr>
</tbody>
</table>

```python
>>> mode("logo")    # resets turtle heading to nor
>>> mode()           # resets turtle heading to nor
'logo'
```

turtle.**colormode**(cmode=None)
Parameters:  
cmode – one of the values 1.0 or 255  

Return the colormode or set it to 1.0 or 255. Subsequently r, g, b values of color triples have to be in the range 0..cmode.

```python
>>> screen.colormode(1)
>>> turtle.pencolor(240, 160, 80)
Traceback (most recent call last):
 ...  
TurtleGraphicsError: bad color sequence: (240, 16
```  
```python
>>> screen.colormode()
1.0
>>> screen.colormode(255)
>>> screen.colormode()
255
>>> turtle.pencolor(240,160,80)
```

turtle.getcanvas()  
Return the Canvas of this TurtleScreen. Useful for insiders who know what to do with a Tkinter Canvas.

```python
>>> cv = screen.getcanvas()
>>> cv
<turtle.ScrolledCanvas object ...>
```

turtle.getshapes()  
Return a list of names of all currently available turtle shapes.

```python
>>> screen.getshapes()
['arrow', 'blank', 'circle', ..., 'turtle']
```

turtle.register_shape(name, shape=None)  
turtle.addshape(name, shape=None)  
There are three different ways to call this function:
1. *name* is the name of a gif-file and *shape* is None: Install the corresponding image shape.

```python
>>> screen.register_shape("turtle.gif")
```

**Note:** Image shapes *do not* rotate when turning the turtle, so they do not display the heading of the turtle!

2. *name* is an arbitrary string and *shape* is a tuple of pairs of coordinates: Install the corresponding polygon shape.

```python
>>> screen.register_shape("triangle", ((5, -3),
```

3. *name* is an arbitrary string and shape is a (compound) *Shape* object: Install the corresponding compound shape.

Add a turtle shape to TurtleScreen’s shapelist. Only thusly registered shapes can be used by issuing the command `shape(shapename)`.

```python
turtle.turtles()
```

Return the list of turtles on the screen.

```python
>>> for turtle in screen.turtles():
...     turtle.color("red")
```

```python
turtle.window_height()
```

Return the height of the turtle window.

```python
>>> screen.window_height()
480
```

```python
turtle.window_width()
```
Return the width of the turtle window.

```python
>>> screen.window_width()
640
```

### 24.1.4.6. Methods specific to Screen, not inherited from TurtleScreen

**turtle**. `bye()`  
Shut the turtlegraphics window.

**turtle**. `exitonclick()`  
Bind `bye()` method to mouse clicks on the Screen.

If the value “using_IDLE” in the configuration dictionary is False (default value), also enter mainloop. Remark: If IDLE with the `-n` switch (no subprocess) is used, this value should be set to True in `turtle.cfg`. In this case IDLE’s own mainloop is active also for the client script.

**turtle**. `setup(width=_CFG["width"], height=_CFG["height"],
                    startx=_CFG["leftright"], starty=_CFG["topbottom"])`  
Set the size and position of the main window. Default values of arguments are stored in the configuration dictionary and can be changed via a `turtle.cfg` file.

- **width** – if an integer, a size in pixels, if a float, a fraction of the screen; default is 50% of screen  
- **height** – if an integer, the height in pixels, if a float, a fraction of the screen; default is 75% of screen
### Parameters:

- **startx** – if positive, starting position in pixels from the left edge of the screen, if negative from the right edge, if None, center window horizontally
- **starty** – if positive, starting position in pixels from the top edge of the screen, if negative from the bottom edge, if None, center window vertically

```python
goldenrod
>>> screen.setup (width=200, height=200, startx=0)
# sets window to 200x200 pixels,
>>> screen.setup(width=.75, height=0.5, startx=None)
# sets window to 75% of screen b
```

### turtle.title(titlestring)

**Parameters:**
- **titlestring** – a string that is shown in the titlebar of the turtle graphics window

Set title of turtle window to *titlestring*.

```python
>>> screen.title("Welcome to the turtle zoo!")
```
24.1.5. Public classes

class turtle.RawTurtle(canvas)
class turtle.RawPen(canvas)

| Parameters: | canvas – a tkinter.Canvas, a ScrolledCanvas or a TurtleScreen |

Create a turtle. The turtle has all methods described above as “methods of Turtle/RawTurtle”.

class turtle.Turtle
Subclass of RawTurtle, has the same interface but draws on a default Screen object created automatically when needed for the first time.

class turtle.TurtleScreen(cv)

| Parameters: | cv – a tkinter.Canvas |

Provides screen oriented methods like setbg() etc. that are described above.

class turtle.Screen
Subclass of TurtleScreen, with four methods added.

class turtle.ScrolledCanvas(master)

| Parameters: | master – some Tkinter widget to contain the ScrolledCanvas, i.e. a Tkinter-canvas with scrollbars added |

Used by class Screen, which thus automatically provides a ScrolledCanvas as playground for the turtles.
class turtle.Shape(type_, data)

Parameters:
- **type_** – one of the strings “polygon”, “image”, “compound”

Data structure modeling shapes. The pair (type_, data) must follow this specification:

<table>
<thead>
<tr>
<th>type_</th>
<th>data</th>
</tr>
</thead>
<tbody>
<tr>
<td>“polygon”</td>
<td>a polygon-tuple, i.e. a tuple of pairs of coordinates</td>
</tr>
<tr>
<td>“image”</td>
<td>an image (in this form only used internally!)</td>
</tr>
<tr>
<td>“compound”</td>
<td>None (a compound shape has to be constructed using the addcomponent() method)</td>
</tr>
</tbody>
</table>

addcomponent(poly, fill, outline=None)

Parameters:
- **poly** – a polygon, i.e. a tuple of pairs of numbers
- **fill** – a color the poly will be filled with
- **outline** – a color for the poly’s outline (if given)

Example:

```python
>>> poly = ((0, 0), (10, -5), (0, 10), (-10, -5))
>>> s = Shape("compound")
>>> s.addcomponent(poly, "red", "blue")
>>> # ... add more components and then use register_shape()
```

See Compound shapes.

class turtle.Turtles.Vec2D(x, y)

A two-dimensional vector class, used as a helper class for implementing turtle graphics. May be useful for turtle graphics
programs too. Derived from tuple, so a vector is a tuple!

Provides (for $a$, $b$ vectors, $k$ number):

- $a + b$ vector addition
- $a - b$ vector subtraction
- $a \times b$ inner product
- $k \times a$ and $a \times k$ multiplication with scalar
- $\text{abs}(a)$ absolute value of $a$
- $a\.\text{rotate}(\text{angle})$ rotation
24.1.6. Help and configuration

24.1.6.1. How to use help

The public methods of the Screen and Turtle classes are documented extensively via docstrings. So these can be used as online-help via the Python help facilities:

- When using IDLE, tooltips show the signatures and first lines of the docstrings of typed in function-/method calls.

- Calling help() on methods or functions displays the docstrings:

```python
>>> help(Screen.bgcolor)
Help on method bgcolor in module turtle:

bgcolor(self, *args) unbound turtle.Screen method
    Set or return backgroundcolor of the TurtleScreen

    Arguments (if given): a color string or three numbers in
    the range 0..colormode or a 3-tuple of such numbers.

>>> screen.bgcolor("orange")
>>> screen.bgcolor()
"orange"
>>> screen.bgcolor(0.5,0,0.5)
>>> screen.bgcolor()
"#800080"

>>> help(Turtle.penup)
Help on method penup in module turtle:

penup(self) unbound turtle.Turtle method
    Pull the pen up -- no drawing when moving.
```
Aliases: penup | pu | up

No argument

>>> turtle.penup()

The docstrings of the functions which are derived from methods have a modified form:

>>> help(bgcolor)
Help on function bgcolor in module turtle:

bgcolor(*args)
    Set or return backgroundcolor of the TurtleScreen.

    Arguments (if given): a color string or three numbers in the range
    0..colormode or a 3-tuple of such numbers.

Example::

    >>> bgcolor("orange")
    >>> bgcolor()
    "orange"
    >>> bgcolor(0.5,0,0.5)
    >>> bgcolor()
    "#800080"

>>> help(penup)
Help on function penup in module turtle:

penup()
    Pull the pen up -- no drawing when moving.

    Aliases: penup | pu | up
These modified docstrings are created automatically together with the function definitions that are derived from the methods at import time.

24.1.6.2. Translation of docstrings into different languages

There is a utility to create a dictionary the keys of which are the method names and the values of which are the docstrings of the public methods of the classes Screen and Turtle.

```
turtle.write_docstringdict(filename="turtle_docstringdict")
```

**Parameters:**  
 filename – a string, used as filename

Create and write docstring-dictionary to a Python script with the given filename. This function has to be called explicitly (it is not used by the turtle graphics classes). The docstring dictionary will be written to the Python script `filename.py`. It is intended to serve as a template for translation of the docstrings into different languages.

If you (or your students) want to use `turtle` with online help in your native language, you have to translate the docstrings and save the resulting file as e.g. `turtle_docstringdict_german.py`.

If you have an appropriate entry in your `turtle.cfg` file this dictionary will be read in at import time and will replace the original English docstrings.
At the time of this writing there are docstring dictionaries in German and in Italian. (Requests please to glingl@aon.at.)

24.1.6.3. How to configure Screen and Turtles

The built-in default configuration mimics the appearance and behaviour of the old turtle module in order to retain best possible compatibility with it.

If you want to use a different configuration which better reflects the features of this module or which better fits to your needs, e.g. for use in a classroom, you can prepare a configuration file turtle.cfg which will be read at import time and modify the configuration according to its settings.

The built in configuration would correspond to the following turtle.cfg:

```plaintext
width = 0.5
height = 0.75
leftright = None
topbottom = None
canvwidth = 400
canvheight = 300
mode = standard
colormode = 1.0
delay = 10
undobuffersize = 1000
shape = classic
pencolor = black
fillcolor = black
resizemode = noresize
visible = True
language = english
exampleturtle = turtle
examplescreen = screen
```
Short explanation of selected entries:

- The first four lines correspond to the arguments of the `Screen.setup()` method.
- Line 5 and 6 correspond to the arguments of the method `Screen.screensize()`.
- `shape` can be any of the built-in shapes, e.g: arrow, turtle, etc. For more info try `help(shape)`.
- If you want to use no fillcolor (i.e. make the turtle transparent), you have to write `fillcolor = ""` (but all nonempty strings must not have quotes in the cfg-file).
- If you want to reflect the turtle its state, you have to use `resizemode = auto`.
- If you set e.g. `language = italian` the docstringdict `turtle_docstringdict_italian.py` will be loaded at import time (if present on the import path, e.g. in the same directory as `turtle`.
- The entries `exampleturtle` and `examplescreen` define the names of these objects as they occur in the docstrings. The transformation of method-docstrings to function-docstrings will delete these names from the docstrings.
- `using_IDLE`: Set this to True if you regularly work with IDLE and its -n switch (“no subprocess”). This will prevent `exitonclick()` to enter the mainloop.

There can be a `turtle.cfg` file in the directory where `turtle` is stored and an additional one in the current working directory. The latter will override the settings of the first one.

The Lib/turtledemo directory contains a `turtle.cfg` file. You can study it as an example and see its effects when running the demos
(preferably not from within the demo-viewer).
24.1.7. turtledemo — Demo scripts

The turtledemo package includes a set of demo scripts. These scripts can be run and viewed using the supplied demo viewer as follows:

```
python -m turtledemo
```

Alternatively, you can run the demo scripts individually. For example,

```
python -m turtledemo.bytedesign
```

The turtledemo package directory contains:

- A demo viewer __main__.py which can be used to view the sourcecode of the scripts and run them at the same time.
- Multiple scripts demonstrating different features of the turtle module. Examples can be accessed via the Examples menu. They can also be run standalone.
- A turtle.cfg file which serves as an example of how to write and use such files.

The demo scripts are:

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>bytedesign</td>
<td>complex classical turtle graphics pattern</td>
<td>tracer(), delay, update()</td>
</tr>
<tr>
<td>chaos</td>
<td>graphs Verhulst dynamics, shows that computer's computations can generate results sometimes against the common sense</td>
<td>world coordinates</td>
</tr>
<tr>
<td>Expectations</td>
<td>Analog Clock Showing Time of Your Computer</td>
<td>Turtles as Clock’s Hands, OnTimer</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Colormixer</td>
<td>Experiment with R, G, B</td>
<td>OnDrag()</td>
</tr>
<tr>
<td>Forest</td>
<td>3 Breadth-First Trees</td>
<td>Randomization</td>
</tr>
<tr>
<td>Fractal Curves</td>
<td>Hilbert &amp; Koch Curves</td>
<td>Recursion</td>
</tr>
<tr>
<td>Lindenmayer</td>
<td>Ethnomathematics (Indian Kolams)</td>
<td>L-System</td>
</tr>
<tr>
<td>Minimal Hanoi</td>
<td>Towers of Hanoi</td>
<td>Rectangular Turtles as Hanoi Discs (Shape, Shapsize)</td>
</tr>
<tr>
<td>Nim</td>
<td>Play the Classical Nim Game with Three Heaps of Sticks Against the Computer.</td>
<td>Turtles as Nimsticks, Event Driven (Mouse, Keyboard)</td>
</tr>
<tr>
<td>Paint</td>
<td>Super Minimalistic Drawing Program</td>
<td>OnClick()</td>
</tr>
<tr>
<td>Peace</td>
<td>Elementary</td>
<td>Turtle: Appearance and Animation</td>
</tr>
<tr>
<td>Penrose</td>
<td>Aperiodic Tiling with Kites and Darts</td>
<td>Stamp()</td>
</tr>
<tr>
<td>Planet and Moon</td>
<td>Simulation of Gravitational System</td>
<td>Compound Shapes, Vec2D</td>
</tr>
<tr>
<td>Round Dance</td>
<td>Dancing Turtles Rotating Pairwise in Opposite Direction</td>
<td>Compound Shapes, Clone Shapsize, Tilt, Get_ShapePoly, Update</td>
</tr>
<tr>
<td>Sorting Animate</td>
<td>Visual Demonstration of Different Sorting Methods</td>
<td>Simple Alignment, Randomization</td>
</tr>
<tr>
<td></td>
<td>A (Graphical) Breadth-First</td>
<td></td>
</tr>
<tr>
<td>tree</td>
<td>tree (using generators)</td>
<td>clone()</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>two_canvases</td>
<td>simple design</td>
<td>turtles on two canvases</td>
</tr>
<tr>
<td>wikipedia</td>
<td>a pattern from the wikipedia article on turtle graphics</td>
<td>clone(), undo()</td>
</tr>
<tr>
<td>yingyang</td>
<td>another elementary example</td>
<td>circle()</td>
</tr>
</tbody>
</table>

Have fun!
24.1.8. Changes since Python 2.6

- The methods `Turtle.tracer()`, `Turtle.window_width()` and `Turtle.window_height()` have been eliminated. Methods with these names and functionality are now available only as methods of Screen. The functions derived from these remain available. (In fact already in Python 2.6 these methods were merely duplications of the corresponding `TurtleScreen/Screen`-methods.)
- The method `Turtle.fill()` has been eliminated. The behaviour of `begin_fill()` and `end_fill()` have changed slightly: now every filling-process must be completed with an `end_fill()` call.
- A method `Turtle.filling()` has been added. It returns a boolean value: True if a filling process is under way, False otherwise. This behaviour corresponds to a `fill()` call without arguments in Python 2.6.
24.1.9. Changes since Python 3.0

- The methods `Turtle.shearfactor()`, `Turtle.shapetransform()` and `Turtle.get_shapepoly()` have been added. Thus the full range of regular linear transforms is now available for transforming turtle shapes.
- `Turtle.tiltangle()` has been enhanced in functionality: it now can be used to get or set the tiltangle.
- `Turtle.settiltangle()` has been deprecated.
- The method `Screen.onkeypress()` has been added as a complement to `Screen.onkey()` which in fact binds actions to the keyrelease event. Accordingly the latter has got an alias: `Screen.onkeyrelease()`.
- The method `Screen.mainloop()` has been added. So when working only with `Screen` and `Turtle` objects one must not additionally import `mainloop()` anymore.
- Two input methods have been added `Screen.textinput()` and `Screen.numinput()`. These popup input dialogs and return strings and numbers respectively.
- Two example scripts `tdemo_nim.py` and `tdemo_round_dance.py` have been added to the `Lib/turtledemo` directory.
24.2. cmd — Support for line-oriented command interpreters

Source code: Lib/cmd.py

The Cmd class provides a simple framework for writing line-oriented command interpreters. These are often useful for test harnesses, administrative tools, and prototypes that will later be wrapped in a more sophisticated interface.

```
class cmd.Cmd(completekey='tab', stdin=None, stdout=None)
```

A Cmd instance or subclass instance is a line-oriented interpreter framework. There is no good reason to instantiate Cmd itself; rather, it’s useful as a superclass of an interpreter class you define yourself in order to inherit Cmd’s methods and encapsulate action methods.

The optional argument completekey is the readline name of a completion key; it defaults to Tab. If completekey is not None and readline is available, command completion is done automatically.

The optional arguments stdin and stdout specify the input and output file objects that the Cmd instance or subclass instance will use for input and output. If not specified, they will default to sys.stdin and sys.stdout.

If you want a given stdin to be used, make sure to set the instance's use_rawinput attribute to False, otherwise stdin will
be ignored.
24.2.1. Cmd Objects

A `Cmd` instance has the following methods:

`Cmd.cmdloop(intro= None)`

Repeatedly issue a prompt, accept input, parse an initial prefix off the received input, and dispatch to action methods, passing them the remainder of the line as argument.

The optional argument is a banner or intro string to be issued before the first prompt (this overrides the `intro` class attribute).

If the `readline` module is loaded, input will automatically inherit `bash`-like history-list editing (e.g. Control-P scrolls back to the last command, Control-N forward to the next one, Control-F moves the cursor to the right non-destructively, Control-B moves the cursor to the left non-destructively, etc.).

An end-of-file on input is passed back as the string 'EOF'.

An interpreter instance will recognize a command name foo if and only if it has a method `do_foo()`. As a special case, a line beginning with the character '?' is dispatched to the method `do_help()`. As another special case, a line beginning with the character '!' is dispatched to the method `do_shell()` (if such a method is defined).

This method will return when the `postcmd()` method returns a true value. The `stop` argument to `postcmd()` is the return value from the command's corresponding `do_*()` method.

If completion is enabled, completing commands will be done
automatically, and completing of commands args is done by calling complete_foo() with arguments text, line, begidx, and endidx. text is the string prefix we are attempting to match: all returned matches must begin with it. line is the current input line with leading whitespace removed, begidx and endidx are the beginning and ending indexes of the prefix text, which could be used to provide different completion depending upon which position the argument is in.

All subclasses of Cmd inherit a predefined do_help(). This method, called with an argument 'bar', invokes the corresponding method help_bar(), and if that is not present, prints the docstring of do_bar(), if available. With no argument, do_help() lists all available help topics (that is, all commands with corresponding help_*() methods or commands that have docstrings), and also lists any undocumented commands.

Cmd.onecmd(str)

Interpret the argument as though it had been typed in response to the prompt. This may be overridden, but should not normally need to be; see the precmd() and postcmd() methods for useful execution hooks. The return value is a flag indicating whether interpretation of commands by the interpreter should stop. If there is a do_*( ) method for the command str, the return value of that method is returned, otherwise the return value from the default() method is returned.

Cmd.emptyline()

Method called when an empty line is entered in response to the prompt. If this method is not overridden, it repeats the last nonempty command entered.
Cmd. **default**(line)

Method called on an input line when the command prefix is not recognized. If this method is not overridden, it prints an error message and returns.

Cmd. **completesdefault**(text, line, begidx, endidx)

Method called to complete an input line when no command-specific complete_*() method is available. By default, it returns an empty list.

Cmd. **precmd**(line)

Hook method executed just before the command line line is interpreted, but after the input prompt is generated and issued. This method is a stub in Cmd; it exists to be overridden by subclasses. The return value is used as the command which will be executed by the onecmd() method; the precmd() implementation may re-write the command or simply return line unchanged.

Cmd. **postcmd**(stop, line)

Hook method executed just after a command dispatch is finished. This method is a stub in Cmd; it exists to be overridden by subclasses. line is the command line which was executed, and stop is a flag which indicates whether execution will be terminated after the call to postcmd(); this will be the return value of the onecmd() method. The return value of this method will be used as the new value for the internal flag which corresponds to stop; returning false will cause interpretation to continue.

Cmd. **preloop()**

Hook method executed once when cmdloop() is called. This method is a stub in Cmd; it exists to be overridden by subclasses.
**Cmd.postloop()**

Hook method executed once when `cmdloop()` is about to return. This method is a stub in `Cmd`; it exists to be overridden by subclasses.

Instances of `Cmd` subclasses have some public instance variables:

**Cmd.prompt**

The prompt issued to solicit input.

**Cmd.identchars**

The string of characters accepted for the command prefix.

**Cmd.lastcmd**

The last nonempty command prefix seen.

**Cmd.cmdqueue**

A list of queued input lines. The cmdqueue list is checked in `cmdloop()` when new input is needed; if it is nonempty, its elements will be processed in order, as if entered at the prompt.

**Cmd.intro**

A string to issue as an intro or banner. May be overridden by giving the `cmdloop()` method an argument.

**Cmd.doc_header**

The header to issue if the help output has a section for documented commands.

**Cmd.misc_header**

The header to issue if the help output has a section for miscellaneous help topics (that is, there are `help_*()` methods
without corresponding do_*() methods).

Cmd. **undoc_header**
The header to issue if the help output has a section for undocumented commands (that is, there are do_*() methods without corresponding help_*() methods).

Cmd. **ruler**
The character used to draw separator lines under the help-message headers. If empty, no ruler line is drawn. It defaults to '='.

Cmd. **use_rawinput**
A flag, defaulting to true. If true, cmdloop() uses input() to display a prompt and read the next command; if false, sys.stdout.write() and sys.stdin.readline() are used. (This means that by importing readline, on systems that support it, the interpreter will automatically support Emacs-like line editing and command-history keystrokes.)
24.2.2. Cmd Example

The `cmd` module is mainly useful for building custom shells that let a user work with a program interactively.

This section presents a simple example of how to build a shell around a few of the commands in the `turtle` module.

Basic turtle commands such as `forward()` are added to a `Cmd` subclass with method named `do_forward()`. The argument is converted to a number and dispatched to the turtle module. The docstring is used in the help utility provided by the shell.

The example also includes a basic record and playback facility implemented with the `precmd()` method which is responsible for converting the input to lowercase and writing the commands to a file. The `do_playback()` method reads the file and adds the recorded commands to the `cmdqueue` for immediate playback:

```python
import cmd, sys
from turtle import *

class TurtleShell(cmd.Cmd):
    intro = 'Welcome to the turtle shell. Type help or ? to list commands.

    prompt = '(turtle) '
    file = None

    # ----- basic turtle commands -----
    def do_forward(self, arg):
        'Move the turtle forward by the specified distance:
        forward(*parse(arg))

    def do_right(self, arg):
        'Turn turtle right by given number of degrees:
```
right(*parse(arg))

def do_left(self, arg):
    'Turn turtle left by given number of degrees'
    left(*parse(arg))

def do_goto(self, arg):
    'Move turtle to an absolute position with changing orientation.'
    goto(*parse(arg))

def do_home(self, arg):
    'Return turtle to the home position: HOME'
    home()

def do_circle(self, arg):
    'Draw circle with given radius and options'  
    circle(*parse(arg))

def do_position(self, arg):
    'Print the current turtle position: POSITION'
    print('Current position is %d %d\n' % position)

def do_heading(self, arg):
    'Print the current turtle heading in degrees:'
    print('Current heading is %d\n' % (heading()))

def do_color(self, arg):
    'Set the color: COLOR BLUE'
    color(arg.lower())

def do_undo(self, arg):
    'Undo (repeatedly) the last turtle action(s)'

def do_reset(self, arg):
    'Clear the screen and return turtle to center'
    reset()

def do_bye(self, arg):
    'Stop recording, close the turtle window, and exit'
    print('Thank you for using Turtle')
    self.close()
    bye()
    return True

# ----- record and playback -----  
def do_record(self, arg):
    'Save future commands to filename: RECORD rose.cmd'
self.file = open(arg, 'w')

def do_playback(self, arg):
    'Playback commands from a file: PLAYBACK records commands from
    a file and replays them.
    '    self.close()
    with open(arg) as f:
        self.cmdqueue.extend(f.read().splitlines)

def precmd(self, line):
    line = line.lower()
    if self.file and 'playback' not in line:
        print(line, file=self.file)
        return line

def close(self):
    if self.file:
        self.file.close()
        self.file = None

def parse(arg):
    'Convert a series of zero or more numbers to an argument tuple'
    return tuple(map(int, arg.split()))

if __name__ == '__main__':
    TurtleShell().cmdloop()

Here is a sample session with the turtle shell showing the help functions, using blank lines to repeat commands, and the simple record and playback facility:

Welcome to the turtle shell. Type help or ? to list commands.
(turtle) ?

Documented commands (type help <topic>):
bye  color  goto  home  playback  record  right  circle  forward  heading  left  position  reset  undo
Move the turtle forward by the specified distance:

```
(turtle) forward 10
(turtle) record spiral.cmd
(turtle) position
Current position is 0 0

(turtle) heading
Current heading is 0

(turtle) reset
(turtle) circle 20
(turtle) right 30
(turtle) circle 40
(turtle) right 30
(turtle) circle 60
(turtle) right 30
(turtle) circle 80
(turtle) right 30
(turtle) circle 100
(turtle) right 30
(turtle) circle 120
(turtle) right 30
(turtle) circle 120
(turtle) heading
Current heading is 180

(turtle) forward 100
(turtle)
(turtle) right 90
(turtle) forward 100
(turtle)
(turtle) right 90
(turtle) forward 400
(turtle) right 90
(turtle) forward 500
(turtle) right 90
(turtle) forward 400
```
(turtle) right 90
(turtle) forward 300
(turtle) playback spiral.cmd
Current position is 0 0

Current heading is 0

Current heading is 180

(turtle) bye
Thank you for using Turtle
24.3. `shlex` — Simple lexical analysis

**Source code:** Lib/shlex.py

The `shlex` class makes it easy to write lexical analyzers for simple syntaxes resembling that of the Unix shell. This will often be useful for writing minilanguages, (for example, in run control files for Python applications) or for parsing quoted strings.

The `shlex` module defines the following functions:

```python
shlex.split(s, comments=False, posix=True)
```

Split the string `s` using shell-like syntax. If `comments` is `False` (the default), the parsing of comments in the given string will be disabled (setting the `commenters` attribute of the `shlex` instance to the empty string). This function operates in POSIX mode by default, but uses non-POSIX mode if the `posix` argument is false.

**Note:** Since the `split()` function instantiates a `shlex` instance, passing `None` for `s` will read the string to split from standard input.

```python
shlex.quote(s)
```

Return a shell-escaped version of the string `s`. The returned value is a string that can safely be used as one token in a shell command line, for cases where you cannot use a list.

This idiom would be unsafe:
```python
>>> filename = 'somefile; rm -rf ~'
>>> command = 'ls -l {}'.format(filename)
>>> print(command)  # executed by a shell: boom!
ls -l somefile; rm -rf ~
```

`quote()` lets you plug the security hole:

```python
>>> command = 'ls -l {}'.format(quote(filename))
>>> print(command)
ls -l 'somefile; rm -rf ~'
>>> remote_command = 'ssh home {}'.format(quote(command))
>>> print(remote_command)
ssh home 'ls -l """somefile; rm -rf ~"""'
```

The quoting is compatible with UNIX shells and with `split()`:

```python
>>> remote_command = split(remote_command)
>>> remote_command
['ssh', 'home', 'ls -l """somefile; rm -rf ~"""
>>> command = split(remote_command[-1])
>>> command
['ls', '-l', 'somefile; rm -rf ~']
```

*New in version 3.3.*

The `shlex` module defines the following class:

```python
class shlex.**shlex**(instream=None, infile=None, posix=False)
```

A `shlex` instance or subclass instance is a lexical analyzer object. The initialization argument, if present, specifies where to read characters from. It must be a file-/stream-like object with `read()` and `readline()` methods, or a string. If no argument is given, input will be taken from `sys.stdin`. The second optional
argument is a filename string, which sets the initial value of the `inFILE` attribute. If the `inSTREAM` argument is omitted or equal to `sys.stdin`, this second argument defaults to “stdin”. The `posix` argument defines the operational mode: when `posix` is not true (default), the `shlex` instance will operate in compatibility mode. When operating in POSIX mode, `shlex` will try to be as close as possible to the POSIX shell parsing rules.

**See also:**

**Module** `configparser`

Parser for configuration files similar to the Windows `.ini` files.
24.3.1. shlex Objects

A shlex instance has the following methods:

shlex.get_token()
Return a token. If tokens have been stacked using push_token(), pop a token off the stack. Otherwise, read one from the input stream. If reading encounters an immediate end-of-file, eof is returned (the empty string ('') in non-POSIX mode, and None in POSIX mode).

shlex.push_token(str)
Push the argument onto the token stack.

shlex.read_token()
Read a raw token. Ignore the pushback stack, and do not interpret source requests. (This is not ordinarily a useful entry point, and is documented here only for the sake of completeness.)

shlex.sourcehook(filename)
When shlex detects a source request (see source below) this method is given the following token as argument, and expected to return a tuple consisting of a filename and an open file-like object.

Normally, this method first strips any quotes off the argument. If the result is an absolute pathname, or there was no previous source request in effect, or the previous source was a stream (such as sys.stdin), the result is left alone. Otherwise, if the result is a relative pathname, the directory part of the name of the file immediately before it on the source inclusion stack is prepended (this behavior is like the way the C preprocessor handles
#include "file.h").

The result of the manipulations is treated as a filename, and returned as the first component of the tuple, with open() called on it to yield the second component. (Note: this is the reverse of the order of arguments in instance initialization!)

This hook is exposed so that you can use it to implement directory search paths, addition of file extensions, and other namespace hacks. There is no corresponding ‘close’ hook, but a shlex instance will call the close() method of the sourced input stream when it returns EOF.

For more explicit control of source stacking, use the push_source() and pop_source() methods.

shlex.push_source(newstream, newfile=None)

Push an input source stream onto the input stack. If the filename argument is specified it will later be available for use in error messages. This is the same method used internally by the sourcehook() method.

shlex.pop_source()

Pop the last-pushed input source from the input stack. This is the same method used internally when the lexer reaches EOF on a stacked input stream.

shlex.error_leader(infile=None, lineno=None)

This method generates an error message leader in the format of a Unix C compiler error label; the format is ""%s", line %d: ", where the %s is replaced with the name of the current source file and the %d with the current input line number (the optional
arguments can be used to override these).

This convenience is provided to encourage `shlex` users to generate error messages in the standard, parseable format understood by Emacs and other Unix tools.

Instances of `shlex` subclasses have some public instance variables which either control lexical analysis or can be used for debugging:

**shlex.commenters**

The string of characters that are recognized as comment beginners. All characters from the comment beginner to end of line are ignored. Includes just '#' by default.

**shlex.wordchars**

The string of characters that will accumulate into multi-character tokens. By default, includes all ASCII alphanumerics and underscore.

**shlex.whitespace**

Characters that will be considered whitespace and skipped. Whitespace bounds tokens. By default, includes space, tab, linefeed and carriage-return.

**shlex.escape**

Characters that will be considered as escape. This will be only used in POSIX mode, and includes just '\' by default.

**shlex.quotes**

Characters that will be considered string quotes. The token accumulates until the same quote is encountered again (thus, different quote types protect each other as in the shell.) By default, includes ASCII single and double quotes.
shlex.**escapedquotes**
Characters in *quotes* that will interpret escape characters defined in *escape*. This is only used in POSIX mode, and includes just `'"' by default.

shlex.**whitespace_split**
If True, tokens will only be split in whitespaces. This is useful, for example, for parsing command lines with *shlex*, getting tokens in a similar way to shell arguments.

shlex.**infile**
The name of the current input file, as initially set at class instantiation time or stacked by later source requests. It may be useful to examine this when constructing error messages.

shlex.**instream**
The input stream from which this *shlex* instance is reading characters.

shlex.**source**
This attribute is None by default. If you assign a string to it, that string will be recognized as a lexical-level inclusion request similar to the source keyword in various shells. That is, the immediately following token will opened as a filename and input taken from that stream until EOF, at which point the *close()* method of that stream will be called and the input source will again become the original input stream. Source requests may be stacked any number of levels deep.

shlex.**debug**
If this attribute is numeric and 1 or more, a *shlex* instance will print verbose progress output on its behavior. If you need to use
this, you can read the module source code to learn the details.

**shlex.lineno**

Source line number (count of newlines seen so far plus one).

**shlex.token**

The token buffer. It may be useful to examine this when catching exceptions.

**shlex.eof**

Token used to determine end of file. This will be set to the empty string (''), in non-POSIX mode, and to None in POSIX mode.
24.3.2. Parsing Rules

When operating in non-POSIX mode, `shlex` will try to obey to the following rules.

- Quote characters are not recognized within words (Do"Not"Separate is parsed as the single word Do"Not"Separate);
- Escape characters are not recognized;
- Enclosing characters in quotes preserve the literal value of all characters within the quotes;
- Closing quotes separate words ("Do"Separate is parsed as "Do" and Separate);
- If `whitespace_split` is False, any character not declared to be a word character, whitespace, or a quote will be returned as a single-character token. If it is True, `shlex` will only split words in whitespaces;
- EOF is signaled with an empty string (' ');
- It’s not possible to parse empty strings, even if quoted.

When operating in POSIX mode, `shlex` will try to obey to the following parsing rules.

- Quotes are stripped out, and do not separate words ("Do"Not"Separate" is parsed as the single word DoNotSeparate);
- Non-quoted escape characters (e.g. '\') preserve the literal value of the next character that follows;
- Enclosing characters in quotes which are not part of `escapedquotes` (e.g. '""") preserve the literal value of all characters within the quotes;
- Enclosing characters in quotes which are part of
escapedquotes (e.g. "'"') preserves the literal value of all characters within the quotes, with the exception of the characters mentioned in escape. The escape characters retain its special meaning only when followed by the quote in use, or the escape character itself. Otherwise the escape character will be considered a normal character.

- EOF is signaled with a None value;
- Quoted empty strings ("'") are allowed.
25. Graphical User Interfaces with Tk

Tk/Tcl has long been an integral part of Python. It provides a robust and platform independent windowing toolkit, that is available to Python programmers using the `tkinter` package, and its extension, the `tkinter.tix` and the `tkinter.ttk` modules.

The `tkinter` package is a thin object-oriented layer on top of Tcl/Tk. To use `tkinter`, you don't need to write Tcl code, but you will need to consult the Tk documentation, and occasionally the Tcl documentation. `tkinter` is a set of wrappers that implement the Tk widgets as Python classes. In addition, the internal module `_tkinter` provides a threadsafe mechanism which allows Python and Tcl to interact.

`tkinter`'s chief virtues are that it is fast, and that it usually comes bundled with Python. Although its standard documentation is weak, good material is available, which includes: references, tutorials, a book and others. `tkinter` is also famous for having an outdated look and feel, which has been vastly improved in Tk 8.5. Nevertheless, there are many other GUI libraries that you could be interested in. For more information about alternatives, see the Other Graphical User Interface Packages section.

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- 25.6. Other Graphical User Interface Packages
25.1. **tkinter — Python interface to Tcl/Tk**

The `tkinter` package ("Tk interface") is the standard Python interface to the Tk GUI toolkit. Both Tk and `tkinter` are available on most Unix platforms, as well as on Windows systems. (Tk itself is not part of Python; it is maintained at ActiveState.) You can check that `tkinter` is properly installed on your system by running `python -m tkinter` from the command line; this should open a window demonstrating a simple Tk interface.

---

**See also:**

**Python Tkinter Resources**
- The Python Tkinter Topic Guide provides a great deal of information on using Tk from Python and links to other sources of information on Tk.

**TKDocs**
- Extensive tutorial plus friendlier widget pages for some of the widgets.

**Tkinter reference: a GUI for Python**
- On-line reference material.

**Tkinter docs from effbot**
- Online reference for tkinter supported by effbot.org.

**Tcl/Tk manual**
- Official manual for the latest tcl/tk version.

**Programming Python**
- Book by Mark Lutz, has excellent coverage of Tkinter.

**Modern Tkinter for Busy Python Developers**
Book by Mark Rozerman about building attractive and modern graphical user interfaces with Python and Tkinter.

**Python and Tkinter Programming**

25.1.1. Tkinter Modules

Most of the time, tkinter is all you really need, but a number of additional modules are available as well. The Tk interface is located in a binary module named _tkinter. This module contains the low-level interface to Tk, and should never be used directly by application programmers. It is usually a shared library (or DLL), but might in some cases be statically linked with the Python interpreter.

In addition to the Tk interface module, tkinter includes a number of Python modules, tkinter.constants being one of the most important. Importing tkinter will automatically import tkinter.constants, so, usually, to use Tkinter all you need is a simple import statement:

```python
import tkinter
```

Or, more often:

```python
from tkinter import *
```

class tkinter.Tk(screenName=None, baseName=None, className='Tk', useTk=1)

The Tk class is instantiated without arguments. This creates a toplevel widget of Tk which usually is the main window of an application. Each instance has its own associated Tcl interpreter.

tkinter.Tcl(screenName=None, baseName=None, className='Tk', useTk=0)

The Tcl() function is a factory function which creates an object much like that created by the Tk class, except that it does not
initialize the Tk subsystem. This is most often useful when driving
the Tcl interpreter in an environment where one doesn’t want to
create extraneous toplevel windows, or where one cannot (such as
Unix/Linux systems without an X server). An object created by the
Tcl() object can have a Toplevel window created (and the Tk
subsystem initialized) by calling its loadtk() method.

Other modules that provide Tk support include:

**tkinter.scrolledtext**
Text widget with a vertical scroll bar built in.

**tkinter.colorchooser**
Dialog to let the user choose a color.

**tkinter.commondialog**
Base class for the dialogs defined in the other modules listed here.

**tkinter.filedialog**
Common dialogs to allow the user to specify a file to open or save.

**tkinter.font**
Utilities to help work with fonts.

**tkinter.messagebox**
Access to standard Tk dialog boxes.

**tkinter.simpledialog**
Basic dialogs and convenience functions.

**tkinter.dnd**
Drag-and-drop support for tkinter. This is experimental and
should become deprecated when it is replaced with the Tk DND.

**turtle**
Turtle graphics in a Tk window.
25.1.2. Tkinter Life Preserver

This section is not designed to be an exhaustive tutorial on either Tk or Tkinter. Rather, it is intended as a stop gap, providing some introductory orientation on the system.

Credits:

- Tk was written by John Ousterhout while at Berkeley.
- Tkinter was written by Steen Lumholt and Guido van Rossum.
- This Life Preserver was written by Matt Conway at the University of Virginia.
- The HTML rendering, and some liberal editing, was produced from a FrameMaker version by Ken Manheimer.
- Fredrik Lundh elaborated and revised the class interface descriptions, to get them current with Tk 4.2.
- Mike Clarkson converted the documentation to LaTeX, and compiled the User Interface chapter of the reference manual.

25.1.2.1. How To Use This Section

This section is designed in two parts: the first half (roughly) covers background material, while the second half can be taken to the keyboard as a handy reference.

When trying to answer questions of the form “how do I do blah”, it is often best to find out how to do"blah” in straight Tk, and then convert this back into the corresponding `tkinter` call. Python programmers can often guess at the correct Python command by looking at the Tk documentation. This means that in order to use Tkinter, you will have to know a little bit about Tk. This document can’t fulfill that role, so the best we can do is point you to the best documentation that exists.
Here are some hints:

- The authors strongly suggest getting a copy of the Tk man pages. Specifically, the man pages in the manN directory are most useful. The man3 man pages describe the C interface to the Tk library and thus are not especially helpful for script writers.
- Addison-Wesley publishes a book called Tcl and the Tk Toolkit by John Ousterhout (ISBN 0-201-63337-X) which is a good introduction to Tcl and Tk for the novice. The book is not exhaustive, and for many details it defers to the man pages.
- tkinter/__init__.py is a last resort for most, but can be a good place to go when nothing else makes sense.

See also:

**Tcl/Tk 8.6 man pages**
The Tcl/Tk manual on www.tcl.tk.

**ActiveState Tcl Home Page**
The Tk/Tcl development is largely taking place at ActiveState.

**Tcl and the Tk Toolkit**
The book by John Ousterhout, the inventor of Tcl.

**Practical Programming in Tcl and Tk**
Brent Welch’s encyclopedic book.

25.1.2.2. A Simple Hello World Program

```python
import tkinter as tk

class Application(tk.Frame):
    def __init__(self, master=None):
        tk.Frame.__init__(self, master)
        self.pack()
        self.createWidgets()
```
```python
def createWidgets(self):
    self.hi_there = tk.Button(self)
    self.hi_there['text'] = 'Hello World
    (click me)
    self.hi_there['command'] = self.say_hi
    self.hi_there.pack(side="top")

    self.QUIT = tk.Button(self, text="QUIT", fg=
                             command=self.quit)
    self.QUIT.pack(side="bottom")

    def say_hi(self):
        print("hi there, everyone!")

root = tk.Tk()
app = Application(master=root)
app.mainloop()
```
25.1.3. A (Very) Quick Look at Tcl/Tk

The class hierarchy looks complicated, but in actual practice, application programmers almost always refer to the classes at the very bottom of the hierarchy.

Notes:

- These classes are provided for the purposes of organizing certain functions under one namespace. They aren’t meant to be instantiated independently.
- The Tk class is meant to be instantiated only once in an application. Application programmers need not instantiate one explicitly, the system creates one whenever any of the other classes are instantiated.
- The Widget class is not meant to be instantiated, it is meant only for subclassing to make “real” widgets (in C++, this is called an ‘abstract class’).

To make use of this reference material, there will be times when you will need to know how to read short passages of Tk and how to identify the various parts of a Tk command. (See section Mapping Basic Tk into Tkinter for the tkinter equivalents of what’s below.)

Tk scripts are Tcl programs. Like all Tcl programs, Tk scripts are just lists of tokens separated by spaces. A Tk widget is just its class, the options that help configure it, and the actions that make it do useful things.

To make a widget in Tk, the command is always of the form:

```
classCommand newPathname options
```
classCommand
denotes which kind of widget to make (a button, a label, a menu...)

newPathname
is the new name for this widget. All names in Tk must be unique. To help enforce this, widgets in Tk are named with pathnames, just like files in a file system. The top level widget, the root, is called . (period) and children are delimited by more periods. For example, .myApp.controlPanel.okButton might be the name of a widget.

options
configure the widget’s appearance and in some cases, its behavior. The options come in the form of a list of flags and values. Flags are preceded by a ‘-‘, like Unix shell command flags, and values are put in quotes if they are more than one word.

For example:

```
button .fred -fg red -text "hi there"
          ^          ^                  \______________________/
           |          |                  /         |
        class    new        options
    command  widget  (-opt val -opt val ...)
```

Once created, the pathname to the widget becomes a new command. This new widget command is the programmer’s handle for getting the new widget to perform some action. In C, you’d express this as someAction(fred, someOptions), in C++, you would express this as fred.someAction(someOptions), and in Tk, you say:

```
.fred someAction someOptions
```

Note that the object name, .fred, starts with a dot.
As you’d expect, the legal values for *someAction* will depend on the widget’s class: `.fred disable` works if fred is a button (fred gets greyed out), but does not work if fred is a label (disabling of labels is not supported in Tk).

The legal values of *someOptions* is action dependent. Some actions, like disable, require no arguments, others, like a text-entry box’s delete command, would need arguments to specify what range of text to delete.
25.1.4. Mapping Basic Tk into Tkinter

Class commands in Tk correspond to class constructors in Tkinter.

```
button .fred          ===>  fred = Button()
```

The master of an object is implicit in the new name given to it at creation time. In Tkinter, masters are specified explicitly.

```
button .panel.fred    ===>  fred = Button(panel)
```

The configuration options in Tk are given in lists of hyphenated tags followed by values. In Tkinter, options are specified as keyword-arguments in the instance constructor, and keyword-args for configure calls or as instance indices, in dictionary style, for established instances. See section Setting Options on setting options.

```
button .fred -fg red  ===>  fred = Button(panel)
.fred configure -fg red ===>  fred["fg"] = red
OR ===>  fred.config(fg=
```

In Tk, to perform an action on a widget, use the widget name as a command, and follow it with an action name, possibly with arguments (options). In Tkinter, you call methods on the class instance to invoke actions on the widget. The actions (methods) that a given widget can perform are listed in tkinter/__init__.py.

```
.fred invoke          ===>  fred.invoke()
```

To give a widget to the packer (geometry manager), you call pack with optional arguments. In Tkinter, the Pack class holds all this
functionality, and the various forms of the pack command are implemented as methods. All widgets in tkinter are subclassed from the Packer, and so inherit all the packing methods. See the tkinter.tix module documentation for additional information on the Form geometry manager.

```python
def pack(fred, side='left')
```

```
pack .fred -side left ======> fred.pack(side='left')
```
25.1.5. How Tk and Tkinter are Related

From the top down:

Your App Here (Python)
A Python application makes a tkinter call.

tkinter (Python Package)
This call (say, for example, creating a button widget), is implemented in the tkinter package, which is written in Python. This Python function will parse the commands and the arguments and convert them into a form that makes them look as if they had come from a Tk script instead of a Python script.

ltkinter (C)
These commands and their arguments will be passed to a C function in the _tkinter - note the underscore - extension module.

Tk Widgets (C and Tcl)
This C function is able to make calls into other C modules, including the C functions that make up the Tk library. Tk is implemented in C and some Tcl. The Tcl part of the Tk widgets is used to bind certain default behaviors to widgets, and is executed once at the point where the Python tkinter package is imported. (The user never sees this stage).

Tk (C)
The Tk part of the Tk Widgets implement the final mapping to ...

Xlib (C)
the Xlib library to draw graphics on the screen.
25.1.6. Handy Reference

25.1.6.1. Setting Options

Options control things like the color and border width of a widget. Options can be set in three ways:

At object creation time, using keyword arguments

```python
fred = Button(self, fg="red", bg="blue")
```

After object creation, treating the option name like a dictionary index

```python
fred["fg"] = "red"
fred["bg"] = "blue"
```

Use the config() method to update multiple attrs subsequent to object creation

```python
fred.config(fg="red", bg="blue")
```

For a complete explanation of a given option and its behavior, see the Tk man pages for the widget in question.

Note that the man pages list “STANDARD OPTIONS” and “WIDGET SPECIFIC OPTIONS” for each widget. The former is a list of options that are common to many widgets, the latter are the options that are idiosyncratic to that particular widget. The Standard Options are documented on the options(3) man page.

No distinction between standard and widget-specific options is made in this document. Some options don’t apply to some kinds of widgets. Whether a given widget responds to a particular option depends on the class of the widget; buttons have a command option, labels do not.
The options supported by a given widget are listed in that widget’s man page, or can be queried at runtime by calling the `config()` method without arguments, or by calling the `keys()` method on that widget. The return value of these calls is a dictionary whose key is the name of the option as a string (for example, 'relief') and whose values are 5-tuples.

Some options, like bg are synonyms for common options with long names (bg is shorthand for “background”). Passing the `config()` method the name of a shorthand option will return a 2-tuple, not a 5-tuple. The 2-tuple passed back will contain the name of the synonym and the “real” option (such as ('bg', 'background')).

<table>
<thead>
<tr>
<th>Index</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>option name</td>
<td>'relief'</td>
</tr>
<tr>
<td>1</td>
<td>option name for database lookup</td>
<td>'relief'</td>
</tr>
<tr>
<td>2</td>
<td>option class for database lookup</td>
<td>'Relief'</td>
</tr>
<tr>
<td>3</td>
<td>default value</td>
<td>'raised'</td>
</tr>
<tr>
<td>4</td>
<td>current value</td>
<td>'groove'</td>
</tr>
</tbody>
</table>

Example:

```python
>>> print(fred.config())
{'relief': ('relief', 'relief', 'Relief', 'raised', 'groove')}
```

Of course, the dictionary printed will include all the options available and their values. This is meant only as an example.

25.1.6.2. The Packer
The packer is one of Tk’s geometry-management mechanisms. Geometry managers are used to specify the relative positioning of the positioning of widgets within their container - their mutual master. In contrast to the more cumbersome placer (which is used less commonly, and we do not cover here), the packer takes qualitative relationship specification - above, to the left of, filling, etc - and works everything out to determine the exact placement coordinates for you.

The size of any master widget is determined by the size of the “slave widgets” inside. The packer is used to control where slave widgets appear inside the master into which they are packed. You can pack widgets into frames, and frames into other frames, in order to achieve the kind of layout you desire. Additionally, the arrangement is dynamically adjusted to accommodate incremental changes to the configuration, once it is packed.

Note that widgets do not appear until they have had their geometry specified with a geometry manager. It’s a common early mistake to leave out the geometry specification, and then be surprised when the widget is created but nothing appears. A widget will appear only after it has had, for example, the packer’s pack() method applied to it.

The pack() method can be called with keyword-option/value pairs that control where the widget is to appear within its container, and how it is to behave when the main application window is resized. Here are some examples:

```python
fred.pack()  # defaults to side =
fred.pack(side="left")
fred.pack(expand=1)
```

25.1.6.3. Packer Options
For more extensive information on the packer and the options that it can take, see the man pages and page 183 of John Ousterhout's book.

anchor
   Anchor type. Denotes where the packer is to place each slave in its parcel.

expand
   Boolean, 0 or 1.

fill
   Legal values: 'x', 'y', 'both', 'none'.

ipadx and ipady
   A distance - designating internal padding on each side of the slave widget.

padx and pady
   A distance - designating external padding on each side of the slave widget.

side
   Legal values are: 'left', 'right', 'top', 'bottom'.

25.1.6.4. Coupling Widget Variables

The current-value setting of some widgets (like text entry widgets) can be connected directly to application variables by using special options. These options are variable, textvariable, onvalue, offvalue, and value. This connection works both ways: if the variable changes for any reason, the widget it's connected to will be updated to reflect the new value.

Unfortunately, in the current implementation of tkinter it is not possible to hand over an arbitrary Python variable to a widget through
a variable or textvariable option. The only kinds of variables for which this works are variables that are subclassed from a class called Variable, defined in tkinter.

There are many useful subclasses of Variable already defined: StringVar, IntVar, DoubleVar, and BooleanVar. To read the current value of such a variable, call the get() method on it, and to change its value you call the set() method. If you follow this protocol, the widget will always track the value of the variable, with no further intervention on your part.

For example:

class App(Frame):
    def __init__(self, master=None):
        Frame.__init__(self, master)
        self.pack()

        self.entrythingy = Entry()
        self.entrythingy.pack()

        # here is the application variable
        self.contents = StringVar()
        # set it to some value
        self.contents.set("this is a variable")
        # tell the entry widget to watch this variable
        self.entrythingy["textvariable"] = self.contents

        # and here we get a callback when the user hits return
        # we will have the program print out the value of
        # application variable when the user hits return
        self.entrythingy.bind('<Key-Return>',
                                self.print_contents)

def print_contents(self, event):
25.1.6.5. The Window Manager

In Tk, there is a utility command, `wm`, for interacting with the window manager. Options to the `wm` command allow you to control things like titles, placement, icon bitmaps, and the like. In `tkinter`, these commands have been implemented as methods on the `Wm` class. Toplevel widgets are subclassed from the `Wm` class, and so can call the `Wm` methods directly.

To get at the toplevel window that contains a given widget, you can often just refer to the widget's master. Of course if the widget has been packed inside of a frame, the master won't represent a toplevel window. To get at the toplevel window that contains an arbitrary widget, you can call the `_root()` method. This method begins with an underscore to denote the fact that this function is part of the implementation, and not an interface to Tk functionality.

Here are some examples of typical usage:

```python
from tkinter import *
class App(Frame):
    def __init__(self, master=None):
        Frame.__init__(self, master)
        self.pack()

# create the application
myapp = App()
```

```python
print("hi. contents of entry is now -->", self.contents.get())
```
here are method calls to the window manager class

myapp.master.title("My Do-Nothing Application")
myapp.master.maxsize(1000, 400)

# start the program
myapp.mainloop()

25.1.6.6. Tk Option Data Types

anchor
Legal values are points of the compass: "n", "ne", "e", "se", "s", "sw", "w", "nw", and also "center".

bitmap
There are eight built-in, named bitmaps: 'error', 'gray25', 'gray50', 'hourglass', 'info', 'questhead', 'question', 'warning'. To specify an X bitmap filename, give the full path to the file, preceded with an @, as in '@/usr/contrib/bitmap/gumby.bit'.

boolean
You can pass integers 0 or 1 or the strings "yes" or "no".

callback
This is any Python function that takes no arguments. For example:

```python
def print_it():
    print("hi there")
fred["command"] = print_it
```

color
Colors can be given as the names of X colors in the rgb.txt file, or as strings representing RGB values in 4 bit: "#RGB", 8 bit: "#RRGGBB", 12 bit "#RRRGGGGBBB", or 16 bit "#RRRRGGGGGBBBB"

cursor
The standard X cursor names from cursorfont.h can be used, without the XC_ prefix. For example to get a hand cursor (XC_hand2), use the string "hand2". You can also specify a bitmap and mask file of your own. See page 179 of Ousterhout's book.

distance
Screen distances can be specified in either pixels or absolute distances. Pixels are given as numbers and absolute distances as strings, with the trailing character denoting units: c for centimetres, i for inches, m for millimetres, p for printer's points. For example, 3.5 inches is expressed as "3.5i".

font
Tk uses a list font name format, such as {courier 10 bold}. Font sizes with positive numbers are measured in points; sizes with negative numbers are measured in pixels.

geometry
This is a string of the form widthxheight, where width and height are measured in pixels for most widgets (in characters for widgets displaying text). For example: fred["geometry"] = "200x100".

justify
Legal values are the strings: "left", "center", "right", and "fill".

region
This is a string with four space-delimited elements, each of which is a legal distance (see above). For example: "2 3 4 5" and "3i 2i 4.5i 2i" and "3c 2c 4c 10.43c" are all legal regions.
relief
Determines what the border style of a widget will be. Legal values are: "raised", "sunken", "flat", "groove", and "ridge".

scrollcommand
This is almost always the set() method of some scrollbar widget, but can be any widget method that takes a single argument.

wrap:
Must be one of: "none", "char", or "word".

25.1.6.7. Bindings and Events

The bind method from the widget command allows you to watch for certain events and to have a callback function trigger when that event type occurs. The form of the bind method is:

```python
def bind(self, sequence, func, add=' '):
```

where:

sequence
is a string that denotes the target kind of event. (See the bind man page and page 201 of John Ousterhout's book for details).

func
is a Python function, taking one argument, to be invoked when the event occurs. An Event instance will be passed as the argument. (Functions deployed this way are commonly known as callbacks.)

add
is optional, either '' or '+' . Passing an empty string denotes that this binding is to replace any other bindings that this event is associated with. Passing a '+' means that this function is to be added to the list of functions bound to this event type.
def turnRed(self, event):
    event.widget["activeforeground"] = "red"

self.button.bind("<Enter>", self.turnRed)

Notice how the widget field of the event is being accessed in the turnRed() callback. This field contains the widget that caught the X event. The following table lists the other event fields you can access, and how they are denoted in Tk, which can be useful when referring to the Tk man pages.

<table>
<thead>
<tr>
<th>Tk</th>
<th>Tkinter Event Field</th>
<th>Tk</th>
<th>Tkinter Event Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>%f</td>
<td>focus</td>
<td>%A</td>
<td>char</td>
</tr>
<tr>
<td>%h</td>
<td>height</td>
<td>%E</td>
<td>send_event</td>
</tr>
<tr>
<td>%k</td>
<td>keycode</td>
<td>%K</td>
<td>keysym</td>
</tr>
<tr>
<td>%s</td>
<td>state</td>
<td>%N</td>
<td>keysym_num</td>
</tr>
<tr>
<td>%t</td>
<td>time</td>
<td>%T</td>
<td>type</td>
</tr>
<tr>
<td>%w</td>
<td>width</td>
<td>%W</td>
<td>widget</td>
</tr>
<tr>
<td>%x</td>
<td>x</td>
<td>%X</td>
<td>x_root</td>
</tr>
<tr>
<td>%y</td>
<td>y</td>
<td>%Y</td>
<td>y_root</td>
</tr>
</tbody>
</table>

25.1.6.8. The index Parameter

A number of widgets require “index” parameters to be passed. These are used to point at a specific place in a Text widget, or to particular characters in an Entry widget, or to particular menu items in a Menu widget.

Entry widget indexes (index, view index, etc.)
Entry widgets have options that refer to character positions in the text being displayed. You can use these tkinter functions to access these special points in text widgets:

Text widget indexes
The index notation for Text widgets is very rich and is best described in the Tk man pages.

Menu indexes (menu.invoke(), menu.entryconfig(), etc.)
Some options and methods for menus manipulate specific menu entries. Anytime a menu index is needed for an option or a parameter, you may pass in:

- an integer which refers to the numeric position of the entry in the widget, counted from the top, starting with 0;
- the string "active", which refers to the menu position that is currently under the cursor;
- the string "last" which refers to the last menu item;
- An integer preceded by @, as in @6, where the integer is interpreted as a y pixel coordinate in the menu’s coordinate system;
- the string "none", which indicates no menu entry at all, most often used with menu.activate() to deactivate all entries, and
- a text string that is pattern matched against the label of the menu entry, as scanned from the top of the menu to the bottom. Note that this index type is considered after all the others, which means that matches for menu items labelled last, active, or none may be interpreted as the above literals, instead.

25.1.6.9. Images
Bitmap/ Pixelmap images can be created through the subclasses of
tkinter.Image:

- BitmapImage can be used for X11 bitmap data.
- PhotoImage can be used for GIF and PPM/PGM color bitmaps.

Either type of image is created through either the file or the data option (other options are available as well).

The image object can then be used wherever an image option is supported by some widget (e.g. labels, buttons, menus). In these cases, Tk will not keep a reference to the image. When the last Python reference to the image object is deleted, the image data is deleted as well, and Tk will display an empty box wherever the image was used.
25.1.7. File Handlers

Tk allows you to register and unregister a callback function which will be called from the Tk mainloop when I/O is possible on a file descriptor. Only one handler may be registered per file descriptor. Example code:

```python
import tkinter
widget = tkinter.Tk()
mask = tkinter.READABLE | tkinter.WRITABLE
widget.tk.createfilehandler(file, mask, callback)
...
widget.tk.deletefilehandler(file)
```

This feature is not available on Windows.

Since you don’t know how many bytes are available for reading, you may not want to use the `BufferedIOBase` or `TextIOBase` `read()` or `readline()` methods, since these will insist on reading a predefined number of bytes. For sockets, the `recv()` or `recvfrom()` methods will work fine; for other files, use raw reads or `os.read(file.fileno(), maxbytecount)`. 

`Widget.tk.createfilehandler(file, mask, func)`

Registers the file handler callback function `func`. The `file` argument may either be an object with a `fileno()` method (such as a file or socket object), or an integer file descriptor. The `mask` argument is an ORed combination of any of the three constants below. The callback is called as follows:

```python
callback(file, mask)
```
Widget.tk.deletefilehandler(file)

Unregisters a file handler.

tkinter.READABLE
tkinter.WRITABLE
tkinter.EXCEPTION

Constants used in the mask arguments.
25.2. **tkinter.ttk** — Tk themed widgets

The `tkinter.ttk` module provides access to the Tk themed widget set, introduced in Tk 8.5. If Python has not been compiled against Tk 8.5, this module can still be accessed if *Tile* has been installed. The former method using Tk 8.5 provides additional benefits including anti-aliased font rendering under X11 and window transparency (requiring a composition window manager on X11).

The basic idea for `tkinter.ttk` is to separate, to the extent possible, the code implementing a widget's behavior from the code implementing its appearance.

**See also:**

**Tk Widget Styling Support**
A document introducing theming support for Tk
25.2.1. Using Ttk

To start using Ttk, import its module:

```python
from tkinter import ttk
```

To override the basic Tk widgets, the import should follow the Tk import:

```python
from tkinter import *
from tkinter.ttk import *
```

That code causes several `tkinter.ttk` widgets (Button, Checkbutton, Entry, Frame, Label, LabelFrame, Menubutton, PanedWindow, Radiobutton, Scale and Scrollbar) to automatically replace the Tk widgets.

This has the direct benefit of using the new widgets which gives a better look and feel across platforms; however, the replacement widgets are not completely compatible. The main difference is that widget options such as “fg”, “bg” and others related to widget styling are no longer present in Ttk widgets. Instead, use the `ttk.Style` class for improved styling effects.

**See also:**

**Converting existing applications to use Tile widgets**

A monograph (using Tcl terminology) about differences typically encountered when moving applications to use the new widgets.
25.2.2. Ttk Widgets

Ttk comes with 17 widgets, eleven of which already existed in tkinter: Button, Checkbutton, Entry, Frame, Label, LabelFrame, Menubutton, PanedWindow, Radiobutton, Scale and Scrollbar. The other six are new: Combobox, Notebook, Progressbar, Separator, Sizegrip and Treeview. And all them are subclasses of Widget.

Using the Ttk widgets gives the application an improved look and feel. As discussed above, there are differences in how the styling is coded.

Tk code:

```python
l1 = tkinter.Label(text="Test", fg="black", bg="white")
l2 = tkinter.Label(text="Test", fg="black", bg="white")
```

Ttk code:

```python
style = ttk.Style()
style.configure("BW.TLabel", foreground="black", background="white")

l1 = ttk.Label(text="Test", style="BW.TLabel")
l2 = ttk.Label(text="Test", style="BW.TLabel")
```

For more information about TtkStyling, see the Style class documentation.
25.2.3. Widget

ttk.Widget defines standard options and methods supported by Tk themed widgets and is not supposed to be directly instantiated.

25.2.3.1. Standard Options

All the ttk Widgets accepts the following options:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>class</td>
<td>Specifies the window class. The class is used when querying the option database for the window's other options, to determine the default bindtags for the window, and to select the widget's default layout and style. This option is read-only, and may only be specified when the window is created.</td>
</tr>
<tr>
<td>cursor</td>
<td>Specifies the mouse cursor to be used for the widget. If set to the empty string (the default), the cursor is inherited for the parent widget.</td>
</tr>
<tr>
<td>takefocus</td>
<td>Determines whether the window accepts the focus during keyboard traversal. 0, 1 or an empty string is returned. If 0 is returned, it means that the window should be skipped entirely during keyboard traversal. If 1, it means that the window should receive the input focus as long as it is viewable. And an empty string means that the traversal scripts make the decision about whether or not to focus on the window.</td>
</tr>
<tr>
<td>style</td>
<td>May be used to specify a custom widget style.</td>
</tr>
</tbody>
</table>

25.2.3.2. Scrollable Widget Options
The following options are supported by widgets that are controlled by a scrollbar.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>xscrollcommand</td>
<td>Used to communicate with horizontal scrollbars. When the view in the widget's window change, the widget will generate a Tcl command based on the scrollcommand. Usually this option consists of the method Scrollbar.set() of some scrollbar. This will cause the scrollbar to be updated whenever the view in the window changes.</td>
</tr>
<tr>
<td>yscrollcommand</td>
<td>Used to communicate with vertical scrollbars. For some more information, see above.</td>
</tr>
</tbody>
</table>

25.2.3.3. Label Options

The following options are supported by labels, buttons and other button-like widgets.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>text</td>
<td>Specifies a text string to be displayed inside the widget.</td>
</tr>
<tr>
<td>textvariable</td>
<td>Specifies a name whose value will be used in place of the text option resource.</td>
</tr>
<tr>
<td>underline</td>
<td>If set, specifies the index (0-based) of a character to underline in the text string. The underline</td>
</tr>
</tbody>
</table>
character is used for mnemonic activation.

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>image</td>
<td>Specifies an image to display. This is a list of 1 or more elements. The first element is the default image name. The rest of the list if a sequence of statespec/value pairs as defined by Style.map(), specifying different images to use when the widget is in a particular state or a combination of states. All images in the list should have the same size.</td>
</tr>
<tr>
<td>compound</td>
<td>Specifies how to display the image relative to the text, in the case both text and images options are present. Valid values are:</td>
</tr>
<tr>
<td></td>
<td>- text: display text only</td>
</tr>
<tr>
<td></td>
<td>- image: display image only</td>
</tr>
<tr>
<td></td>
<td>- top, bottom, left, right: display image above, below, left of, or right of the text, respectively.</td>
</tr>
<tr>
<td></td>
<td>- none: the default. display the image if present, otherwise the text.</td>
</tr>
<tr>
<td>width</td>
<td>If greater than zero, specifies how much space, in character widths, to allocate for the text label, if less than zero, specifies a minimum width. If zero or unspecified, the natural width of the text label is used.</td>
</tr>
</tbody>
</table>

25.2.3.4. Compatibility Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>state</td>
<td>May be set to “normal” or “disabled” to control the “disabled” state bit. This is a write-only option: setting it changes the widget state, but the Widget.state() method does not affect this option.</td>
</tr>
</tbody>
</table>
25.2.3.5. Widget States

The widget state is a bitmap of independent state flags.

<table>
<thead>
<tr>
<th>Flag</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>active</td>
<td>The mouse cursor is over the widget and pressing a mouse button will cause some action to occur</td>
</tr>
<tr>
<td>disabled</td>
<td>Widget is disabled under program control</td>
</tr>
<tr>
<td>focus</td>
<td>Widget has keyboard focus</td>
</tr>
<tr>
<td>pressed</td>
<td>Widget is being pressed</td>
</tr>
<tr>
<td>selected</td>
<td>“On”, “true”, or “current” for things like Checkbuttons and radiobuttons</td>
</tr>
<tr>
<td>background</td>
<td>Windows and Mac have a notion of an “active” or foreground window. The background state is set for widgets in a background window, and cleared for those in the foreground window</td>
</tr>
<tr>
<td>readonly</td>
<td>Widget should not allow user modification</td>
</tr>
<tr>
<td>alternate</td>
<td>A widget-specific alternate display format</td>
</tr>
<tr>
<td>invalid</td>
<td>The widget’s value is invalid</td>
</tr>
</tbody>
</table>

A state specification is a sequence of state names, optionally prefixed with an exclamation point indicating that the bit is off.

25.2.3.6. ttk.Widget

Besides the methods described below, the ttk.Widget supports the methods tkinter.Widget.cget() and tkinter.Widget.configure().
class tkinter.ttk.Widget

identify(x, y)

Returns the name of the element at position x y, or the empty string if the point does not lie within any element.

x and y are pixel coordinates relative to the widget.

instate(statespec, callback=None, *args, **kw)

Test the widget's state. If a callback is not specified, returns True if the widget state matches statespec and False otherwise. If callback is specified then it is called with args if widget state matches statespec.

state(statespec=None)

Modify or inquire widget state. If statespec is specified, sets the widget state according to it and return a new statespec indicating which flags were changed. If statespec is not specified, returns the currently-enabled state flags.

statespec will usually be a list or a tuple.
25.2.4. Combobox

The `ttk.Combobox` widget combines a text field with a pop-down list of values. This widget is a subclass of `Entry`.

Besides the methods inherited from `Widget`: `Widget.cget()`, `Widget.configure()`, `Widget.identify()`, `Widget.instate()` and `Widget.state()`, and the following inherited from `Entry`: `Entry.bbox()`, `Entry.delete()`, `Entry.icursor()`, `Entry.index()`, `Entry.inset()`, `Entry.selection()`, `Entry.xview()`, it has some other methods, described at `ttk.Combobox`.

25.2.4.1. Options

This widget accepts the following specific options:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>exportselection</td>
<td>Boolean value. If set, the widget selection is linked to the Window Manager selection (which can be returned by invoking Misc.selection_get, for example).</td>
</tr>
<tr>
<td>justify</td>
<td>Specifies how the text is aligned within the widget. One of “left”, “center”, or “right”.</td>
</tr>
<tr>
<td>height</td>
<td>Specifies the height of the pop-down listbox, in rows.</td>
</tr>
<tr>
<td>postcommand</td>
<td>A script (possibly registered with Misc.register) that is called immediately before displaying the values. It may specify which values to display.</td>
</tr>
</tbody>
</table>
One of “normal”, “readonly”, or “disabled”. In the “readonly” state, the value may not be edited directly, and the user can only selection of the values from the dropdown list. In the “normal” state, the text field is directly editable. In the “disabled” state, no interaction is possible.

Specifies a name whose value is linked to the widget value. Whenever the value associated with that name changes, the widget value is updated, and vice versa. See tkinter.StringVar.

Specifies the list of values to display in the drop-down listbox.

Specifies an integer value indicating the desired width of the entry window, in average-size characters of the widget’s font.

25.2.4.2. Virtual events

The combobox widgets generates a <<ComboboxSelected>> virtual event when the user selects an element from the list of values.

25.2.4.3. ttk.Combobox

class tkinter.ttk.Combobox
current(newindex=None)

If newindex is specified, sets the combobox value to the element position newindex. Otherwise, returns the index of the current value or -1 if the current value is not in the values list.

get()

Returns the current value of the combobox.
set(value)

Sets the value of the combobox to value.
25.2.5. Notebook

Ttk Notebook widget manages a collection of windows and displays a single one at a time. Each child window is associated with a tab, which the user may select to change the currently-displayed window.

25.2.5.1. Options

This widget accepts the following specific options:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>height</td>
<td>If present and greater than zero, specifies the desired height of the pane area (not including internal padding or tabs). Otherwise, the maximum height of all panes is used.</td>
</tr>
<tr>
<td>padding</td>
<td>Specifies the amount of extra space to add around the outside of the notebook. The padding is a list up to four length specifications left top right bottom. If fewer than four elements are specified, bottom defaults to top, right defaults to left, and top defaults to left.</td>
</tr>
<tr>
<td>width</td>
<td>If present and greater than zero, specified the desired width of the pane area (not including internal padding). Otherwise, the maximum width of all panes is used.</td>
</tr>
</tbody>
</table>

25.2.5.2. Tab Options

There are also specific options for tabs:
<table>
<thead>
<tr>
<th><strong>state</strong></th>
<th>Either “normal”, “disabled” or “hidden”. If “disabled”, then the tab is not selectable. If “hidden”, then the tab is not shown.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>sticky</strong></td>
<td>Specifies how the child window is positioned within the pane area. Value is a string containing zero or more of the characters “n”, “s”, “e” or “w”. Each letter refers to a side (north, south, east or west) that the child window will stick to, as per the <code>grid()</code> geometry manager.</td>
</tr>
<tr>
<td><strong>padding</strong></td>
<td>Specifies the amount of extra space to add between the notebook and this pane. Syntax is the same as for the option padding used by this widget.</td>
</tr>
<tr>
<td><strong>text</strong></td>
<td>Specifies a text to be displayed in the tab.</td>
</tr>
<tr>
<td><strong>image</strong></td>
<td>Specifies an image to display in the tab. See the option image described in <code>Widget</code>.</td>
</tr>
<tr>
<td><strong>compound</strong></td>
<td>Specifies how to display the image relative to the text, in the case both options text and image are present. See <code>Label Options</code> for legal values.</td>
</tr>
<tr>
<td><strong>underline</strong></td>
<td>Specifies the index (0-based) of a character to underline in the text string. The underlined character is used for mnemonic activation if <code>Notebook.enable_traversal()</code> is called.</td>
</tr>
</tbody>
</table>

### 25.2.5.3. Tab Identifiers

The `tab_id` present in several methods of `ttk.Notebook` may take any of the following forms:

- An integer between zero and the number of tabs
- The name of a child window
- A positional specification of the form “@x,y”, which identifies the tab
The literal string “current”, which identifies the currently-selected tab

The literal string “end”, which returns the number of tabs (only valid for Notebook.index())

25.2.5.4. Virtual Events

This widget generates a <<NotebookTabChanged>> virtual event after a new tab is selected.

25.2.5.5. ttk.Notebook

class tkinter.ttk.Notebook

    add(child, **kw)

    Adds a new tab to the notebook.

    If window is currently managed by the notebook but hidden, it is restored to its previous position.

    See Tab Options for the list of available options.

    forget(tab_id)

    Removes the tab specified by tab_id, unmaps and unmanages the associated window.

    hide(tab_id)

    Hides the tab specified by tab_id.

    The tab will not be displayed, but the associated window remains managed by the notebook and its configuration remembered. Hidden tabs may be restored with the add() command.
identify\((x, y)\)

Returns the name of the tab element at position \(x, y\), or the empty string if none.

index\((tab_id)\)

Returns the numeric index of the tab specified by \(tab_id\), or the total number of tabs if \(tab_id\) is the string “end”.

insert\((pos, child, **kw)\)

Inserts a pane at the specified position.

\(pos\) is either the string “end”, an integer index, or the name of a managed child. If \(child\) is already managed by the notebook, moves it to the specified position.

See Tab Options for the list of available options.

select\((tab_id=\text{None})\)

Selects the specified \(tab_id\).

The associated child window will be displayed, and the previously-selected window (if different) is unmapped. If \(tab_id\) is omitted, returns the widget name of the currently selected pane.

tab\((tab_id, option=\text{None}, **kw)\)

Query or modify the options of the specific \(tab_id\).

If \(kw\) is not given, returns a dictionary of the tab option values. If \(option\) is specified, returns the value of that \(option\). Otherwise, sets the options to the corresponding values.

tabs()
Returns a list of windows managed by the notebook.

**enable_traversal()**

Enable keyboard traversal for a toplevel window containing this notebook.

This will extend the bindings for the toplevel window containing the notebook as follows:

- **Control-Tab**: selects the tab following the currently selected one.
- **Shift-Control-Tab**: selects the tab preceding the currently selected one.
- **Alt-K**: where K is the mnemonic (underlined) character of any tab, will select that tab.

Multiple notebooks in a single toplevel may be enabled for traversal, including nested notebooks. However, notebook traversal only works properly if all panes have the notebook they are in as master.
25.2.6. Progressbar

The `ttk.Progressbar` widget shows the status of a long-running operation. It can operate in two modes: 1) the determinate mode which shows the amount completed relative to the total amount of work to be done and 2) the indeterminate mode which provides an animated display to let the user know that work is progressing.

25.2.6.1. Options

This widget accepts the following specific options:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>orient</td>
<td>One of “horizontal” or “vertical”. Specifies the orientation of the progress bar.</td>
</tr>
<tr>
<td>length</td>
<td>Specifies the length of the long axis of the progress bar (width if horizontal, height if vertical).</td>
</tr>
<tr>
<td>mode</td>
<td>One of “determinate” or “indeterminate”.</td>
</tr>
<tr>
<td>maximum</td>
<td>A number specifying the maximum value. Defaults to 100.</td>
</tr>
<tr>
<td>value</td>
<td>The current value of the progress bar. In “determinate” mode, this represents the amount of work completed. In “indeterminate” mode, it is interpreted as modulo <code>maximum</code>; that is, the progress bar completes one “cycle” when its value increases by <code>maximum</code>.</td>
</tr>
<tr>
<td>variable</td>
<td>A name which is linked to the option value. If specified, the value of the progress bar is automatically set to the value of this name whenever the latter is modified.</td>
</tr>
<tr>
<td></td>
<td>Read-only option. The widget periodically</td>
</tr>
</tbody>
</table>


phase

increments the value of this option whenever its value is greater than 0 and, in determinate mode, less than maximum. This option may be used by the current theme to provide additional animation effects.

25.2.6.2. ttk.Progressbar

class tkinter.ttk.Progressbar

start(interval=None)

Begin autoincrement mode: schedules a recurring timer event that calls Progressbar.step() every interval milliseconds. If omitted, interval defaults to 50 milliseconds.

step(amount=None)

Increments the progress bar’s value by amount.

amount defaults to 1.0 if omitted.

stop()

Stop autoincrement mode: cancels any recurring timer event initiated by Progressbar.start() for this progress bar.
25.2.7. Separator

The `ttk.Separator` widget displays a horizontal or vertical separator bar.

It has no other methods besides the ones inherited from `ttk.Widget`.

25.2.7.1. Options

This widget accepts the following specific option:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>orient</td>
<td>One of “horizontal” or “vertical”. Specifies the orientation of the separator.</td>
</tr>
</tbody>
</table>
25.2.8. Sizegrip

The `ttk.Sizegrip` widget (also known as a grow box) allows the user to resize the containing toplevel window by pressing and dragging the grip.

This widget has neither specific options nor specific methods, besides the ones inherited from `ttk.Widget`.

25.2.8.1. Platform-specific notes

- On MacOS X, toplevel windows automatically include a built-in size grip by default. Adding a `Sizegrip` is harmless, since the built-in grip will just mask the widget.

25.2.8.2. Bugs

- If the containing toplevel’s position was specified relative to the right or bottom of the screen (e.g. ...), the `Sizegrip` widget will not resize the window.
- This widget supports only “southeast” resizing.
25.2.9. Treeview

The ttk.Treeview widget displays a hierarchical collection of items. Each item has a textual label, an optional image, and an optional list of data values. The data values are displayed in successive columns after the tree label.

The order in which data values are displayed may be controlled by setting the widget option displaycolumns. The tree widget can also display column headings. Columns may be accessed by number or symbolic names listed in the widget option columns. See Column Identifiers.

Each item is identified by an unique name. The widget will generate item IDs if they are not supplied by the caller. There is a distinguished root item, named {}. The root item itself is not displayed; its children appear at the top level of the hierarchy.

Each item also has a list of tags, which can be used to associate event bindings with individual items and control the appearance of the item.

The Treeview widget supports horizontal and vertical scrolling, according to the options described in Scrollable Widget Options and the methods Treeview.xview() and Treeview.yview().

25.2.9.1. Options

This widget accepts the following specific options:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>columns</td>
<td>A list of column identifiers, specifying the number of columns and their names.</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>displaycolumns</td>
<td>A list of column identifiers (either symbolic or integer indices) specifying which data columns are displayed and the order in which they appear, or the string “#all”.</td>
</tr>
<tr>
<td>height</td>
<td>Specifies the number of rows which should be visible. Note: the requested width is determined from the sum of the column widths.</td>
</tr>
<tr>
<td>padding</td>
<td>Specifies the internal padding for the widget. The padding is a list of up to four length specifications.</td>
</tr>
<tr>
<td>selectmode</td>
<td>Controls how the built-in class bindings manage the selection. One of “extended”, “browse” or “none”. If set to “extended” (the default), multiple items may be selected. If “browse”, only a single item will be selected at a time. If “none”, the selection will not be changed. Note that the application code and tag bindings can set the selection however they wish, regardless of the value of this option.</td>
</tr>
</tbody>
</table>
| show       | A list containing zero or more of the following values, specifying which elements of the tree to display.  

- tree: display tree labels in column #0.  
- headings: display the heading row.  

The default is “tree headings”, i.e., show all elements. |
**Note:** Column #0 always refers to the tree column, even if show="tree" is not specified.

25.2.9.2. Item Options

The following item options may be specified for items in the insert and item widget commands.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>text</td>
<td>The textual label to display for the item.</td>
</tr>
<tr>
<td>image</td>
<td>A Tk Image, displayed to the left of the label.</td>
</tr>
<tr>
<td>values</td>
<td>The list of values associated with the item. Each item should have the same number of values as the widget option columns. If there are fewer values than columns, the remaining values are assumed empty. If there are more values than columns, the extra values are ignored.</td>
</tr>
<tr>
<td>open</td>
<td>True/False value indicating whether the item's children should be displayed or hidden.</td>
</tr>
<tr>
<td>tags</td>
<td>A list of tags associated with this item.</td>
</tr>
</tbody>
</table>

25.2.9.3. Tag Options

The following options may be specified on tags:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>foreground</td>
<td>Specifies the text foreground color.</td>
</tr>
<tr>
<td>background</td>
<td>Specifies the cell or item background color.</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>font</td>
<td>Specifies the font to use when drawing text.</td>
</tr>
<tr>
<td>image</td>
<td>Specifies the item image, in case the item’s image option is empty.</td>
</tr>
</tbody>
</table>

### 25.2.9.4. Column Identifiers

Column identifiers take any of the following forms:

- A symbolic name from the list of columns option.
- An integer n, specifying the nth data column.
- A string of the form #n, where n is an integer, specifying the nth display column.

**Notes:**

- Item’s option values may be displayed in a different order than the order in which they are stored.
- Column #0 always refers to the tree column, even if show="tree" is not specified.

A data column number is an index into an item’s option values list; a display column number is the column number in the tree where the values are displayed. Tree labels are displayed in column #0. If option displaycolumns is not set, then data column n is displayed in column #n+1. Again, **column #0 always refers to the tree column**.

### 25.2.9.5. Virtual Events

The Treeview widget generates the following virtual events.
The `Treeview.focus()` and `Treeview.selection()` methods can be used to determine the affected item or items.

### 25.2.9.6. `ttk.Treeview`

#### `bbox`(*item*, `column=None`)

Returns the bounding box (relative to the treeview widget's window) of the specified `item` in the form `(x, y, width, height)`.

If `column` is specified, returns the bounding box of that cell. If the `item` is not visible (i.e., if it is a descendant of a closed item or is scrolled offscreen), returns an empty string.

#### `get_children`(*item=None*)

Returns the list of children belonging to `item`.

If `item` is not specified, returns root children.

#### `set_children`(*item*, `*newchildren*)

Replaces `item`'s child with `newchildren`.

Children present in `item` that are not present in `newchildren` are detached from the tree. No items in `newchildren` may be an ancestor of `item`. Note that not specifying `newchildren` results in
detaching item's children.

**column**(*column*, *option=None, **kw*)

Query or modify the options for the specified *column*.

If *kw* is not given, returns a dict of the column option values. If *option* is specified then the value for that *option* is returned. Otherwise, sets the options to the corresponding values.

The valid options/values are:

- **id**
  Returns the column name. This is a read-only option.

- **anchor**: One of the standard Tk anchor values.
  Specifies how the text in this column should be aligned with respect to the cell.

- **minwidth**: width
  The minimum width of the column in pixels. The treeview widget will not make the column any smaller than specified by this option when the widget is resized or the user drags a column.

- **stretch**: True/False
  Specifies whether the column’s width should be adjusted when the widget is resized.

- **width**: width
  The width of the column in pixels.

To configure the tree column, call this with column = “#0”

**delete**(*items*)
Delete all specified *items* and all their descendants.

The root item may not be deleted.

**detach(*items*)**
Unlinks all of the specified *items* from the tree.

The items and all of their descendants are still present, and may be reinserted at another point in the tree, but will not be displayed.

The root item may not be detached.

**exists(item)**
Returns True if the specified *item* is present in the tree.

**focus(item=None)**
If *item* is specified, sets the focus item to *item*. Otherwise, returns the current focus item, or ‘ ’ if there is none.

**heading(column, option=None, **kw)**
Query or modify the heading options for the specified *column*.

If *kw* is not given, returns a dict of the heading option values. If *option* is specified then the value for that *option* is returned. Otherwise, sets the options to the corresponding values.

The valid options/values are:

- **text: text**
  The text to display in the column heading.

- **image: imageName**
  Specifies an image to display to the right of the column
heading.

- anchor: anchor
  Specifies how the heading text should be aligned. One of the standard Tk anchor values.

- command: callback
  A callback to be invoked when the heading label is pressed.

To configure the tree column heading, call this with column = “#0”.

**identify**(component, x, y)
Returns a description of the specified component under the point given by x and y, or the empty string if no such component is present at that position.

**identify_row**(y)
Returns the item ID of the item at position y.

**identify_column**(x)
Returns the data column identifier of the cell at position x.

The tree column has ID #0.

**identify_region**(x, y)
Returns one of:

<table>
<thead>
<tr>
<th>region</th>
<th>meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>heading</td>
<td>Tree heading area.</td>
</tr>
<tr>
<td>separator</td>
<td>Space between two columns headings.</td>
</tr>
<tr>
<td>tree</td>
<td>The tree area.</td>
</tr>
<tr>
<td>cell</td>
<td>A data cell.</td>
</tr>
</tbody>
</table>

Availability: Tk 8.6.

**identify_element**(\(x, y\))
Returns the element at position \(x, y\).

Availability: Tk 8.6.

**index**(\(item\))
Returns the integer index of \(item\) within its parent’s list of children.

**insert**(\(parent, index, iid=None, **kw\))
Creates a new item and returns the item identifier of the newly created item.

\(parent\) is the item ID of the parent item, or the empty string to create a new top-level item. \(index\) is an integer, or the value “end”, specifying where in the list of parent’s children to insert the new item. If \(index\) is less than or equal to zero, the new node is inserted at the beginning; if \(index\) is greater than or equal to the current number of children, it is inserted at the end. If \(iid\) is specified, it is used as the item identifier; \(iid\) must not already exist in the tree. Otherwise, a new unique identifier is generated.

See Item Options for the list of available points.

**item**(\(item, option=None, **kw\))
Query or modify the options for the specified \(item\).

If no options are given, a dict with options/values for the item is returned. If \(option\) is specified then the value for that option is
returned. Otherwise, sets the options to the corresponding values as given by *kw*.

**move**(item, parent, index)

Moves *item* to position *index* in *parent*'s list of children.

It is illegal to move an item under one of its descendants. If *index* is less than or equal to zero, *item* is moved to the beginning; if greater than or equal to the number of children, it is moved to the end. If *item* was detached it is reattached.

**next**(item)

Returns the identifier of *item*'s next sibling, or "" if *item* is the last child of its parent.

**parent**(item)

Returns the ID of the parent of *item*, or "" if *item* is at the top level of the hierarchy.

**prev**(item)

Returns the identifier of *item*'s previous sibling, or "" if *item* is the first child of its parent.

**reattach**(item, parent, index)

An alias for *Treeview.move()*.

**see**(item)

Ensure that *item* is visible.

Sets all of *item*'s ancestors open option to True, and scrolls the widget if necessary so that *item* is within the visible portion of the tree.
selection selop=None, items=None
If selop is not specified, returns selected items. Otherwise, it will act according to the following selection methods.

selection_set(items)
items becomes the new selection.

selection_add(items)
Add items to the selection.

selection_remove(items)
Remove items from the selection.

selection_toggle(items)
Toggle the selection state of each item in items.

set(item, column=None, value=None)
With one argument, returns a dictionary of column/value pairs for the specified item. With two arguments, returns the current value of the specified column. With three arguments, sets the value of given column in given item to the specified value.

tag_bind(tagname, sequence=None, callback=None)
Bind a callback for the given event sequence to the tag tagname. When an event is delivered to an item, the callbacks for each of the item’s tags option are called.

tag_configure(tagname, option=None, **kw)
Query or modify the options for the specified tagname.
If kw is not given, returns a dict of the option settings for tagname. If option is specified, returns the value for that option for the specified tagname. Otherwise, sets the options to the
corresponding values for the given *tagname*.

**tag_has(tagname, item=None)**

If *item* is specified, returns 1 or 0 depending on whether the specified *item* has the given *tagname*. Otherwise, returns a list of all items that have the specified tag.

Availability: Tk 8.6

**xview(**args**)**

Query or modify horizontal position of the treeview.

**yview(**args**)**

Query or modify vertical position of the treeview.
25.2.10. Ttk Styling

Each widget in ttk is assigned a style, which specifies the set of elements making up the widget and how they are arranged, along with dynamic and default settings for element options. By default the style name is the same as the widget's class name, but it may be overridden by the widget's style option. If you don't know the class name of a widget, use the method Misc.winfo_class() (somewidget.winfo_class()).

See also:

Tcl'2004 conference presentation
   This document explains how the theme engine works

```python
class tkinter.ttk.Style
   This class is used to manipulate the style database.

configure(style, query_opt=None, **kw)
   Query or set the default value of the specified option(s) in style.

   Each key in kw is an option and each value is a string identifying the value for that option.

   For example, to change every default button to be a flat button with some padding and a different background color:

   from tkinter import ttk
   import tkinter

   root = tkinter.Tk()```
```python
ttk.Style().configure("TButton", padding=6, relief="flat", background="#ccc")
btn = ttk.Button(text="Sample")
btn.pack()
root.mainloop()
```

The `map` function:
```
map(style, query_opt=None, **kw)
```

Query or sets dynamic values of the specified option(s) in `style`.

Each key in `kw` is an option and each value should be a list or a tuple (usually) containing statespecs grouped in tuples, lists, or some other preference. A statespec is a compound of one or more states and then a value.

An example may make it more understandable:

```python
import tkinter
from tkinter import ttk
root = tkinter.Tk()
style = ttk.Style()
style.map("C.TButton",
    foreground=[('pressed', 'red'), ('active',
    background=[('pressed', '!disabled', 'black')
]
colored_btn = ttk.Button(text="Test", style="C.
root.mainloop()
```

Note that the order of the `(states, value)` sequences for an
option does matter, if the order is changed to [('active', 'blue'), ('pressed', 'red')] in the foreground option, for example, the result would be a blue foreground when the widget were in active or pressed states.

**lookup(style, option, state=None, default=None)**

Returns the value specified for `option` in `style`.

If `state` is specified, it is expected to be a sequence of one or more states. If the `default` argument is set, it is used as a fallback value in case no specification for `option` is found.

To check what font a Button uses by default:

```python
from tkinter import ttk

print(ttk.Style().lookup("TButton", "font"))
```

**layout(style, layoutspec=None)**

Define the widget layout for given `style`. If `layoutspec` is omitted, return the layout specification for given `style`.

`layoutspec`, if specified, is expected to be a list or some other sequence type (excluding strings), where each item should be a tuple and the first item is the layout name and the second item should have the format described in Layouts.

To understand the format, see the following example (it is not intended to do anything useful):

```python
from tkinter import ttk
import tkinter

root = tkinter.Tk()
```
```python
style = ttk.Style()  
style.layout("TMenubutton", [  
    ("Menubutton.background", None),  
    ("Menubutton.button", {"children":  
        [("Menubutton.focus", {"children":  
            [("Menubutton.padding", {"children":  
                ["Menubutton.label", {"side": "}  
            }  
        }  
    }  
])  
mbtn = ttk.Menubutton(text='Text')  
mbtn.pack()  
root.mainloop()
```

**element_create(elementname, etype, *args, **kw)**

Create a new element in the current theme, of the given *etype* which is expected to be either “image”, “from” or “vsapi”. The latter is only available in Tk 8.6a for Windows XP and Vista and is not described here.

If “image” is used, *args* should contain the default image name followed by statespec/value pairs (this is the imagespec), and *kw* may have the following options:

- **border=padding**
  padding is a list of up to four integers, specifying the left, top, right, and bottom borders, respectively.

- **height=height**
  Specifies a minimum height for the element. If less than zero, the base image's height is used as a
• padding=padding
  Specifies the element’s interior padding. Defaults to border’s value if not specified.

• sticky=spec
  Specifies how the image is placed within the final parcel. spec contains zero or more characters “n”, “s”, “w”, or “e”.

• width=width
  Specifies a minimum width for the element. If less than zero, the base image’s width is used as a default.

If “from” is used as the value of etype, element_create() will clone an existing element. args is expected to contain a themename, from which the element will be cloned, and optionally an element to clone from. If this element to clone from is not specified, an empty element will be used. kw is discarded.

**element_names()**
Returns the list of elements defined in the current theme.

**element_options(elementname)**
Returns the list of elementname's options.

**theme_create(themename, parent=None, settings=None)**
Create a new theme.

It is an error if themename already exists. If parent is specified,
the new theme will inherit styles, elements and layouts from the parent theme. If settings are present they are expected to have the same syntax used for `theme_settings()`.

**theme_settings**(themename, settings)
Temporarily sets the current theme to themename, apply specified settings and then restore the previous theme.

Each key in settings is a style and each value may contain the keys ‘configure’, ‘map’, ‘layout’ and ‘element create’ and they are expected to have the same format as specified by the methods `Style.configure()`, `Style.map()`, `Style.layout()` and `Style.element_create()` respectively.

As an example, let’s change the Combobox for the default theme a bit:

```python
from tkinter import ttk
import tkinter

root = tkinter.Tk()

style = ttk.Style()
style.theme_settings("default", {
    "TCombobox": {
        "configure": {"padding": 5},
        "map": {
            "background": [("active", "green2"),
                           ("!disabled", "green4"),
                          "fieldbackground": [("!disabled", "green3"),
                                              "foreground": [("focus", "OliveDrab1"),
                                                             ("!disabled", "OliveDrab2")]
                                      }
        }
    }
})
```
```python
combo = ttk.Combobox().pack()
root.mainloop()
```

**theme_names()**

Returns a list of all known themes.

**theme_use(themename=None)**

If `themename` is not given, returns the theme in use. Otherwise, sets the current theme to `themename`, refreshes all widgets and emits a `<<ThemeChanged>>` event.

### 25.2.10.1. Layouts

A layout can be just `None`, if it takes no options, or a dict of options specifying how to arrange the element. The layout mechanism uses a simplified version of the pack geometry manager: given an initial cavity, each element is allocated a parcel. Valid options/values are:

- **side**: `whichside`
  
  Specifies which side of the cavity to place the element; one of top, right, bottom or left. If omitted, the element occupies the entire cavity.

- **sticky**: `nswe`
  
  Specifies where the element is placed inside its allocated parcel.

- **unit**: `0` or `1`
  
  If set to `1`, causes the element and all of its descendants
to be treated as a single element for the purposes of `Widget.identify()` et al. It's used for things like scrollbar thumbs with grips.

- **children: [sublayout...]**
  Specifies a list of elements to place inside the element. Each element is a tuple (or other sequence type) where the first item is the layout name, and the other is a `Layout`.
25.3. `tkinter.tix` — Extension widgets for Tk

The `tkinter.tix` (Tk Interface Extension) module provides an additional rich set of widgets. Although the standard Tk library has many useful widgets, they are far from complete. The `tkinter.tix` library provides most of the commonly needed widgets that are missing from standard Tk: `HList`, `ComboBox`, `Control` (a.k.a. SpinBox) and an assortment of scrollable widgets. `tkinter.tix` also includes many more widgets that are generally useful in a wide range of applications: `NoteBook`, `FileEntry`, `PanedWindow`, etc; there are more than 40 of them.

With all these new widgets, you can introduce new interaction techniques into applications, creating more useful and more intuitive user interfaces. You can design your application by choosing the most appropriate widgets to match the special needs of your application and users.

**See also:**

[Tix Homepage](#)
   The home page for Tix. This includes links to additional documentation and downloads.

[Tix Man Pages](#)
   On-line version of the man pages and reference material.

[Tix Programming Guide](#)
   On-line version of the programmer’s reference material.

[Tix Development Applications](#)
Tix applications for development of Tix and Tkinter programs. Tide applications work under Tk or Tkinter, and include TixInspect, an inspector to remotely modify and debug Tix/Tk/Tkinter applications.
25.3.1. Using Tix

class tkinter.tix.Tk(screenName=None, baseName=None, className='Tix')

Toplevel widget of Tix which represents mostly the main window of an application. It has an associated Tcl interpreter.

Classes in the tkinter.tix module subclasses the classes in the tkinter. The former imports the latter, so to use tkinter.tix with Tkinter, all you need to do is to import one module. In general, you can just import tkinter.tix, and replace the toplevel call to tkinter.Tk with tix.Tk:

```python
from tkinter import tix
from tkinter.constants import *
root = tix.Tk()
```

To use tkinter.tix, you must have the Tix widgets installed, usually alongside your installation of the Tk widgets. To test your installation, try the following:

```python
from tkinter import tix
root = tix.Tk()
root.tk.eval('package require Tix')
```

If this fails, you have a Tk installation problem which must be resolved before proceeding. Use the environment variable TIX_LIBRARY to point to the installed Tix library directory, and make sure you have the dynamic object library (tix8183.dll or libtix8183.so) in the same directory that contains your Tk dynamic object library (tk8183.dll or libtk8183.so). The directory with the dynamic
object library should also have a file called pkgIndex.tcl (case sensitive), which contains the line:

```tcl
package ifneeded Tix 8.1 [list load "$[file join $dir tix8183.dll]"
```
25.3.2. Tix Widgets

Tix introduces over 40 widget classes to the tkinter repertoire.

25.3.2.1. Basic Widgets

*class tkinter.tix.Balloon*

A Balloon that pops up over a widget to provide help. When the user moves the cursor inside a widget to which a Balloon widget has been bound, a small pop-up window with a descriptive message will be shown on the screen.

*class tkinter.tix.ButtonBox*

The ButtonBox widget creates a box of buttons, such as is commonly used for Ok Cancel.

*class tkinter.tix.ComboBox*

The ComboBox widget is similar to the combo box control in MS Windows. The user can select a choice by either typing in the entry subwidget or selecting from the listbox subwidget.

*class tkinter.tix.Control*

The Control widget is also known as the SpinBox widget. The user can adjust the value by pressing the two arrow buttons or by entering the value directly into the entry. The new value will be checked against the user-defined upper and lower limits.

*class tkinter.tix.LabelEntry*

The LabelEntry widget packages an entry widget and a label into one mega widget. It can be used to simplify the creation of “entry-form” type of interface.
class tkinter.tix.LabelFrame

The LabelFrame widget packages a frame widget and a label into one mega widget. To create widgets inside a LabelFrame widget, one creates the new widgets relative to the frame subwidget and manage them inside the frame subwidget.

class tkinter.tix.Meter

The Meter widget can be used to show the progress of a background job which may take a long time to execute.

class tkinter.tix.OptionMenu

The OptionMenu creates a menu button of options.

class tkinter.tix.PopupMenu

The PopupMenu widget can be used as a replacement of the tk_popup command. The advantage of the Tix PopupMenu widget is it requires less application code to manipulate.

class tkinter.tix.Select

The Select widget is a container of button subwidgets. It can be used to provide radio-box or check-box style of selection options for the user.

class tkinter.tix.StdButtonBox

The StdButtonBox widget is a group of standard buttons for Motif-like dialog boxes.

25.3.2.2. File Selectors

class tkinter.tix.DirList

The DirList widget displays a list view of a directory, its previous directories and its sub-directories. The user can choose one of the
directories displayed in the list or change to another directory.

**class tkinter.tix.DirTree**

The `DirTree` widget displays a tree view of a directory, its previous directories and its sub-directories. The user can choose one of the directories displayed in the list or change to another directory.

**class tkinter.tix.DirSelectDialog**

The `DirSelectDialog` widget presents the directories in the file system in a dialog window. The user can use this dialog window to navigate through the file system to select the desired directory.

**class tkinter.tix.DirSelectBox**

The `DirSelectBox` is similar to the standard Motif(TM) directory-selection box. It is generally used for the user to choose a directory. DirSelectBox stores the directories mostly recently selected into a ComboBox widget so that they can be quickly selected again.

**class tkinter.tix.ExFileSelectBox**

The `ExFileSelectBox` widget is usually embedded in a tixExFileSelectDialog widget. It provides an convenient method for the user to select files. The style of the `ExFileSelectBox` widget is very similar to the standard file dialog on MS Windows 3.1.

**class tkinter.tix.FileSelectBox**

The `FileSelectBox` is similar to the standard Motif(TM) file-selection box. It is generally used for the user to choose a file. FileSelectBox stores the files mostly recently selected into a ComboBox widget so that they can be quickly selected again.

**class tkinter.tix.FileEntry**

The `FileEntry` widget can be used to input a filename. The user can type in the filename manually. Alternatively, the user can press the
button widget that sits next to the entry, which will bring up a file selection dialog.

### 25.3.2.3. Hierarchical ListBox

*class* `tkinter.tix.HList`

The *HList* widget can be used to display any data that have a hierarchical structure, for example, file system directory trees. The list entries are indented and connected by branch lines according to their places in the hierarchy.

*class* `tkinter.tix.CheckList`

The *CheckList* widget displays a list of items to be selected by the user. *CheckList* acts similarly to the Tk checkbutton or radiobutton widgets, except it is capable of handling many more items than checkbuttons or radiobuttons.

*class* `tkinter.tix.Tree`

The *Tree* widget can be used to display hierarchical data in a tree form. The user can adjust the view of the tree by opening or closing parts of the tree.

### 25.3.2.4. Tabular ListBox

*class* `tkinter.tix.TList`

The *TList* widget can be used to display data in a tabular format. The list entries of a *TList* widget are similar to the entries in the Tk listbox widget. The main differences are (1) the *TList* widget can display the list entries in a two dimensional format and (2) you can use graphical images as well as multiple colors and fonts for the list entries.
25.3.2.5. Manager Widgets

class tkinter.tix.PanedWindow
The PanedWindow widget allows the user to interactively manipulate the sizes of several panes. The panes can be arranged either vertically or horizontally. The user changes the sizes of the panes by dragging the resize handle between two panes.

class tkinter.tix.ListNoteBook
The ListNoteBook widget is very similar to the TixNoteBook widget: it can be used to display many windows in a limited space using a notebook metaphor. The notebook is divided into a stack of pages (windows). At one time only one of these pages can be shown. The user can navigate through these pages by choosing the name of the desired page in the hlist subwidget.

class tkinter.tix.NoteBook
The NoteBook widget can be used to display many windows in a limited space using a notebook metaphor. The notebook is divided into a stack of pages. At one time only one of these pages can be shown. The user can navigate through these pages by choosing the visual “tabs” at the top of the NoteBook widget.

25.3.2.6. Image Types

The tkinter.tix module adds:

- **Pixmap** capabilities to all tkinter.tix and tkinter widgets to create color images from XPM files.
- **Compound** image types can be used to create images that consists of multiple horizontal lines; each line is composed of a series of items (texts, bitmaps, images or spaces) arranged from
left to right. For example, a compound image can be used to display a bitmap and a text string simultaneously in a Tk Button widget.

25.3.2.7. Miscellaneous Widgets

class tkinter.tix.InputOnly

The InputOnly widgets are to accept inputs from the user, which can be done with the bind command (Unix only).

25.3.2.8. Form Geometry Manager

In addition, tkinter.tix augments tkinter by providing:

class tkinter.tix.Form

The Form geometry manager based on attachment rules for all Tk widgets.
25.3.3. Tix Commands

class tkinter.tix.tixCommand

The tix commands provide access to miscellaneous elements of Tix's internal state and the Tix application context. Most of the information manipulated by these methods pertains to the application as a whole, or to a screen or display, rather than to a particular window.

To view the current settings, the common usage is:

```python
from tkinter import tix
root = tix.Tk()
print(root.tix_configure())
```

tixCommand.tix_configure(cnf=None, **kw)

Query or modify the configuration options of the Tix application context. If no option is specified, returns a dictionary all of the available options. If option is specified with no value, then the method returns a list describing the one named option (this list will be identical to the corresponding sublist of the value returned if no option is specified). If one or more option-value pairs are specified, then the method modifies the given option(s) to have the given value(s); in this case the method returns an empty string. Option may be any of the configuration options.

tixCommand.tix_cget(option)

Returns the current value of the configuration option given by option. Option may be any of the configuration options.

tixCommand.tix_getbitmap(name)

Locates a bitmap file of the name name.xpm or name in one of the
bitmap directories (see the tix_addbitmapdir() method). By using tix_getbitmap(), you can avoid hard coding the pathnames of the bitmap files in your application. When successful, it returns the complete pathname of the bitmap file, prefixed with the character @. The returned value can be used to configure the bitmap option of the Tk and Tix widgets.

\begin{tixcommand}
\texttt{tix_addbitmapdir(directory)}
\end{tixcommand}

Tix maintains a list of directories under which the tix_getimage() and tix_getbitmap() methods will search for image files. The standard bitmap directory is \$TIX_LIBRARY/bitmaps. The tix_addbitmapdir() method adds directory into this list. By using this method, the image files of an applications can also be located using the tix_getimage() or tix_getbitmap() method.

\begin{tixcommand}
\texttt{tix_filedialog([dlgclass])}
\end{tixcommand}

Returns the file selection dialog that may be shared among different calls from this application. This method will create a file selection dialog widget when it is called the first time. This dialog will be returned by all subsequent calls to tix_filedialog(). An optional dlgclass parameter can be passed as a string to specified what type of file selection dialog widget is desired. Possible options are tix, FileSelectDialog or tixExFileSelectDialog.

\begin{tixcommand}
\texttt{tix_getimage(self, name)}
\end{tixcommand}

Locates an image file of the name name.xpm, name.xbm or name.ppm in one of the bitmap directories (see the tix_addbitmapdir() method above). If more than one file with the same name (but different extensions) exist, then the image type
is chosen according to the depth of the X display: xbm images are chosen on monochrome displays and color images are chosen on color displays. By using \texttt{tix\_getimage()}, you can avoid hard coding the pathnames of the image files in your application. When successful, this method returns the name of the newly created image, which can be used to configure the image option of the Tk and Tix widgets.

\begin{verbatim}
tixCommand.tix\_option\_get(name)
\end{verbatim}

Gets the options maintained by the Tix scheme mechanism.

\begin{verbatim}
tixCommand.tix\_resetoptions(newScheme, newFontSet[, newScmPrio])
\end{verbatim}

Resets the scheme and fontset of the Tix application to \textit{newScheme} and \textit{newFontSet}, respectively. This affects only those widgets created after this call. Therefore, it is best to call the resetoptions method before the creation of any widgets in a Tix application.

The optional parameter \textit{newScmPrio} can be given to reset the priority level of the Tk options set by the Tix schemes.

Because of the way Tk handles the X option database, after Tix has been has imported and inited, it is not possible to reset the color schemes and font sets using the \texttt{tix\_config()} method. Instead, the \texttt{tix\_resetoptions()} method must be used.
25. Graphical User Interfaces with Tk
25.4. `tkinter.scrolledtext` — Scrolled Text Widget

The `tkinter.scrolledtext` module provides a class of the same name which implements a basic text widget which has a vertical scrollbar configured to do the “right thing.” Using the ScrolledText class is a lot easier than setting up a text widget and scroll bar directly. The constructor is the same as that of the `tkinter.Text` class.

The text widget and scrollbar are packed together in a Frame, and the methods of the Grid and Pack geometry managers are acquired from the Frame object. This allows the ScrolledText widget to be used directly to achieve most normal geometry management behavior.

Should more specific control be necessary, the following attributes are available:

**ScrolledText.frame**

The frame which surrounds the text and scroll bar widgets.

**ScrolledText.vbar**

The scroll bar widget.
25.5. IDLE

IDLE is Python's Integrated Development and Learning Environment.

IDLE has the following features:

- coded in 100% pure Python, using the tkinter GUI toolkit
- cross-platform: works mostly the same on Windows, Unix, and Mac OS X
- Python shell window (interactive interpreter) with colorizing of code input, output, and error messages
- multi-window text editor with multiple undo, Python colorizing, smart indent, call tips, auto completion, and other features
- search within any window, replace within editor windows, and search through multiple files (grep)
- debugger with persistent breakpoints, stepping, and viewing of global and local namespaces
- configuration, browsers, and other dialogs
25.5.1. Menus

IDLE has two main window types, the Shell window and the Editor window. It is possible to have multiple editor windows simultaneously. Output windows, such as used for Edit / Find in Files, are a subtype of edit window. They currently have the same top menu as Editor windows but a different default title and context menu.

IDLE’s menus dynamically change based on which window is currently selected. Each menu documented below indicates which window type it is associated with.

25.5.1.1. File menu (Shell and Editor)

New File
  Create a new file editing window.

Open...
  Open an existing file with an Open dialog.

Recent Files
  Open a list of recent files. Click one to open it.

Open Module...
  Open an existing module (searches sys.path).

Class Browser
  Show functions, classes, and methods in the current Editor file in a tree structure. In the shell, open a module first.

Path Browser
  Show sys.path directories, modules, functions, classes and methods in a tree structure.

Save
  Save the current window to the associated file, if there is one.
Windows that have been changed since being opened or last saved have a * before and after the window title. If there is no associated file, do Save As instead.

Save As...
Save the current window with a Save As dialog. The file saved becomes the new associated file for the window.

Save Copy As...
Save the current window to different file without changing the associated file.

Print Window
Print the current window to the default printer.

Close
Close the current window (ask to save if unsaved).

Exit
Close all windows and quit IDLE (ask to save unsaved windows).

25.5.1.2. Edit menu (Shell and Editor)

Undo
Undo the last change to the current window. A maximum of 1000 changes may be undone.

Redo
Redo the last undone change to the current window.

Cut
Copy selection into the system-wide clipboard; then delete the selection.

Copy
Copy selection into the system-wide clipboard.

Paste
Insert contents of the system-wide clipboard into the current
The clipboard functions are also available in context menus.

Select All
Select the entire contents of the current window.

Find...
Open a search dialog with many options

Find Again
Repeat the last search, if there is one.

Find Selection
Search for the currently selected string, if there is one.

Find in Files...
Open a file search dialog. Put results in an new output window.

Replace...
Open a search-and-replace dialog.

Go to Line
Move cursor to the line number requested and make that line visible.

Show Completions
Open a scrollable list allowing selection of keywords and attributes. See Completions in the Tips sections below.

Expand Word
Expand a prefix you have typed to match a full word in the same window; repeat to get a different expansion.

Show call tip
After an unclosed parenthesis for a function, open a small window with function parameter hints.

Show surrounding parens
Highlight the surrounding parenthesis.
25.5.1.3. Format menu (Editor window only)

Indent Region
   Shift selected lines right by the indent width (default 4 spaces).

Dedent Region
   Shift selected lines left by the indent width (default 4 spaces).

Comment Out Region
   Insert ## in front of selected lines.

Uncomment Region
   Remove leading # or ## from selected lines.

Tabify Region
   Turn leading stretches of spaces into tabs. (Note: We recommend using 4 space blocks to indent Python code.)

Untabify Region
   Turn all tabs into the correct number of spaces.

Toggle Tabs
   Open a dialog to switch between indenting with spaces and tabs.

New Indent Width
   Open a dialog to change indent width. The accepted default by the Python community is 4 spaces.

Format Paragraph
   Reformat the current blank-line-delimited paragraph in comment block or multiline string or selected line in a string. All lines in the paragraph will be formatted to less than N columns, where N defaults to 72.

Strip trailing whitespace
   Remove any space characters after the last non-space character of a line.

25.5.1.4. Run menu (Editor window only)
Python Shell
Open or wake up the Python Shell window.

Check Module
Check the syntax of the module currently open in the Editor window. If the module has not been saved IDLE will either prompt the user to save or autosave, as selected in the General tab of the Idle Settings dialog. If there is a syntax error, the approximate location is indicated in the Editor window.

Run Module
Do Check Module (above). If no error, restart the shell to clean the environment, then execute the module. Output is displayed in the Shell window. Note that output requires use of print or write. When execution is complete, the Shell retains focus and displays a prompt. At this point, one may interactively explore the result of execution. This is similar to executing a file with python -i file at a command line.

25.5.1.5. Shell menu (Shell window only)

View Last Restart
Scroll the shell window to the last Shell restart.

Restart Shell
Restart the shell to clean the environment.

25.5.1.6. Debug menu (Shell window only)

Go to File/Line
Look on the current line, with the cursor, and the line above for a filename and line number. If found, open the file if not already open, and show the line. Use this to view source lines referenced in an exception traceback and lines found by Find in Files. Also
available in the context menu of the Shell window and Output windows.

Debugger (toggle)
When actived, code entered in the Shell or run from an Editor will run under the debugger. In the Editor, breakpoints can be set with the context menu. This feature is still incomplete and somewhat experimental.

Stack Viewer
Show the stack traceback of the last exception in a tree widget, with access to locals and globals.

Auto-open Stack Viewer
Toggle automatically opening the stack viewer on an unhandled exception.

25.5.1.7. Options menu (Shell and Editor)

Configure IDLE
Open a configuration dialog and change preferences for the following: fonts, indentation, keybindings, text color themes, startup windows and size, additional help sources, and extensions (see below). On OS X, open the configuration dialog by selecting Preferences in the application menu. To use a new built-in color theme (IDLE Dark) with older IDLEs, save it as a new custom theme.

Non-default user settings are saved in a .idlerc directory in the user’s home directory. Problems caused by bad user configuration files are solved by editing or deleting one or more of the files in .idlerc.

Code Context (toggle)(Editor Window only)
Open a pane at the top of the edit window which shows the block
context of the code which has scrolled above the top of the window.

25.5.1.8. Window menu (Shell and Editor)

Zoom Height
Toggles the window between normal size and maximum height. The initial size defaults to 40 lines by 80 chars unless changed on the General tab of the Configure IDLE dialog.

The rest of this menu lists the names of all open windows; select one to bring it to the foreground (deiconifying it if necessary).

25.5.1.9. Help menu (Shell and Editor)

About IDLE
Display version, copyright, license, credits, and more.

IDLE Help
Display a help file for IDLE detailing the menu options, basic editing and navigation, and other tips.

Python Docs
Access local Python documentation, if installed, or start a web browser and open docs.python.org showing the latest Python documentation.

Turtle Demo
Run the turtledemo module with example python code and turtle drawings.

Additional help sources may be added here with the Configure IDLE dialog under the General tab.

25.5.1.10. Context Menus
Open a context menu by right-clicking in a window (Control-click on OS X). Context menus have the standard clipboard functions also on the Edit menu.

Cut

  Copy selection into the system-wide clipboard; then delete the selection.

Copy

  Copy selection into the system-wide clipboard.

Paste

  Insert contents of the system-wide clipboard into the current window.

Editor windows also have breakpoint functions. Lines with a breakpoint set are specially marked. Breakpoints only have an effect when running under the debugger. Breakpoints for a file are saved in the user’s .idlerc directory.

Set Breakpoint

  Set a breakpoint on the current line.

Clear Breakpoint

  Clear the breakpoint on that line.

Shell and Output windows have the following.

Go to file/line

  Same as in Debug menu.
25.5.2. Editing and navigation

In this section, ‘C’ refers to the Control key on Windows and Unix and the Command key on Mac OS X.

- Backspace deletes to the left; Del deletes to the right
- C-Backspace delete word left; C-Del delete word to the right
- Arrow keys and Page Up/Page Down to move around
- C-LeftArrow and C-RightArrow moves by words
- Home/End go to begin/end of line
- C-Home/C-End go to begin/end of file
- Some useful Emacs bindings are inherited from Tcl/Tk:
  - C-a beginning of line
  - C-e end of line
  - C-k kill line (but doesn’t put it in clipboard)
  - C-l center window around the insertion point
  - C-b go backwards one character without deleting (usually you can also use the cursor key for this)
  - C-f go forward one character without deleting (usually you can also use the cursor key for this)
  - C-p go up one line (usually you can also use the cursor key for this)
  - C-d delete next character

Standard keybindings (like C-c to copy and C-v to paste) may work. Keybindings are selected in the Configure IDLE dialog.
25.5.2.1. Automatic indentation

After a block-opening statement, the next line is indented by 4 spaces (in the Python Shell window by one tab). After certain keywords (break, return etc.) the next line is dedented. In leading indentation, Backspace deletes up to 4 spaces if they are there. Tab inserts spaces (in the Python Shell window one tab), number depends on Indent width. Currently tabs are restricted to four spaces due to Tcl/Tk limitations.

See also the indent/dedent region commands in the edit menu.

25.5.2.2. Completions

Completions are supplied for functions, classes, and attributes of classes, both built-in and user-defined. Completions are also provided for filenames.

The AutoCompleteWindow (ACW) will open after a predefined delay (default is two seconds) after a ‘.’ or (in a string) an os.sep is typed. If after one of those characters (plus zero or more other characters) a tab is typed the ACW will open immediately if a possible continuation is found.

If there is only one possible completion for the characters entered, a Tab will supply that completion without opening the ACW.

‘Show Completions’ will force open a completions window, by default the C-space will open a completions window. In an empty string, this will contain the files in the current directory. On a blank line, it will contain the built-in and user-defined functions and classes in the current name spaces, plus any modules imported. If some characters
have been entered, the ACW will attempt to be more specific.

If a string of characters is typed, the ACW selection will jump to the entry most closely matching those characters. Entering a tab will cause the longest non-ambiguous match to be entered in the Editor window or Shell. Two tab in a row will supply the current ACW selection, as will return or a double click. Cursor keys, Page Up/Down, mouse selection, and the scroll wheel all operate on the ACW.

“Hidden” attributes can be accessed by typing the beginning of hidden name after a ‘.’, e.g. ‘_’. This allows access to modules with __all__ set, or to class-private attributes.

Completions and the ‘Expand Word’ facility can save a lot of typing!

Completions are currently limited to those in the namespaces. Names in an Editor window which are not via __main__ and sys.modules will not be found. Run the module once with your imports to correct this situation. Note that IDLE itself places quite a few modules in sys.modules, so much can be found by default, e.g. the re module.

If you don’t like the ACW popping up unbidden, simply make the delay longer or disable the extension.

25.5.2.3. Calltips

A calltip is shown when one types ( after the name of an accessible function. A name expression may include dots and subscripts. A calltip remains until it is clicked, the cursor is moved out of the argument area, or ) is typed. When the cursor is in the argument part of a definition, the menu or shortcut display a calltip.

A calltip consists of the function signature and the first line of the
docstring. For builtins without an accessible signature, the calltip consists of all lines up the fifth line or the first blank line. These details may change.

The set of accessible functions depends on what modules have been imported into the user process, including those imported by Idle itself, and what definitions have been run, all since the last restart.

For example, restart the Shell and enter `import itertools`. A calltip appears because Idle imports itertools into the user process for its own use. (This could change.) Enter `turtle.write()` and nothing appears. Idle does not import turtle. The menu or shortcut do nothing either. Enter `import turtle` and then `turtle.write()` will work.

In an editor, import statements have no effect until one runs the file. One might want to run a file after writing the import statements at the top, or immediately run an existing file before editing.

25.5.2.4. Python Shell window

- `C-c` interrupts executing command
- `C-d` sends end-of-file; closes window if typed at a `>>>` prompt
- `Alt-/` (Expand word) is also useful to reduce typing

Command history

- `Alt-p` retrieves previous command matching what you have typed. On OS X use `C-p`.
- `Alt-n` retrieves next. On OS X use `C-n`.
- `Return` while on any previous command retrieves that command
25.5.2.5. Text colors

Idle defaults to black on white text, but colors text with special meanings. For the shell, these are shell output, shell error, user output, and user error. For Python code, at the shell prompt or in an editor, these are keywords, builtin class and function names, names following class and def, strings, and comments. For any text window, these are the cursor (when present), found text (when possible), and selected text.

Text coloring is done in the background, so uncolorized text is occasionally visible. To change the color scheme, use the Configure IDLE dialog Highlighting tab. The marking of debugger breakpoint lines in the editor and text in popups and dialogs is not user-configurable.
25.5.3. Startup and code execution

Upon startup with the -s option, IDLE will execute the file referenced by the environment variables IDLESTARTUP or PYTHONSTARTUP. IDLE first checks for IDLESTARTUP; if IDLESTARTUP is present the file referenced is run. If IDLESTARTUP is not present, IDLE checks for PYTHONSTARTUP. Files referenced by these environment variables are convenient places to store functions that are used frequently from the IDLE shell, or for executing import statements to import common modules.

In addition, Tk also loads a startup file if it is present. Note that the Tk file is loaded unconditionally. This additional file is .Idle.py and is looked for in the user’s home directory. Statements in this file will be executed in the Tk namespace, so this file is not useful for importing functions to be used from IDLE’s Python shell.

25.5.3.1. Command line usage

```
idle.py [-c command] [-d] [-e] [-h] [-i] [-r file] [arg...]

-c command  run command in the shell window
-d           enable debugger and open shell window
-e           open editor window
-h           print help message with legal combinations
-i           open shell window
-r file      run file in shell window
-s           run $IDLESTARTUP or $PYTHONSTARTUP first
-t title     set title of shell window
-            run stdin in shell (- must be last option)
```
If there are arguments:

- If `-`, `-c`, or `-r` is used, all arguments are placed in `sys.argv[1:...]` and `sys.argv[0]` is set to `'`, `-c`, or `-r`. No editor window is opened, even if that is the default set in the Options dialog.
- Otherwise, arguments are files opened for editing and `sys.argv` reflects the arguments passed to IDLE itself.

25.5.3.2. IDLE-console differences

As much as possible, the result of executing Python code with IDLE is the same as executing the same code in a console window. However, the different interface and operation occasionally affects results.

For instance, IDLE normally executes user code in a separate process from the IDLE GUI itself. The IDLE versions of `sys.stdin`, `stdout`, and `stderr` in the execution process get input from and send output to the GUI process, which keeps control of the keyboard and screen. This is normally transparent, but code that access these object will see different attribute values. Also, functions that directly access the keyboard and screen will not work.

With IDLE’s Shell, one enters, edits, and recalls complete statements. Some consoles only work with a single physical line at a time.

25.5.3.3. Running without a subprocess

By default, IDLE executes user code in a separate subprocess via a socket, which uses the internal loopback interface. This connection is not externally visible and no data is sent to or received from the Internet. If firewall software complains anyway, you can ignore it.
If the attempt to make the socket connection fails, Idle will notify you. Such failures are sometimes transient, but if persistent, the problem may be either a firewall blocking the connection or misconfiguration of a particular system. Until the problem is fixed, one can run Idle with the -n command line switch.

If IDLE is started with the -n command line switch it will run in a single process and will not create the subprocess which runs the RPC Python execution server. This can be useful if Python cannot create the subprocess or the RPC socket interface on your platform. However, in this mode user code is not isolated from IDLE itself. Also, the environment is not restarted when Run/Run Module (F5) is selected. If your code has been modified, you must reload() the affected modules and re-import any specific items (e.g. from foo import baz) if the changes are to take effect. For these reasons, it is preferable to run IDLE with the default subprocess if at all possible.

*Deprecated since version 3.4.*
25.5.4. Help and preferences

25.5.4.1. Additional help sources

IDLE includes a help menu entry called “Python Docs” that will open the extensive sources of help, including tutorials, available at docs.python.org. Selected URLs can be added or removed from the help menu at any time using the Configure IDLE dialog. See the IDLE help option in the help menu of IDLE for more information.

25.5.4.2. Setting preferences

The font preferences, highlighting, keys, and general preferences can be changed via Configure IDLE on the Option menu. Keys can be user defined; IDLE ships with four built in key sets. In addition a user can create a custom key set in the Configure IDLE dialog under the keys tab.

25.5.4.3. Extensions

IDLE contains an extension facility. Preferences for extensions can be changed with Configure Extensions. See the beginning of config-extensions.def in the idlelib directory for further information. The default extensions are currently:

- FormatParagraph
- AutoExpand
- ZoomHeight
- ScriptBinding
- CallTips
- ParenMatch
- AutoComplete
- CodeContext
- RstripExtension
25.6. Other Graphical User Interface Packages

Major cross-platform (Windows, Mac OS X, Unix-like) GUI toolkits are available for Python:

See also:

**PyGObject**
provides introspection bindings for C libraries using GObject. One of these libraries is the GTK+ 3 widget set. GTK+ comes with many more widgets than Tkinter provides. An online Python GTK+ 3 Tutorial is available.

**PyGTK** provides bindings for an older version of the library, GTK+ 2. It provides an object oriented interface that is slightly higher level than the C one. There are also bindings to GNOME. An online tutorial is available.

**PyQt**
PyQt is a sip-wrapped binding to the Qt toolkit. Qt is an extensive C++ GUI application development framework that is available for Unix, Windows and Mac OS X. sip is a tool for generating bindings for C++ libraries as Python classes, and is specifically designed for Python. The PyQt3 bindings have a book, GUI Programming with Python: QT Edition by Boudewijn Rempt. The PyQt4 bindings also have a book, Rapid GUI Programming with Python and Qt, by Mark Summerfield.

**PySide**
is a newer binding to the Qt toolkit, provided by Nokia. Compared to PyQt, its licensing scheme is friendlier to non-open source applications.
wxPython is a cross-platform GUI toolkit for Python that is built around the popular wxWidgets (formerly wxWindows) C++ toolkit. It provides a native look and feel for applications on Windows, Mac OS X, and Unix systems by using each platform’s native widgets where ever possible, (GTK+ on Unix-like systems). In addition to an extensive set of widgets, wxPython provides classes for online documentation and context sensitive help, printing, HTML viewing, low-level device context drawing, drag and drop, system clipboard access, an XML-based resource format and more, including an ever growing library of user-contributed modules. wxPython has a book, wxPython in Action, by Noel Rappin and Robin Dunn.

PyGTK, PyQt, and wxPython, all have a modern look and feel and more widgets than Tkinter. In addition, there are many other GUI toolkits for Python, both cross-platform, and platform-specific. See the GUI Programming page in the Python Wiki for a much more complete list, and also for links to documents where the different GUI toolkits are compared.
26. Development Tools

The modules described in this chapter help you write software. For example, the `pydoc` module takes a module and generates documentation based on the module's contents. The `doctest` and `unittest` modules contain frameworks for writing unit tests that automatically exercise code and verify that the expected output is produced. `2to3` can translate Python 2.x source code into valid Python 3.x code.

The list of modules described in this chapter is:

- **26.1. typing — Support for type hints**
  - 26.1.1. Type aliases
  - 26.1.2. Callable
  - 26.1.3. Generics
  - 26.1.4. User-defined generic types
  - 26.1.5. The `Any` type
  - 26.1.6. Classes, functions, and decorators
- **26.2. pydoc — Documentation generator and online help system**
- **26.3. doctest — Test interactive Python examples**
  - 26.3.1. Simple Usage: Checking Examples in Docstrings
  - 26.3.2. Simple Usage: Checking Examples in a Text File
  - 26.3.3. How It Works
    - 26.3.3.1. Which Docstrings Are Examined?
    - 26.3.3.2. How are Docstring Examples Recognized?
    - 26.3.3.3. What's the Execution Context?
    - 26.3.3.4. What About Exceptions?
    - 26.3.3.5. Option Flags
    - 26.3.3.6. Directives
    - 26.3.3.7. Warnings
  - 26.3.4. Basic API
26.3.5. Unittest API
26.3.6. Advanced API
  ■ 26.3.6.1. DocTest Objects
  ■ 26.3.6.2. Example Objects
  ■ 26.3.6.3. DocTestFinder objects
  ■ 26.3.6.4. DocTestParser objects
  ■ 26.3.6.5. DocTestRunner objects
  ■ 26.3.6.6. OutputChecker objects
26.3.7. Debugging
26.3.8. Soapbox

• 26.4. unittest — Unit testing framework
  ■ 26.4.1. Basic example
  ■ 26.4.2. Command-Line Interface
    ■ 26.4.2.1. Command-line options
  ■ 26.4.3. Test Discovery
  ■ 26.4.4. Organizing test code
  ■ 26.4.5. Re-using old test code
  ■ 26.4.6. Skipping tests and expected failures
  ■ 26.4.7. Distinguishing test iterations using subtests
  ■ 26.4.8. Classes and functions
    ■ 26.4.8.1. Test cases
      ■ 26.4.8.1.1. Deprecated aliases
    ■ 26.4.8.2. Grouping tests
    ■ 26.4.8.3. Loading and running tests
      ■ 26.4.8.3.1. load_tests Protocol
  ■ 26.4.9. Class and Module Fixtures
    ■ 26.4.9.1. setUpClass and tearDownClass
    ■ 26.4.9.2. setUpModule and tearDownModule
  ■ 26.4.10. Signal Handling

• 26.5. unittest.mock — mock object library
  ■ 26.5.1. Quick Guide
  ■ 26.5.2. The Mock Class
    ■ 26.5.2.1. Calling
    ■ 26.5.2.2. Deleting Attributes
- 26.5.2.3. Mock names and the name attribute
- 26.5.2.4. Attaching Mocks as Attributes

- 26.5.3. The patchers
  - 26.5.3.1. patch
  - 26.5.3.2. patch.object
  - 26.5.3.3. patch.dict
  - 26.5.3.4. patch.multiple
  - 26.5.3.5. patch methods: start and stop
  - 26.5.3.6. patch builtins
  - 26.5.3.7. TEST_PREFIX
  - 26.5.3.8. Nesting Patch Decorators
  - 26.5.3.9. Where to patch
  - 26.5.3.10. Patching Descriptors and Proxy Objects

- 26.5.4. MagicMock and magic method support
  - 26.5.4.1. Mocking Magic Methods
  - 26.5.4.2. Magic Mock

- 26.5.5. Helpers
  - 26.5.5.1. sentinel
  - 26.5.5.2. DEFAULT
  - 26.5.5.3. call
  - 26.5.5.4. create_autospec
  - 26.5.5.5. ANY
  - 26.5.5.6. FILTER_DIR
  - 26.5.5.7. mock_open
  - 26.5.5.8. Autospeccing

- 26.6. unittest.mock — getting started
  - 26.6.1. Using Mock
    - 26.6.1.1. Mock Patching Methods
    - 26.6.1.2. Mock for Method Calls on an Object
    - 26.6.1.3. Mocking Classes
    - 26.6.1.4. Naming your mocks
    - 26.6.1.5. Tracking all Calls
    - 26.6.1.6. Setting Return Values and Attributes
    - 26.6.1.7. Raising exceptions with mocks
- 26.6.1.8. Side effect functions and iterables
- 26.6.1.9. Creating a Mock from an Existing Object
- 26.6.2. Patch Decorators
- 26.6.3. Further Examples
  - 26.6.3.1. Mocking chained calls
  - 26.6.3.2. Partial mocking
  - 26.6.3.3. Mocking a Generator Method
  - 26.6.3.4. Applying the same patch to every test method
  - 26.6.3.5. Mocking Unbound Methods
  - 26.6.3.6. Checking multiple calls with mock
  - 26.6.3.7. Coping with mutable arguments
  - 26.6.3.8. Nesting Patches
  - 26.6.3.9. Mocking a dictionary with MagicMock
  - 26.6.3.10. Mock subclasses and their attributes
  - 26.6.3.11. Mocking imports with patch.dict
  - 26.6.3.12. Tracking order of calls and less verbose call assertions
  - 26.6.3.13. More complex argument matching
- 26.7. 2to3 - Automated Python 2 to 3 code translation
  - 26.7.1. Using 2to3
  - 26.7.2. Fixers
  - 26.7.3. lib2to3 - 2to3’s library
- 26.8. test — Regression tests package for Python
  - 26.8.1. Writing Unit Tests for the test package
  - 26.8.2. Running tests using the command-line interface
- 26.9. test.support — Utilities for the Python test suite
26.1. typing — Support for type hints

Source code: Lib/typing.py

This module supports type hints as specified by PEP 484. The most fundamental support consists of the type Any, Union, Tuple, Callable, TypeVar, and Generic. For full specification please see PEP 484. For a simplified introduction to type hints see PEP 483.

The function below takes and returns a string and is annotated as follows:

```python
def greeting(name: str) -> str:
    return 'Hello ' + name
```

In the function greeting, the argument name is expected to by of type str and the return type str. Subtypes are accepted as arguments.
26.1.1. Type aliases

A type alias is defined by assigning the type to the alias:

```
Vector = List[float]
```
26.1.2. Callable

Frameworks expecting callback functions of specific signatures might be type hinted using `Callable[[Arg1Type, Arg2Type], ReturnType]`.

For example:

```python
from typing import Callable

def feeder(get_next_item: Callable[[], str]) -> None:
    # Body

def async_query(on_success: Callable[[int], None],
                 on_error: Callable[[int, Exception],
                                 None],
                 # Body
```

It is possible to declare the return type of a callable without specifying the call signature by substituting a literal ellipsis for the list of arguments in the type hint: `Callable[... , ReturnType]`. None as a type hint is a special case and is replaced by `type(None)`. 
26.1.3. Generics

Since type information about objects kept in containers cannot be statically inferred in a generic way, abstract base classes have been extended to support subscription to denote expected types for container elements.

```python
from typing import Mapping, Sequence

def notify_by_email(employees: Sequence[Employee], overrides: Mapping[str, str]) -> ...
```

Generics can be parametrized by using a new factory available in typing called `TypeVar`.

```python
from typing import Sequence, TypeVar

T = TypeVar('T')  # Declare type variable

def first(l: Sequence[T]) -> T:  # Generic function
    return l[0]
```
26.1.4. User-defined generic types

A user-defined class can be defined as a generic class.

```python
from typing import TypeVar, Generic
from logging import Logger

T = TypeVar('T')

class LoggedVar(Generic[T]):
    def __init__(self, value: T, name: str, logger: Logger):
        self.name = name
        self.logger = logger
        self.value = value

    def set(self, new: T) -> None:
        self.log('Set ' + repr(self.value))
        self.value = new

    def get(self) -> T:
        self.log('Get ' + repr(self.value))
        return self.value

    def log(self, message: str) -> None:
        self.logger.info('{}: {}'.format(self.name, message))
```

Generic[T] as a base class defines that the class LoggedVar takes a single type parameter T. This also makes T valid as a type within the class body.

The Generic base class uses a metaclass that defines `__getitem__()` so that LoggedVar[t] is valid as a type:

```python
from typing import Iterable
```
```python
def zero_all_vars(vars: Iterable[LoggedVar[int]]) ->
    for var in vars:
        var.set(0)
```

A generic type can have any number of type variables, and type variables may be constrained:

```python
from typing import TypeVar, Generic...

T = TypeVar('T')
S = TypeVar('S', int, str)

class StrangePair(Generic[T, S]): ...
```

Each type variable argument to `Generic` must be distinct. This is thus invalid:

```python
from typing import TypeVar, Generic...

T = TypeVar('T')

class Pair(Generic[T, T]):    # INVALID ...
```

You can use multiple inheritance with `Generic`:

```python
from typing import TypeVar, Generic, Sized

T = TypeVar('T')

class LinkedList(Sized, Generic[T]):
```
When inheriting from generic classes, some type variables could be fixed:

```python
from typing import TypeVar, Mapping

T = TypeVar('T')

class MyDict(Mapping[str, T]):
...
```

In this case `MyDict` has a single parameter, `T`.

Subclassing a generic class without specifying type parameters assumes `Any` for each position. In the following example, `MyIterable` is not generic but implicitly inherits from `Iterable[Any]`:

```python
from typing import Iterable

class MyIterable(Iterable):  # Same as Iterable[Any]
...
```

The metaclass used by `Generic` is a subclass of `abc.ABCMeta`. A generic class can be an ABC by including abstract methods or properties, and generic classes can also have ABCs as base classes without a metaclass conflict. Generic metaclasses are not supported.
26.1.5. The *Any* type

A special kind of type is *Any*. Every type is a subtype of *Any*. This is also true for the builtin type object. However, to the static type checker these are completely different.

When the type of a value is *object*, the type checker will reject almost all operations on it, and assigning it to a variable (or using it as a return value) of a more specialized type is a type error. On the other hand, when a value has type *Any*, the type checker will allow all operations on it, and a value of type *Any* can be assigned to a variable (or used as a return value) of a more constrained type.
26.1.6. Classes, functions, and decorators

The module defines the following classes, functions and decorators:

```python
class typing.Any
    Special type indicating an unconstrained type.
    
    - Any object is an instance of `Any`.
    - Any class is a subclass of `Any`.
    - As a special case, `Any` and `object` are subclasses of each other.

class typing.TypeVar
    Type variable.
```

Usage:

```python
T = TypeVar('T')  # Can be anything
A = TypeVar('A', str, bytes)  # Must be str or by
```

Type variables exist primarily for the benefit of static type checkers. They serve as the parameters for generic types as well as for generic function definitions. See class Generic for more information on generic types. Generic functions work as follows:

```python
def repeat(x: T, n: int) -> Sequence[T]:
    """Return a list containing n references to x""
    return [x] * n

def longest(x: A, y: A) -> A:
    """Return the longest of two strings.""
    return x if len(x) >= len(y) else y
```

```
The latter example’s signature is essentially the overloading of (str, str) -> str and (bytes, bytes) -> bytes. Also note that if the arguments are instances of some subclass of str, the return type is still plain str.

At runtime, isinstance(x, T) will raise TypeError. In general, isinstance() and issubclass() should not be used with types.

Type variables may be marked covariant or contravariant by passing covariant=True or contravariant=True. See PEP 484 for more details. By default type variables are invariant. Alternatively, a type variable may specify an upper bound using bound=<type>. This means that an actual type substituted (explicitly or implicitly) for the type variable must be a subclass of the boundary type, see PEP 484.

class typing.Union
Union type; Union[X, Y] means either X or Y.

To define a union, use e.g. Union[int, str]. Details:

- The arguments must be types and there must be at least one.

- Unions of unions are flattened, e.g.:

  ```python
  Union[Union[int, str], float] == Union[int, str]
  ```

- Unions of a single argument vanish, e.g.:

  ```python
  Union[int] == int  # The constructor actually
  ```
- Redundant arguments are skipped, e.g.:

  ```python
  Union[int, str, int] == Union[int, str]
  ```

- When comparing unions, the argument order is ignored, e.g.:

  ```python
  Union[int, str] == Union[str, int]
  ```

- If `Any` is present it is the sole survivor, e.g.:

  ```python
  Union[int, Any] == Any
  ```

- You cannot subclass or instantiate a union.

- You cannot write `Union[X][Y]`.

- You can use `Optional[X]` as a shorthand for `Union[X, None]`.

```python
class typing.Optional

Optional type.

Optional[X] is equivalent to Union[X, type(None)].
```

```python
class typing.Tuple

Tuple type; Tuple[X, Y] is the is the type of a tuple of two items with the first item of type X and the second of type Y.

Example: Tuple[T1, T2] is a tuple of two elements corresponding to type variables T1 and T2. Tuple[int, float, str] is a tuple of an int, a float and a string.

To specify a variable-length tuple of homogeneous type, use literal ellipsis, e.g. Tuple[int, ...].
```
class typing.Callable
Callable type; Callable[[int], str] is a function of (int) -> str.

The subscription syntax must always be used with exactly two values: the argument list and the return type. The argument list must be a list of types; the return type must be a single type.

There is no syntax to indicate optional or keyword arguments, such function types are rarely used as callback types. Callable[...], ReturnType] could be used to type hint a callable taking any number of arguments and returning ReturnType. A plain Callable is equivalent to Callable[...], Any].

class typing.Generic
Abstract base class for generic types.

A generic type is typically declared by inheriting from an instantiation of this class with one or more type variables. For example, a generic mapping type might be defined as:

class Mapping(Generic[KT, VT]):
    def __getitem__(self, key: KT) -> VT:
        ...
        # Etc.

This class can then be used as follows:

X = TypeVar('X')
Y = TypeVar('Y')

def lookup_name(mapping: Mapping[X, Y], key: X, d:
    try:
        return mapping[key]
except KeyError:
    return default

class typing.Iterable(Generic[T_co])
    A generic version of the collections.abc.Iterable.

class typing.Iterator(Iterable[T_co])
    A generic version of the collections.abc.Iterator.

class typing.SupportsInt
    An ABC with one abstract method __int__.

class typing.SupportsFloat
    An ABC with one abstract method __float__.

class typing.SupportsAbs
    An ABC with one abstract method __abs__ that is covariant in its return type.

class typing.SupportsRound
    An ABC with one abstract method __round__ that is covariant in its return type.

class typing.Reversible
    An ABC with one abstract method __reversed__ returning an Iterator[T_co].

class typing.Container(Generic[T_co])
    A generic version of collections.abc.Container.

class typing.AbstractSet(Sized, Iterable[T_co], Container[T_co])
A generic version of `collections.abc.Set`.

```python
class typing.MutableSet(AbstractSet[T])
```
A generic version of `collections.abc.MutableSet`.

```python
class typing.Mapping(Sized, Iterable[KT], Container[KT], Generic[VT_co])
```
A generic version of `collections.abc.Mapping`.

```python
class typing.MutableMapping(Mapping[KT, VT])
```
A generic version of `collections.abc.MutableMapping`.

```python
class typing.Sequence(Sized, Iterable[T_co], Container[T_co])
```
A generic version of `collections.abc.Sequence`.

```python
class typing.MutableSequence(Sequence[T])
```
A generic version of `collections.abc.MutableSequence`.

```python
class typing.ByteString(Sequence[int])
```
A generic version of `collections.abc.ByteString`.

This type represents the types `bytes`, `bytearray`, and `memoryview`.

As a shorthand for this type, `bytes` can be used to annotate arguments of any of the types mentioned above.

```python
class typing.List(list, MutableSequence[T])
```
Generic version of `list`. Useful for annotating return types. To annotate arguments it is preferred to use abstract collection types such as `Mapping`, `Sequence`, or `AbstractSet`.

This type may be used as follows:
\[ T = \text{TypeVar}'T', \text{int}, \text{float} \]

def vec2(x: T, y: T) -> List[T]:
    return [x, y]

def slice__to_4(vector: Sequence[T]) -> List[T]:
    return vector[0:4]

class typing.AbstractSet(set, MutableSet[T])
    A generic version of collections.abc.Set.

class typing.MappingView(Sized, Iterable[T_co])
    A generic version of collections.abc.MappingView.

class typing.KeysView(MappingView[KT_co], AbstractSet[KT_co])
    A generic version of collections.abc.KeysView.

class typing.ItemsView(MappingView[KT_co], Generic[KT_co, VT_co])
    A generic version of collections.abc.ItemsView.

class typing.ValuesView(MappingView[VT_co])
    A generic version of collections.abc.ValuesView.

class typing.Dict(dict, MutableMapping[KT, VT])
    A generic version of dict. The usage of this type is as follows:

def get_position_in_index(word_list: Dict[str, int]):
    return word_list[word]

class typing.Generator(Iterator[T_co], Generic[T_co, T_contra, V_co])
class typing.io
Wrapper namespace for I/O stream types.

This defines the generic type IO[AnyStr] and aliases TextIO and BinaryIO for respectively IO[str] and IO[bytes]. These representing the types of I/O streams such as returned by open().

class typing.re
Wrapper namespace for regular expression matching types.

This defines the type aliases Pattern and Match which correspond to the return types from re.compile() and re.match(). These types (and the corresponding functions) are generic in AnyStr and can be made specific by writing Pattern[str], Pattern[bytes], Match[str], or Match[bytes].

typing.NamedTuple(typename, fields)
Typed version of namedtuple.

Usage:

```
Employee = typing.NamedTuple('Employee', [('name', str), ('age', int)])
```

This is equivalent to:

```
Employee = collections.namedtuple('Employee', ['name', 'age'])
```

The resulting class has one extra attribute: _field_types, giving a dict mapping field names to types. (The field names are in the _fields attribute, which is part of the namedtuple API.)
typing.cast(typ, val)
Cast a value to a type.

This returns the value unchanged. To the type checker this signals that the return value has the designated type, but at runtime we intentionally don’t check anything (we want this to be as fast as possible).

typing.get_type_hints(obj)
Return type hints for a function or method object.

This is often the same as obj.__annotations__, but it handles forward references encoded as string literals, and if necessary adds Optional[t] if a default value equal to None is set.

@typing.no_type_check(arg)
Decorator to indicate that annotations are not type hints.

The argument must be a class or function; if it is a class, it applies recursively to all methods defined in that class (but not to methods defined in its superclasses or subclasses).

This mutates the function(s) in place.

@typing.no_type_check_decorator(decorator)
Decorator to give another decorator the no_type_check() effect.

This wraps the decorator with something that wraps the decorated function in no_type_check().
The Python Software Foundation is a non-profit corporation. Please donate.

Last updated on Dec 06, 2015. Found a bug?

Created using Sphinx 1.3.1.
26.2. **pydoc** — Documentation generator and online help system

**Source code**: Lib/pydoc.py

The **pydoc** module automatically generates documentation from Python modules. The documentation can be presented as pages of text on the console, served to a Web browser, or saved to HTML files.

For modules, classes, functions and methods, the displayed documentation is derived from the docstring (i.e. the `__doc__` attribute) of the object, and recursively of its documentable members. If there is no docstring, **pydoc** tries to obtain a description from the block of comment lines just above the definition of the class, function or method in the source file, or at the top of the module (see `inspect.getcomments()`).

The built-in function `help()` invokes the online help system in the interactive interpreter, which uses **pydoc** to generate its documentation as text on the console. The same text documentation can also be viewed from outside the Python interpreter by running **pydoc** as a script at the operating system’s command prompt. For example, running

```bash
pydoc sys
```

at a shell prompt will display documentation on the `sys` module, in a style similar to the manual pages shown by the Unix `man` command. The argument to **pydoc** can be the name of a function, module, or
package, or a dotted reference to a class, method, or function within a module or module in a package. If the argument to pydoc looks like a path (that is, it contains the path separator for your operating system, such as a slash in Unix), and refers to an existing Python source file, then documentation is produced for that file.

**Note:** In order to find objects and their documentation, pydoc imports the module(s) to be documented. Therefore, any code on module level will be executed on that occasion. Use an if

```python
__name__ == '__main__':
```

guard to only execute code when a file is invoked as a script and not just imported.

When printing output to the console, pydoc attempts to paginate the output for easier reading. If the PAGER environment variable is set, pydoc will use its value as a pagination program.

Specifying a -w flag before the argument will cause HTML documentation to be written out to a file in the current directory, instead of displaying text on the console.

Specifying a -k flag before the argument will search the synopsis lines of all available modules for the keyword given as the argument, again in a manner similar to the Unix man command. The synopsis line of a module is the first line of its documentation string.

You can also use pydoc to start an HTTP server on the local machine that will serve documentation to visiting Web browsers. pydoc -p 1234 will start a HTTP server on port 1234, allowing you to browse the documentation at http://localhost:1234/ in your preferred Web browser. Specifying 0 as the port number will select an arbitrary unused port.
pydoc -b will start the server and additionally open a web browser to a module index page. Each served page has a navigation bar at the top where you can Get help on an individual item, Search all modules with a keyword in their synopsis line, and go to the Module index, Topics and Keywords pages.

When pydoc generates documentation, it uses the current environment and path to locate modules. Thus, invoking pydoc spam documents precisely the version of the module you would get if you started the Python interpreter and typed import spam.

Module docs for core modules are assumed to reside in https://docs.python.org/X.Y/library/ where X and Y are the major and minor version numbers of the Python interpreter. This can be overridden by setting the PYTHONDONTCS environment variable to a different URL or to a local directory containing the Library Reference Manual pages.

*Changed in version 3.2:* Added the -b option.

*Changed in version 3.3:* The -g command line option was removed.

*Changed in version 3.4:* pydoc now uses inspect.signature() rather than inspect.getfullargspec() to extract signature information from callables.
26.3. doctest — Test interactive Python examples

The doctest module searches for pieces of text that look like interactive Python sessions, and then executes those sessions to verify that they work exactly as shown. There are several common ways to use doctest:

- To check that a module’s docstrings are up-to-date by verifying that all interactive examples still work as documented.
- To perform regression testing by verifying that interactive examples from a test file or a test object work as expected.
- To write tutorial documentation for a package, liberally illustrated with input-output examples. Depending on whether the examples or the expository text are emphasized, this has the flavor of “literate testing” or “executable documentation”.

Here’s a complete but small example module:

```python
"""
This is the "example" module.

The example module supplies one function, factorial().

>>> factorial(5)
120
"""

def factorial(n):
    """Return the factorial of n, an exact integer >

>>> [factorial(n) for n in range(6)]
[1, 1, 2, 6, 24, 120]
```
>>> factorial(30)
2652528598121910586363084800000000
>>> factorial(-1)
Traceback (most recent call last):
...
ValueError: n must be >= 0

Factorials of floats are OK, but the float must
>>> factorial(30.1)
Traceback (most recent call last):
...
ValueError: n must be exact integer
>>> factorial(30.0)
2652528598121910586363084800000000

It must also not be ridiculously large:
>>> factorial(1e100)
Traceback (most recent call last):
...
OverflowError: n too large

import math
if not n >= 0:
    raise ValueError("n must be >= 0")
if math.floor(n) != n:
    raise ValueError("n must be exact integer")
if n+1 == n:  # catch a value like 1e300
    raise OverflowError("n too large")
result = 1
factor = 2
while factor <= n:
    result *= factor
    factor += 1
return result
If you run `example.py` directly from the command line, `doctest` works its magic:

```bash
$ python example.py
$ 
```

There's no output! That's normal, and it means all the examples worked. Pass `-v` to the script, and `doctest` prints a detailed log of what it's trying, and prints a summary at the end:

```bash
$ python example.py -v
Trying:
    factorial(5)
Expecting:
    120
ok
Trying:
    [factorial(n) for n in range(6)]
Expecting:
    [1, 1, 2, 6, 24, 120]
ok
```

And so on, eventually ending with:

```bash
Trying:
    factorial(1e100)
Expecting:
    Traceback (most recent call last):
      ...
    OverflowError: n too large
ok
```
2 items passed all tests:
  1 tests in __main__
  8 tests in __main__.factorial
9 tests in 2 items.
9 passed and 0 failed.
Test passed.
$

That's all you need to know to start making productive use of \texttt{doctest}! Jump in. The following sections provide full details. Note that there are many examples of doctests in the standard Python test suite and libraries. Especially useful examples can be found in the standard test file \texttt{Lib/test/test_doctest.py}. 
26.3.1. Simple Usage: Checking Examples in Docstrings

The simplest way to start using doctest (but not necessarily the way you'll continue to do it) is to end each module M with:

```python
if __name__ == "__main__":
    import doctest
    doctest.testmod()
```

doctest then examines docstrings in module M.

Running the module as a script causes the examples in the docstrings to get executed and verified:

```bash
python M.py
```

This won't display anything unless an example fails, in which case the failing example(s) and the cause(s) of the failure(s) are printed to stdout, and the final line of output is ***Test Failed*** N failures., where N is the number of examples that failed.

Run it with the -v switch instead:

```bash
python M.py -v
```

and a detailed report of all examples tried is printed to standard output, along with assorted summaries at the end.

You can force verbose mode by passing verbose=True to testmod(), or prohibit it by passing verbose=False. In either of those cases, sys.argv is not examined by testmod() (so passing -
v or not has no effect).

There is also a command line shortcut for running `testmod()`. You can instruct the Python interpreter to run the doctest module directly from the standard library and pass the module name(s) on the command line:

```
python -m doctest -v example.py
```

This will import example.py as a standalone module and run `testmod()` on it. Note that this may not work correctly if the file is part of a package and imports other submodules from that package.

For more information on `testmod()`, see section Basic API.
26.3.2. Simple Usage: Checking Examples in a Text File

Another simple application of doctest is testing interactive examples in a text file. This can be done with the `testfile()` function:

```python
import doctest
doctest.testfile("example.txt")
```

That short script executes and verifies any interactive Python examples contained in the file `example.txt`. The file content is treated as if it were a single giant docstring; the file doesn’t need to contain a Python program! For example, perhaps `example.txt` contains this:

```
The ``example`` module
======================

Using ``factorial``
-----------------

This is an example text file in reStructuredText for ``factorial`` from the ``example`` module:

    >>> from example import factorial

Now use it:

    >>> factorial(6)
    120
```

Running `doctest.testfile("example.txt")` then finds the error
As with \texttt{testmod()}, \texttt{testfile()} won't display anything unless an example fails. If an example does fail, then the failing example(s) and the cause(s) of the failure(s) are printed to stdout, using the same format as \texttt{testmod()}.

By default, \texttt{testfile()} looks for files in the calling module's directory. See section \texttt{Basic API} for a description of the optional arguments that can be used to tell it to look for files in other locations.

Like \texttt{testmod()}, \texttt{testfile()}'s verbosity can be set with the \texttt{-v} command-line switch or with the optional keyword argument \texttt{verbose}.

There is also a command line shortcut for running \texttt{testfile()}. You can instruct the Python interpreter to run the doctest module directly from the standard library and pass the file name(s) on the command line:

\begin{verbatim}
python -m doctest -v example.txt
\end{verbatim}

Because the file name does not end with \texttt{.py}, \texttt{doctest} infers that it must be run with \texttt{testfile()}, not \texttt{testmod()}.

For more information on \texttt{testfile()}, see section \texttt{Basic API}. 
26.3.3. How It Works

This section examines in detail how doctest works: which docstrings it looks at, how it finds interactive examples, what execution context it uses, how it handles exceptions, and how option flags can be used to control its behavior. This is the information that you need to know to write doctest examples; for information about actually running doctest on these examples, see the following sections.

26.3.3.1. Which Docstrings Are Examined?

The module docstring, and all function, class and method docstrings are searched. Objects imported into the module are not searched.

In addition, if M.__test__ exists and “is true”, it must be a dict, and each entry maps a (string) name to a function object, class object, or string. Function and class object docstrings found from M.__test__ are searched, and strings are treated as if they were docstrings. In output, a key K in M.__test__ appears with name

<name of M>.__test__.K

Any classes found are recursively searched similarly, to test docstrings in their contained methods and nested classes.

**CPython implementation detail:** Prior to version 3.4, extension modules written in C were not fully searched by doctest.

26.3.3.2. How are Docstring Examples Recognized?

In most cases a copy-and-paste of an interactive console session
works fine, but doctest isn't trying to do an exact emulation of any specific Python shell.

```python
>>> # comments are ignored
>>> x = 12
>>> x
12
>>> if x == 13:
...     print("yes")
... else:
...     print("no")
...     print("NO")
...     print("NO!!!")
no
NO
NO!!!
```
NORMALIZE_WHITESPACE option or directive is in effect. Alternatively, the test can be rewritten to capture the output and compare it to an expected value as part of the test. This handling of tabs in the source was arrived at through trial and error, and has proven to be the least error prone way of handling them. It is possible to use a different algorithm for handling tabs by writing a custom DocTestParser class.

- Output to stdout is captured, but not output to stderr (exception tracebacks are captured via a different means).

- If you continue a line via backslashing in an interactive session, or for any other reason use a backslash, you should use a raw docstring, which will preserve your backslashes exactly as you type them:

  ```python
  >>> def f(x):
  ...     r'''Backslashes in a raw docstring: m\n'''
  >>> print(f.__doc__)
  Backslashes in a raw docstring: m
  ```

  Otherwise, the backslash will be interpreted as part of the string. For example, the \n above would be interpreted as a newline character. Alternatively, you can double each backslash in the doctest version (and not use a raw string):

  ```python
  >>> def f(x):
  ...     '''Backslashes in a raw docstring: m\n'''
  >>> print(f.__doc__)
  Backslashes in a raw docstring: m
  ```

- The starting column doesn’t matter:
```python
>>> assert "Easy!"
>>> import math
>>> math.floor(1.9)
1
```

and as many leading whitespace characters are stripped from the expected output as appeared in the initial '>>> ' line that started the example.

26.3.3.3. What’s the Execution Context?

By default, each time doctest finds a docstring to test, it uses a shallow copy of M’s globals, so that running tests doesn’t change the module’s real globals, and so that one test in M can’t leave behind crumbs that accidentally allow another test to work. This means examples can freely use any names defined at top-level in M, and names defined earlier in the docstring being run. Examples cannot see names defined in other docstrings.

You can force use of your own dict as the execution context by passing globs=your_dict to testmod() or testfile() instead.

26.3.3.4. What About Exceptions?

No problem, provided that the traceback is the only output produced by the example: just paste in the traceback. [1] Since tracebacks contain details that are likely to change rapidly (for example, exact file paths and line numbers), this is one case where doctest works hard to be flexible in what it accepts.

Simple example:
That doctest succeeds if `ValueError` is raised, with the `list.remove(x): x not in list` detail as shown.

The expected output for an exception must start with a traceback header, which may be either of the following two lines, indented the same as the first line of the example:

```
Traceback (most recent call last):
Traceback (innermost last):
```

The traceback header is followed by an optional traceback stack, whose contents are ignored by doctest. The traceback stack is typically omitted, or copied verbatim from an interactive session.

The traceback stack is followed by the most interesting part: the line(s) containing the exception type and detail. This is usually the last line of a traceback, but can extend across multiple lines if the exception has a multi-line detail:

```
>>> raise ValueError('multi
 line\ndetail')
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: multi
 line
detail
```

The last three lines (starting with `ValueError`) are compared against the exception’s type and detail, and the rest are ignored.
Best practice is to omit the traceback stack, unless it adds significant documentation value to the example. So the last example is probably better as:

```python
>>> raise ValueError('multi
   line\ndetail')
ValueError: multi
   line
detail
```

Note that tracebacks are treated very specially. In particular, in the rewritten example, the use of ... is independent of doctest's ELLIPSIS option. The ellipsis in that example could be left out, or could just as well be three (or three hundred) commas or digits, or an indented transcript of a Monty Python skit.

Some details you should read once, but won't need to remember:

- Doctest can't guess whether your expected output came from an exception traceback or from ordinary printing. So, e.g., an example that expects `ValueError: 42 is prime` will pass whether `ValueError` is actually raised or if the example merely prints that traceback text. In practice, ordinary output rarely begins with a traceback header line, so this doesn't create real problems.

- Each line of the traceback stack (if present) must be indented further than the first line of the example, or start with a non-alphanumeric character. The first line following the traceback header indented the same and starting with an alphanumeric is taken to be the start of the exception detail. Of course this does the right thing for genuine tracebacks.
• When the **IGNORE_EXCEPTION_DETAIL** doctest option is specified, everything following the leftmost colon and any module information in the exception name is ignored.

• The interactive shell omits the traceback header line for some *SyntaxErrors*. But doctest uses the traceback header line to distinguish exceptions from non-exceptions. So in the rare case where you need to test a *SyntaxError* that omits the traceback header, you will need to manually add the traceback header line to your test example.

• For some *SyntaxErrors*, Python displays the character position of the syntax error, using a ^ marker:

```python
>>> 1 1
    File "<stdin>", line 1
    1 1
^  
SyntaxError: invalid syntax
```

Since the lines showing the position of the error come before the exception type and detail, they are not checked by doctest. For example, the following test would pass, even though it puts the ^ marker in the wrong location:

```python
>>> 1 1
    File "<stdin>", line 1
    1 1
^  
SyntaxError: invalid syntax
```

26.3.3.5. Option Flags
A number of option flags control various aspects of doctest’s behavior. Symbolic names for the flags are supplied as module constants, which can be or’ed together and passed to various functions. The names can also be used in doctest directives, and may be passed to the doctest command line interface via the -o option.

New in version 3.4: The -o command line option.

The first group of options define test semantics, controlling aspects of how doctest decides whether actual output matches an example’s expected output:

**doctest.**

**DONT_ACCEPT_TRUE_FOR_1**

By default, if an expected output block contains just 1, an actual output block containing just 1 or just True is considered to be a match, and similarly for 0 versus False. When **DONT_ACCEPT_TRUE_FOR_1** is specified, neither substitution is allowed. The default behavior caters to that Python changed the return type of many functions from integer to boolean; doctests expecting “little integer” output still work in these cases. This option will probably go away, but not for several years.

**doctest.**

**DONT_ACCEPT_BLANKLINE**

By default, if an expected output block contains a line containing only the string <BLANKLINE>, then that line will match a blank line in the actual output. Because a genuinely blank line delimits the expected output, this is the only way to communicate that a blank line is expected. When **DONT_ACCEPT_BLANKLINE** is specified, this substitution is not allowed.

**doctest.**

**NORMALIZE_WHITESPACE**

When specified, all sequences of whitespace (blanks and
newlines) are treated as equal. Any sequence of whitespace within the expected output will match any sequence of whitespace within the actual output. By default, whitespace must match exactly. NORMALIZE_WHITESPACE is especially useful when a line of expected output is very long, and you want to wrap it across multiple lines in your source.

doctest.ELLIPSIS
When specified, an ellipsis marker (...) in the expected output can match any substring in the actual output. This includes substrings that span line boundaries, and empty substrings, so it’s best to keep usage of this simple. Complicated uses can lead to the same kinds of “oops, it matched too much!” surprises that .* is prone to in regular expressions.

doctest.IGNORE_EXCEPTION_DETAIL
When specified, an example that expects an exception passes if an exception of the expected type is raised, even if the exception detail does not match. For example, an example expecting ValueError: 42 will pass if the actual exception raised is ValueError: 3*14, but will fail, e.g., if TypeError is raised.

It will also ignore the module name used in Python 3 doctest reports. Hence both of these variations will work with the flag specified, regardless of whether the test is run under Python 2.7 or Python 3.2 (or later versions):

```python
>>> raise CustomError('message')
Traceback (most recent call last):
  CustomError: message

>>> raise CustomError('message')
Traceback (most recent call last):
```
my_module.CustomError: message

Note that **ELLIPSIS** can also be used to ignore the details of the exception message, but such a test may still fail based on whether or not the module details are printed as part of the exception name. Using **IGNORE_EXCEPTION_DETAIL** and the details from Python 2.3 is also the only clear way to write a doctest that doesn’t care about the exception detail yet continues to pass under Python 2.3 or earlier (those releases do not support doctest directives and ignore them as irrelevant comments). For example:

```
>>> (1, 2)[3] = 'moo'
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: object doesn't support item assignment
```

passes under Python 2.3 and later Python versions with the flag specified, even though the detail changed in Python 2.4 to say “does not” instead of “doesn’t”.

*Changed in version 3.2:* **IGNORE_EXCEPTION_DETAIL** now also ignores any information relating to the module containing the exception under test.

**doctest.SKIP**

When specified, do not run the example at all. This can be useful in contexts where doctest examples serve as both documentation and test cases, and an example should be included for documentation purposes, but should not be checked. E.g., the example’s output might be random; or the example might depend on resources which would be unavailable to the test driver.

The SKIP flag can also be used for temporarily “commenting out”
doctest.COMPARISON_FLAGS

A bitmask or‘ing together all the comparison flags above.

The second group of options controls how test failures are reported:

doctest.REPORT_UDIFF

When specified, failures that involve multi-line expected and actual outputs are displayed using a unified diff.

doctest.REPORT_CDIFF

When specified, failures that involve multi-line expected and actual outputs will be displayed using a context diff.

doctest.REPORT_NDIFF

When specified, differences are computed by difflib.Differ, using the same algorithm as the popular ndiff.py utility. This is the only method that marks differences within lines as well as across lines. For example, if a line of expected output contains digit 1 where actual output contains letter l, a line is inserted with a caret marking the mismatching column positions.

doctest.REPORT_ONLY_FIRST_FAILURE

When specified, display the first failing example in each doctest, but suppress output for all remaining examples. This will prevent doctest from reporting correct examples that break because of earlier failures; but it might also hide incorrect examples that fail independently of the first failure. When REPORT_ONLY_FIRST_FAILURE is specified, the remaining examples are still run, and still count towards the total number of failures reported; only the output is suppressed.
`doctest.FAIL_FAST`
When specified, exit after the first failing example and don’t attempt to run the remaining examples. Thus, the number of failures reported will be at most 1. This flag may be useful during debugging, since examples after the first failure won’t even produce debugging output.

The doctest command line accepts the option `-f` as a shorthand for `-o FAIL_FAST`.

*New in version 3.4.*

`doctest.REPORTING_FLAGS`
A bitmask or’ing together all the reporting flags above.

There is also a way to register new option flag names, though this isn’t useful unless you intend to extend `doctest` internals via subclassing:

`doctest.register_optionflag(name)`
Create a new option flag with a given name, and return the new flag’s integer value. `register_optionflag()` can be used when subclassing `OutputChecker` or `DocTestRunner` to create new options that are supported by your subclasses. `register_optionflag()` should always be called using the following idiom:

```python
MY_FLAG = register_optionflag('MY_FLAG')
```

### 26.3.3.6. Directives

Doctest directives may be used to modify the option flags for an individual example. Doctest directives are special Python comments
following an example's source code:

```
directive ::= "#" "doctest:" directive
directive_options ::= directive_option ("," directive_option)*
directive_option ::= on_or_off directive_option_name
on_or_off ::= "+" | "-
directive_option_name ::= "DONT_ACCEPT_BLANKLINE" | "NORMALIZE_WHITESPACE" |
...
```

Whitespace is not allowed between the + or - and the directive option name. The directive option name can be any of the option flag names explained above.

An example's doctest directives modify doctest's behavior for that single example. Use + to enable the named behavior, or - to disable it.

For example, this test passes:

```
>>> print(list(range(20)))  # doctest: +NORMALIZE_WHITESPACE
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19]
```

Without the directive it would fail, both because the actual output doesn't have two blanks before the single-digit list elements, and because the actual output is on a single line. This test also passes, and also requires a directive to do so:

```
>>> print(list(range(20)))  # doctest: +ELLIPSIS
[0, 1, ..., 18, 19]
```

Multiple directives can be used on a single physical line, separated by commas:

```
>>> print(list(range(20)))  # doctest: +ELLIPSIS, +NORMALIZE_WHITESPACE
```

If multiple directive comments are used for a single example, then they are combined:

```python
>>> print(list(range(20)))  # doctest: +ELLIPSIS
...  # doctest: +NORMALIZE_WHITESPACE
[0, 1, ..., 18, 19]
```

As the previous example shows, you can add ... lines to your example containing only directives. This can be useful when an example is too long for a directive to comfortably fit on the same line:

```python
>>> print(list(range(5)) + list(range(10, 20)) + list(... # doctest: +ELLIPSIS
[0, ..., 4, 10, ..., 19, 30, ..., 39]
```

Note that since all options are disabled by default, and directives apply only to the example they appear in, enabling options (via + in a directive) is usually the only meaningful choice. However, option flags can also be passed to functions that run doctests, establishing different defaults. In such cases, disabling an option via - in a directive can be useful.

### 26.3.3.7. Warnings

`doctest` is serious about requiring exact matches in expected output. If even a single character doesn’t match, the test fails. This will probably surprise you a few times, as you learn exactly what Python does and doesn’t guarantee about output. For example, when printing a dict, Python doesn’t guarantee that the key-value pairs will be
printed in any particular order, so a test like

```python
>>> foo()
{'Hermione': 'hippogryph', 'Harry': 'broomstick'}
```

is vulnerable! One workaround is to do

```python
>>> foo() == {'Hermione': 'hippogryph', 'Harry': 'broomstick'}
True
```

instead. Another is to do

```python
>>> d = sorted(foo().items())
>>> d
[('Harry', 'broomstick'), ('Hermione', 'hippogryph')]
```

There are others, but you get the idea.

Another bad idea is to print things that embed an object address, like

```python
>>> id(1.0)  # certain to fail some of the time
7948648
>>> class C: pass
>>> C()  # the default repr() for instances embeds
<__main__.C instance at 0x00AC18F0>
```

The ELLIPSIS directive gives a nice approach for the last example:

```python
>>> C()  # doctest: +ELLIPSIS
<__main__.C instance at 0x...>
```

Floating-point numbers are also subject to small output variations across platforms, because Python defers to the platform C library for
float formatting, and C libraries vary widely in quality here.

```python
>>> 1./7  # risky
0.14285714285714285
>>> print(1./7)  # safer
0.142857142857
>>> print(round(1./7, 6))  # much safer
0.142857
```

Numbers of the form I/2.**J are safe across all platforms, and I often contrive doctest examples to produce numbers of that form:

```python
>>> 3./4  # utterly safe
0.75
```

Simple fractions are also easier for people to understand, and that makes for better documentation.
26.3.4. Basic API

The functions `testmod()` and `testfile()` provide a simple interface to doctest that should be sufficient for most basic uses. For a less formal introduction to these two functions, see sections Simple Usage: Checking Examples in Docstrings and Simple Usage: Checking Examples in a Text File.

```python
import doctest
doctest.testfile(filename, module_relative=True, name=None, package=None, globs=None, verbose=None, report=True, optionflags=0, extraglobs=None, raise_on_error=False, parser=DocTestParser(), encoding=None)
```

All arguments except `filename` are optional, and should be specified in keyword form.

Test examples in the file named `filename`. Return `(failure_count, test_count)`.  

Optional argument `module_relative` specifies how the filename should be interpreted:

- If `module_relative` is True (the default), then `filename` specifies an OS-independent module-relative path. By default, this path is relative to the calling module’s directory; but if the `package` argument is specified, then it is relative to that package. To ensure OS-independence, `filename` should use `/` characters to separate path segments, and may not be an absolute path (i.e., it may not begin with `/`).
- If `module_relative` is False, then `filename` specifies an OS-specific path. The path may be absolute or relative; relative paths are resolved with respect to the current working directory.
Optional argument *name* gives the name of the test; by default, or if None, `os.path.basename(filename)` is used.

Optional argument *package* is a Python package or the name of a Python package whose directory should be used as the base directory for a module-relative filename. If no package is specified, then the calling module's directory is used as the base directory for module-relative filenames. It is an error to specify *package* if *module_relative* is False.

Optional argument *globs* gives a dict to be used as the globals when executing examples. A new shallow copy of this dict is created for the doctest, so its examples start with a clean slate. By default, or if None, a new empty dict is used.

Optional argument *extraglobs* gives a dict merged into the globals used to execute examples. This works like `dict.update()`: if *globs* and *extraglobs* have a common key, the associated value in *extraglobs* appears in the combined dict. By default, or if None, no extra globals are used. This is an advanced feature that allows parameterization of doctests. For example, a doctest can be written for a base class, using a generic name for the class, then reused to test any number of subclasses by passing an *extraglobs* dict mapping the generic name to the subclass to be tested.

Optional argument *verbose* prints lots of stuff if true, and prints only failures if false; by default, or if None, it's true if and only if '-v' is in `sys.argv`.

Optional argument *report* prints a summary at the end when true, else prints nothing at the end. In verbose mode, the summary is detailed, else the summary is very brief (in fact, empty if all tests passed).
Optional argument *optionflags* (default value 0) takes the bitwise-or of option flags. See section *Option Flags*.

Optional argument *raise_on_error* defaults to false. If true, an exception is raised upon the first failure or unexpected exception in an example. This allows failures to be post-mortem debugged. Default behavior is to continue running examples.

Optional argument *parser* specifies a DocTestParser (or subclass) that should be used to extract tests from the files. It defaults to a normal parser (i.e., DocTestParser()).

Optional argument *encoding* specifies an encoding that should be used to convert the file to unicode.

doctest.testmod(m=None, name=None, globs=None, verbose=None, report=True, optionflags=0, extraglobs=None, raise_on_error=False, exclude_empty=False)

All arguments are optional, and all except for *m* should be specified in keyword form.

Test examples in docstrings in functions and classes reachable from module *m* (or module *__main__* if *m* is not supplied or is None), starting with *m.__doc__*.  

Also test examples reachable from dict *m.__test__*, if it exists and is not None. *m.__test__* maps names (strings) to functions, classes and strings; function and class docstrings are searched for examples; strings are searched directly, as if they were docstrings.

Only docstrings attached to objects belonging to module *m* are searched.

Return (*failure_count*, *test_count*).
Optional argument *name* gives the name of the module; by default, or if None, `m.__name__` is used.

Optional argument *exclude_empty* defaults to false. If true, objects for which no doctests are found are excluded from consideration. The default is a backward compatibility hack, so that code still using `doctest.master.summarize()` in conjunction with `testmod()` continues to get output for objects with no tests. The *exclude_empty* argument to the newer `DocTestFinder` constructor defaults to true.

Optional arguments *extraglobs*, *verbose*, *report*, *optionflags*, *raise_on_error*, and *globs* are the same as for function `testfile()` above, except that *globs* defaults to `m.__dict__`.

```python
doctest.run_docstring_examples(f, globs, verbose=False, name="NoName", compileflags=None, optionflags=0)
```

Test examples associated with object *f*; for example, *f* may be a string, a module, a function, or a class object.

A shallow copy of dictionary argument *globs* is used for the execution context.

Optional argument *name* is used in failure messages, and defaults to "NoName".

If optional argument *verbose* is true, output is generated even if there are no failures. By default, output is generated only in case of an example failure.

Optional argument *compileflags* gives the set of flags that should be used by the Python compiler when running the examples. By
default, or if None, flags are deduced corresponding to the set of future features found in *globs*.

Optional argument *optionflags* works as for function *testfile()* above.
26.3.5. Unittest API

As your collection of doctest’ed modules grows, you’ll want a way to run all their doctests systematically. `doctest` provides two functions that can be used to create `unittest` test suites from modules and text files containing doctests. To integrate with `unittest` test discovery, include a `load_tests()` function in your test module:

```python
import unittest
import doctest
import my_module_with_doctests

def load_tests(loader, tests, ignore):
    tests.addTests(doctest.DocTestSuite(my_module_with_doctests))
    return tests
```

There are two main functions for creating `unittest.TestSuite` instances from text files and modules with doctests:

`doctest.DocFileSuite(*paths, module_relative=True, package=None, setUp=None, tearDown=None, globs=None, optionflags=0, parser=DocTestParser(), encoding=None)`

- Convert doctest tests from one or more text files to a `unittest.TestSuite`.

The returned `unittest.TestSuite` is to be run by the `unittest` framework and runs the interactive examples in each file. If an example in any file fails, then the synthesized unit test fails, and a `failureException` exception is raised showing the name of the file containing the test and a (sometimes approximate) line number.

Pass one or more paths (as strings) to text files to be examined.
Options may be provided as keyword arguments:

Optional argument `module_relative` specifies how the filenames in `paths` should be interpreted:

- If `module_relative` is `True` (the default), then each filename in `paths` specifies an OS-independent module-relative path. By default, this path is relative to the calling module’s directory; but if the `package` argument is specified, then it is relative to that package. To ensure OS-independence, each filename should use `/` characters to separate path segments, and may not be an absolute path (i.e., it may not begin with `/`).
- If `module_relative` is `False`, then each filename in `paths` specifies an OS-specific path. The path may be absolute or relative; relative paths are resolved with respect to the current working directory.

Optional argument `package` is a Python package or the name of a Python package whose directory should be used as the base directory for module-relative filenames in `paths`. If no package is specified, then the calling module’s directory is used as the base directory for module-relative filenames. It is an error to specify `package` if `module_relative` is `False`.

Optional argument `setUp` specifies a set-up function for the test suite. This is called before running the tests in each file. The `setUp` function will be passed a `DocTest` object. The `setUp` function can access the test globals as the `globs` attribute of the test passed.

Optional argument `tearDown` specifies a tear-down function for the test suite. This is called after running the tests in each file. The `tearDown` function will be passed a `DocTest` object. The `tearDown` function can access the test globals as the `globs` attribute of the test passed.
Optional argument *globs* is a dictionary containing the initial global variables for the tests. A new copy of this dictionary is created for each test. By default, *globs* is a new empty dictionary.

Optional argument *optionflags* specifies the default doctest options for the tests, created by or-ing together individual option flags. See section *Option Flags*. See function *set_unittest_reportflags()* below for a better way to set reporting options.

Optional argument *parser* specifies a *DocTestParser* (or subclass) that should be used to extract tests from the files. It defaults to a normal parser (i.e., *DocTestParser()*).

Optional argument *encoding* specifies an encoding that should be used to convert the file to unicode.

The global __file__ is added to the globals provided to doctests loaded from a text file using *DocFileSuite()*.

doctest.*DocTestSuite*(module=None, globs=None, extraglobs=None, test_finder=None, setUp=None, tearDown=None, checker=None)

Convert doctest tests for a module to a *unittest.TestSuite*.

The returned *unittest.TestSuite* is to be run by the unittest framework and runs each doctest in the module. If any of the doctests fail, then the synthesized unit test fails, and a *failureException* exception is raised showing the name of the file containing the test and a (sometimes approximate) line number.

Optional argument *module* provides the module to be tested. It can be a module object or a (possibly dotted) module name. If not
specified, the module calling this function is used.

Optional argument *globs* is a dictionary containing the initial global variables for the tests. A new copy of this dictionary is created for each test. By default, *globs* is a new empty dictionary.

Optional argument *extraglobs* specifies an extra set of global variables, which is merged into *globs*. By default, no extra globals are used.

Optional argument *test_finder* is the `DocTestFinder` object (or a drop-in replacement) that is used to extract doctests from the module.

Optional arguments *setUp*, *tearDown*, and *optionflags* are the same as for function `DocFileSuite()` above.

This function uses the same search technique as `testmod()`.

*Changed in version 3.5:* `DocTestSuite()` returns an empty `unittest.TestSuite` if *module* contains no docstrings instead of raising `ValueError`.

Under the covers, `DocTestSuite()` creates a `unittest.TestSuite` out of doctest.DoctestCase instances, and `DocTestCase` is a subclass of `unittest.TestCase`. `DocTestCase` isn’t documented here (it’s an internal detail), but studying its code can answer questions about the exact details of `unittest` integration.

Similarly, `DocFileSuite()` creates a `unittest.TestSuite` out of doctest.DocFileCase instances, and `DocFileCase` is a subclass of `DocTestCase`. 
So both ways of creating a `unittest.TestSuite` run instances of DocTestCase. This is important for a subtle reason: when you run doctest functions yourself, you can control the doctest options in use directly, by passing option flags to doctest functions. However, if you're writing a unittest framework, unittest ultimately controls when and how tests get run. The framework author typically wants to control doctest reporting options (perhaps, e.g., specified by command line options), but there's no way to pass options through unittest to doctest test runners.

For this reason, doctest also supports a notion of doctest reporting flags specific to unittest support, via this function:

```python
doctest.set_unittest_reportflags(flags)

Set the doctest reporting flags to use.

Argument flags takes the bitwise-or of option flags. See section Option Flags. Only “reporting flags” can be used.

This is a module-global setting, and affects all future doctests run by module unittest: the runTest() method of DocTestCase looks at the option flags specified for the test case when the DocTestCase instance was constructed. If no reporting flags were specified (which is the typical and expected case), doctest's unittest reporting flags are or’ed into the option flags, and the option flags so augmented are passed to the DocTestRunner instance created to run the doctest. If any reporting flags were specified when the DocTestCase instance was constructed, doctest's unittest reporting flags are ignored.

The value of the unittest reporting flags in effect before the function was called is returned by the function.
26.3.6. Advanced API

The basic API is a simple wrapper that’s intended to make doctest easy to use. It is fairly flexible, and should meet most users’ needs; however, if you require more fine-grained control over testing, or wish to extend doctest’s capabilities, then you should use the advanced API.

The advanced API revolves around two container classes, which are used to store the interactive examples extracted from doctest cases:

- **Example**: A single Python **statement**, paired with its expected output.
- **DocTest**: A collection of **Examples**, typically extracted from a single docstring or text file.

Additional processing classes are defined to find, parse, and run, and check doctest examples:

- **DocTestFinder**: Finds all docstrings in a given module, and uses a **DocTestParser** to create a **DocTest** from every docstring that contains interactive examples.
- **DocTestParser**: Creates a **DocTest** object from a string (such as an object’s docstring).
- **DocTestRunner**: Executes the examples in a **DocTest**, and uses an **OutputChecker** to verify their output.
- **OutputChecker**: Compares the actual output from a doctest example with the expected output, and decides whether they match.

The relationships among these processing classes are summarized in the following diagram:
26.3.6.1. DocTest Objects

class doctest.DocTest(examples, globs, name, filename, lineno, docstring)

A collection of doctest examples that should be run in a single namespace. The constructor arguments are used to initialize the attributes of the same names.

DocTest defines the following attributes. They are initialized by the constructor, and should not be modified directly.

examples
A list of Example objects encoding the individual interactive Python examples that should be run by this test.

globs
The namespace (aka globals) that the examples should be run in. This is a dictionary mapping names to values. Any changes to the namespace made by the examples (such as binding new variables) will be reflected in globs after the test is run.

name
A string name identifying the DocTest. Typically, this is the
name of the object or file that the test was extracted from.

**filename**
The name of the file that this `DocTest` was extracted from; or None if the filename is unknown, or if the `DocTest` was not extracted from a file.

**lineno**
The line number within `filename` where this `DocTest` begins, or None if the line number is unavailable. This line number is zero-based with respect to the beginning of the file.

**docstring**
The string that the test was extracted from, or ‘None’ if the string is unavailable, or if the test was not extracted from a string.

### 26.3.6.2. Example Objects

```python
class doctest.Example(source, want, exc_msg=None, lineno=0, indent=0, options=None)
```

A single interactive example, consisting of a Python statement and its expected output. The constructor arguments are used to initialize the attributes of the same names.

`Example` defines the following attributes. They are initialized by the constructor, and should not be modified directly.

**source**
A string containing the example’s source code. This source code consists of a single Python statement, and always ends with a newline; the constructor adds a newline when necessary.
**want**

The expected output from running the example's source code (either from stdout, or a traceback in case of exception). `want` ends with a newline unless no output is expected, in which case it's an empty string. The constructor adds a newline when necessary.

**exc_msg**

The exception message generated by the example, if the example is expected to generate an exception; or None if it is not expected to generate an exception. This exception message is compared against the return value of `traceback.format_exception_only()`. `exc_msg` ends with a newline unless it's None. The constructor adds a newline if needed.

**lineno**

The line number within the string containing this example where the example begins. This line number is zero-based with respect to the beginning of the containing string.

**indent**

The example's indentation in the containing string, i.e., the number of space characters that precede the example's first prompt.

**options**

A dictionary mapping from option flags to `True` or `False`, which is used to override default options for this example. Any option flags not contained in this dictionary are left at their default value (as specified by the `DocTestRunner`'s `optionflags`). By default, no options are set.
26.3.6.3. DocTestFinder objects

class doctest.DocTestFinder(verbos\ed=False, parser=DocTestParser(), recurse=True, exclude_empty=True)

A processing class used to extract the DocTests that are relevant to a given object, from its docstring and the docstrings of its contained objects. DocTests can be extracted from modules, classes, functions, methods, staticmethods, classmethods, and properties.

The optional argument verbose can be used to display the objects searched by the finder. It defaults to False (no output).

The optional argument parser specifies the DocTestParser object (or a drop-in replacement) that is used to extract doctests from docstrings.

If the optional argument recurse is false, then DocTestFinder.find() will only examine the given object, and not any contained objects.

If the optional argument exclude_empty is false, then DocTestFinder.find() will include tests for objects with empty docstrings.

DocTestFinder defines the following method:

find(obj[, name][, module][, globs][, extraglobs])

Return a list of the DocTests that are defined by obj's docstring, or by any of its contained objects' docstrings.

The optional argument name specifies the object's name; this
name will be used to construct names for the returned DocTests. If name is not specified, then obj.__name__ is used.

The optional parameter module is the module that contains the given object. If the module is not specified or is None, then the test finder will attempt to automatically determine the correct module. The object’s module is used:

- As a default namespace, if globs is not specified.
- To prevent the DocTestFinder from extracting DocTests from objects that are imported from other modules. (Contained objects with modules other than module are ignored.)
- To find the name of the file containing the object.
- To help find the line number of the object within its file.

If module is False, no attempt to find the module will be made. This is obscure, of use mostly in testing doctest itself: if module is False, or is None but cannot be found automatically, then all objects are considered to belong to the (non-existent) module, so all contained objects will (recursively) be searched for doctests.

The globals for each DocTest is formed by combining globs and extraglobs (bindings in extraglobs override bindings in globs). A new shallow copy of the globals dictionary is created for each DocTest. If globs is not specified, then it defaults to the module’s __dict__, if specified, or {} otherwise. If extraglobs is not specified, then it defaults to {}.

26.3.6.4. DocTestParser objects
**class** doctest.**DocTestParser**

A processing class used to extract interactive examples from a string, and use them to create a **DocTest** object.

**DocTestParser** defines the following methods:

**get_doctest**(string, globs, name, filename, lineno)

Extract all doctest examples from the given string, and collect them into a **DocTest** object.

* globs, name, filename, and lineno are attributes for the new **DocTest** object. See the documentation for **DocTest** for more information.

**get_examples**(string, name='<string>')

Extract all doctest examples from the given string, and return them as a list of **Example** objects. Line numbers are 0-based. The optional argument *name* is a name identifying this string, and is only used for error messages.

**parse**(string, name='<string>')

Divide the given string into examples and intervening text, and return them as a list of alternating **Examples** and strings. Line numbers for the **Examples** are 0-based. The optional argument *name* is a name identifying this string, and is only used for error messages.

---

### 26.3.6.5. DocTestRunner objects

**class** doctest.**DocTestRunner**(checker=None, verbose=None, optionflags=0)

A processing class used to execute and verify the interactive
examples in a DocTest.

The comparison between expected outputs and actual outputs is
done by an OutputChecker. This comparison may be customized
with a number of option flags; see section Option Flags for more
information. If the option flags are insufficient, then the comparison
may also be customized by passing a subclass of OutputChecker to the constructor.

The test runner’s display output can be controlled in two ways.
First, an output function can be passed to TestRunner.run();
this function will be called with strings that should be displayed. It
defaults to sys.stdout.write. If capturing the output is not
sufficient, then the display output can be also customized by
subclassing DocTestRunner, and overriding the methods
report_start(), report_success(), report_unexpected_exception(), and report_failure().

The optional keyword argument checker specifies the
OutputChecker object (or drop-in replacement) that should be
used to compare the expected outputs to the actual outputs of
doctest examples.

The optional keyword argument verbose controls the
DocTestRunner’s verbosity. If verbose is True, then information
is printed about each example, as it is run. If verbose is False,
then only failures are printed. If verbose is unspecified, or None,
then verbose output is used iff the command-line switch -v is used.

The optional keyword argument optionflags can be used to control
how the test runner compares expected output to actual output,
and how it displays failures. For more information, see section
Option Flags.

**DocTestParser** defines the following methods:

**report_start**(out, test, example)

Report that the test runner is about to process the given example. This method is provided to allow subclasses of **DocTestRunner** to customize their output; it should not be called directly.

*example* is the example about to be processed. *test* is the test containing *example*. *out* is the output function that was passed to **DocTestRunner.run()**.

**report_success**(out, test, example, got)

Report that the given example ran successfully. This method is provided to allow subclasses of **DocTestRunner** to customize their output; it should not be called directly.

*example* is the example about to be processed. *got* is the actual output from the example. *test* is the test containing *example*. *out* is the output function that was passed to **DocTestRunner.run()**.

**report_failure**(out, test, example, got)

Report that the given example failed. This method is provided to allow subclasses of **DocTestRunner** to customize their output; it should not be called directly.

*example* is the example about to be processed. *got* is the actual output from the example. *test* is the test containing *example*. *out* is the output function that was passed to **DocTestRunner.run()**.
**report_unexpected_exception***(out, test, example, exc_info)***

Report that the given example raised an unexpected exception. This method is provided to allow subclasses of **DocTestRunner** to customize their output; it should not be called directly.

*example* is the example about to be processed. *exc_info* is a tuple containing information about the unexpected exception (as returned by **sys.exc_info()**). *test* is the test containing *example*. *out* is the output function that was passed to **DocTestRunner.run()**.

**run**(test, compileflags=None, out=None, clear_globs=True)

Run the examples in *test* (a **DocTest** object), and display the results using the writer function *out*.

The examples are run in the namespace *test.globs*. If *clear_globs* is true (the default), then this namespace will be cleared after the test runs, to help with garbage collection. If you would like to examine the namespace after the test completes, then use *clear_globs=False*.

*compileflags* gives the set of flags that should be used by the Python compiler when running the examples. If not specified, then it will default to the set of future-import flags that apply to *globs*.

The output of each example is checked using the **DocTestRunner**'s output checker, and the results are formatted by the **DocTestRunner.report_*()** methods.

**summarize**(verbose=None)
Print a summary of all the test cases that have been run by this DocTestRunner, and return a named tuple 
TestResults(failed, attempted).

The optional verbose argument controls how detailed the summary is. If the verbosity is not specified, then the DocTestRunner's verbosity is used.

26.3.6.6. OutputChecker objects

class doctest.OutputChecker
A class used to check the whether the actual output from a doctest example matches the expected output. OutputChecker defines two methods: check_output(), which compares a given pair of outputs, and returns true if they match; and output_difference(), which returns a string describing the differences between two outputs.

OutputChecker defines the following methods:

check_output(want, got, optionflags)
Return True iff the actual output from an example (got) matches the expected output (want). These strings are always considered to match if they are identical; but depending on what option flags the test runner is using, several non-exact match types are also possible. See section Option Flags for more information about option flags.

output_difference(example, got, optionflags)
Return a string describing the differences between the expected output for a given example (example) and the actual output (got). optionflags is the set of option flags used to compare
want and got.
26.3.7. Debugging

Doctest provides several mechanisms for debugging doctest examples:

- Several functions convert doctests to executable Python programs, which can be run under the Python debugger, `pdb`.

- The `DebugRunner` class is a subclass of `DocTestRunner` that raises an exception for the first failing example, containing information about that example. This information can be used to perform post-mortem debugging on the example.

- The `unittest` cases generated by `DocTestSuite()` support the `debug()` method defined by `unittest.TestCase`.

- You can add a call to `pdb.set_trace()` in a doctest example, and you'll drop into the Python debugger when that line is executed. Then you can inspect current values of variables, and so on. For example, suppose `a.py` contains just this module docstring:

```
"
>>> def f(x):
...    g(x*2)
>>> def g(x):
...    print(x+3)
...    import pdb; pdb.set_trace()
>>> f(3)
g
"
```

Then an interactive Python session may look like this:
>>> import a, doctest
>>> doctest.testmod(a)
--Return--
> <doctest a[1]>(3)g()->None
-> import pdb; pdb.set_trace()
(Pdb) list
  1   def g(x):
  2       print(x+3)
  3   ->   import pdb; pdb.set_trace()
[EOF]
(Pdb) p x
6
(Pdb) step
--Return--
> <doctest a[0]>(2)f()->None
-> g(x*2)
(Pdb) list
  1   def f(x):
  2   -> g(x*2)
[EOF]
(Pdb) p x
3
(Pdb) step
--Return--
> <doctest a[2]>(1)?()->None
-> f(3)
(Pdb) cont
(0, 3)
>>>

Functions that convert doctests to Python code, and possibly run the synthesized code under the debugger:

doctest.script_from_examples(s)

Convert text with examples to a script.
Argument `s` is a string containing doctest examples. The string is converted to a Python script, where doctest examples in `s` are converted to regular code, and everything else is converted to Python comments. The generated script is returned as a string. For example,

```python
import doctest
print(doctest.script_from_examples(r""
    Set x and y to 1 and 2.
    >>> x, y = 1, 2

    Print their sum:
    >>> print(x+y)
    3
""))
```

displays:

```
# Set x and y to 1 and 2.
x, y = 1, 2
#
# Print their sum:
print(x+y)
# Expected:
## 3
```

This function is used internally by other functions (see below), but can also be useful when you want to transform an interactive Python session into a Python script.

**doctest.testsource**(module, name)

Convert the doctest for an object to a script.

Argument `module` is a module object, or dotted name of a module, containing the object whose doctests are of interest. Argument
name is the name (within the module) of the object with the doctests of interest. The result is a string, containing the object's docstring converted to a Python script, as described for script_from_examples() above. For example, if module a.py contains a top-level function f(), then

```python
import a, doctest
print(doctest.testsource(a, "a.f"))
```

prints a script version of function f()'s docstring, with doctests converted to code, and the rest placed in comments.

doctest.debug(module, name, pm=False)

Debug the doctests for an object.

The module and name arguments are the same as for function testsource() above. The synthesized Python script for the named object's docstring is written to a temporary file, and then that file is run under the control of the Python debugger, pdb.

A shallow copy of module.__dict__ is used for both local and global execution context.

Optional argument pm controls whether post-mortem debugging is used. If pm has a true value, the script file is run directly, and the debugger gets involved only if the script terminates via raising an unhandled exception. If it does, then post-mortem debugging is invoked, via pdb.post_mortem(), passing the traceback object from the unhandled exception. If pm is not specified, or is false, the script is run under the debugger from the start, via passing an appropriate exec() call to pdb.run().

doctest.debug_src(src, pm=False, globs=None)
Debug the doctests in a string.

This is like function `debug()` above, except that a string containing doctest examples is specified directly, via the `src` argument.

Optional argument `pm` has the same meaning as in function `debug()` above.

Optional argument `globs` gives a dictionary to use as both local and global execution context. If not specified, or `None`, an empty dictionary is used. If specified, a shallow copy of the dictionary is used.

The `DebugRunner` class, and the special exceptions it may raise, are of most interest to testing framework authors, and will only be sketched here. See the source code, and especially `DebugRunner`'s docstring (which is a doctest!) for more details:

```python
class doctest.DebugRunner(checker=None, verbose=None, optionflags=0)
```

A subclass of `DocTestRunner` that raises an exception as soon as a failure is encountered. If an unexpected exception occurs, an `UnexpectedException` exception is raised, containing the test, the example, and the original exception. If the output doesn't match, then a `DocTestFailure` exception is raised, containing the test, the example, and the actual output.

For information about the constructor parameters and methods, see the documentation for `DocTestRunner` in section Advanced API.

There are two exceptions that may be raised by `DebugRunner` instances:
exception doctest.**DocTestFailure**(test, example, got)

An exception raised by **DocTestRunner** to signal that a doctest example's actual output did not match its expected output. The constructor arguments are used to initialize the attributes of the same names.

**DocTestFailure** defines the following attributes:

**DocTestFailure**.**test**

The **DocTest** object that was being run when the example failed.

**DocTestFailure**.**example**

The **Example** that failed.

**DocTestFailure**.**got**

The example's actual output.

exception doctest.**UnexpectedException**(test, example, exc_info)

An exception raised by **DocTestRunner** to signal that a doctest example raised an unexpected exception. The constructor arguments are used to initialize the attributes of the same names.

**UnexpectedException** defines the following attributes:

**UnexpectedException**.**test**

The **DocTest** object that was being run when the example failed.

**UnexpectedException**.**example**

The **Example** that failed.

**UnexpectedException**.**exc_info**

A tuple containing information about the unexpected exception, as
returned by `sys.exc_info()`.
26.3.8. Soapbox

As mentioned in the introduction, doctest has grown to have three primary uses:

1. Checking examples in docstrings.
2. Regression testing.
3. Executable documentation / literate testing.

These uses have different requirements, and it is important to distinguish them. In particular, filling your docstrings with obscure test cases makes for bad documentation.

When writing a docstring, choose docstring examples with care. There's an art to this that needs to be learned—it may not be natural at first. Examples should add genuine value to the documentation. A good example can often be worth many words. If done with care, the examples will be invaluable for your users, and will pay back the time it takes to collect them many times over as the years go by and things change. I'm still amazed at how often one of my doctest examples stops working after a “harmless” change.

Doctest also makes an excellent tool for regression testing, especially if you don’t skimp on explanatory text. By interleaving prose and examples, it becomes much easier to keep track of what’s actually being tested, and why. When a test fails, good prose can make it much easier to figure out what the problem is, and how it should be fixed. It’s true that you could write extensive comments in code-based testing, but few programmers do. Many have found that using doctest approaches instead leads to much clearer tests. Perhaps this is simply because doctest makes writing prose a little easier than writing code, while writing comments in code is a little harder. I think it goes deeper
than just that: the natural attitude when writing a doctest-based test is that you want to explain the fine points of your software, and illustrate them with examples. This in turn naturally leads to test files that start with the simplest features, and logically progress to complications and edge cases. A coherent narrative is the result, instead of a collection of isolated functions that test isolated bits of functionality seemingly at random. It’s a different attitude, and produces different results, blurring the distinction between testing and explaining.

Regression testing is best confined to dedicated objects or files. There are several options for organizing tests:

- Write text files containing test cases as interactive examples, and test the files using `testfile()` or `DocFileSuite()`. This is recommended, although is easiest to do for new projects, designed from the start to use doctest.
- Define functions named `_regrtest_topic` that consist of single docstrings, containing test cases for the named topics. These functions can be included in the same file as the module, or separated out into a separate test file.
- Define a `__test__` dictionary mapping from regression test topics to docstrings containing test cases.

When you have placed your tests in a module, the module can itself be the test runner. When a test fails, you can arrange for your test runner to re-run only the failing doctest while you debug the problem. Here is a minimal example of such a test runner:

```python
if __name__ == '__main__':
    import doctest
    flags = doctest.REPORT_NDIFF|doctest.FAIL_FAST
    if len(sys.argv) > 1:
        name = sys.argv[1]
        if name in globals():
```
```
obj = globals()[name]

else:
    obj = __test__[name]
doctest.run_docstring_examples(obj, globals(), optionflags=flags)

else:
    fail, total = doctest.testmod(optionflags=flags)
    print("{} failures out of {} tests".format(fail, total))
```

Footnotes

Examples containing both expected output and an exception are not supported. Trying to guess where one ends and the other begins is too error-prone, and that also makes for a confusing test.

[1]
26.4. **unittest** — Unit testing framework

(If you are already familiar with the basic concepts of testing, you might want to skip to the list of assert methods.)

The **unittest** unit testing framework was originally inspired by JUnit and has a similar flavor as major unit testing frameworks in other languages. It supports test automation, sharing of setup and shutdown code for tests, aggregation of tests into collections, and independence of the tests from the reporting framework.

To achieve this, **unittest** supports some important concepts in an object-oriented way:

**test fixture**

A *test fixture* represents the preparation needed to perform one or more tests, and any associate cleanup actions. This may involve, for example, creating temporary or proxy databases, directories, or starting a server process.

**test case**

A *test case* is the individual unit of testing. It checks for a specific response to a particular set of inputs. **unittest** provides a base class, **TestCase**, which may be used to create new test cases.

**test suite**

A *test suite* is a collection of test cases, test suites, or both. It is used to aggregate tests that should be executed together.

**test runner**

A *test runner* is a component which orchestrates the execution of tests and provides the outcome to the user. The runner may use a
graphical interface, a textual interface, or return a special value to indicate the results of executing the tests.

See also:

**Module doctest**
Another test-support module with a very different flavor.

**Simple Smalltalk Testing: With Patterns**
Kent Beck’s original paper on testing frameworks using the pattern shared by `unittest`.

**Nose and py.test**
Third-party unittest frameworks with a lighter-weight syntax for writing tests. For example, `assert func(10) == 42`.

**The Python Testing Tools Taxonomy**
An extensive list of Python testing tools including functional testing frameworks and mock object libraries.

**Testing in Python Mailing List**
A special-interest-group for discussion of testing, and testing tools, in Python.

The script `Tools/unittestgui/unittestgui.py` in the Python source distribution is a GUI tool for test discovery and execution. This is intended largely for ease of use for those new to unit testing. For production environments it is recommended that tests be driven by a continuous integration system such as Buildbot, Jenkins or Hudson.
26.4.1. Basic example

The `unittest` module provides a rich set of tools for constructing and running tests. This section demonstrates that a small subset of the tools suffice to meet the needs of most users.

Here is a short script to test three string methods:

```python
import unittest

class TestStringMethods(unittest.TestCase):
    def test_upper(self):
        self.assertEqual('foo'.upper(), 'FOO')

    def test_isupper(self):
        self.assertTrue('FOO'.isupper())
        self.assertFalse('Foo'.isupper())

    def test_split(self):
        s = 'hello world'
        self.assertEqual(s.split(), ['hello', 'world'])
        # check that s.split fails when the separator
        with self.assertRaises(TypeError):
            s.split(2)

if __name__ == '__main__':
    unittest.main()
```

A testcase is created by subclassing `unittest.TestCase`. The three individual tests are defined with methods whose names start with the letters `test`. This naming convention informs the test runner about which methods represent tests.
The crux of each test is a call to `assertEqual()` to check for an expected result; `assertTrue()` or `assertFalse()` to verify a condition; or `assertRaises()` to verify that a specific exception gets raised. These methods are used instead of the `assert` statement so the test runner can accumulate all test results and produce a report.

The `setUp()` and `tearDown()` methods allow you to define instructions that will be executed before and after each test method. They are covered in more details in the section Organizing test code.

The final block shows a simple way to run the tests. `unittest.main()` provides a command-line interface to the test script. When run from the command line, the above script produces an output that looks like this:

```python
... ---------------------------------------------------------------------- Ran 3 tests in 0.000s OK
```

Passing the `-v` option to your test script will instruct `unittest.main()` to enable a higher level of verbosity, and produce the following output:

```python
test_isupper (__main__.TestStringMethods) ... ok
test_split (__main__.TestStringMethods) ... ok
test_upper (__main__.TestStringMethods) ... ok

----------------------------------------------------------------------
Ran 3 tests in 0.001s
OK
```

The above examples show the most commonly used `unittest` features which are sufficient to meet many everyday testing needs. The remainder of the documentation explores the full feature set from first principles.
26.4.2. Command-Line Interface

The unittest module can be used from the command line to run tests from modules, classes or even individual test methods:

```
python -m unittest test_module1 test_module2
python -m unittest test_module.TestClass
python -m unittest test_module.TestClass.test_method
```

You can pass in a list with any combination of module names, and fully qualified class or method names.

Test modules can be specified by file path as well:

```
python -m unittest tests/test_something.py
```

This allows you to use the shell filename completion to specify the test module. The file specified must still be importable as a module. The path is converted to a module name by removing the ‘.py’ and converting path separators into ‘.’. If you want to execute a test file that isn’t importable as a module you should execute the file directly instead.

You can run tests with more detail (higher verbosity) by passing in the -v flag:

```
python -m unittest -v test_module
```

When executed without arguments Test Discovery is started:

```
python -m unittest
```
For a list of all the command-line options:

```
python -m unittest -h
```

*Changed in version 3.2:* In earlier versions it was only possible to run individual test methods and not modules or classes.

### 26.4.2.1. Command-line options

`unittest` supports these command-line options:

- **-b, --buffer**
  
  The standard output and standard error streams are buffered during the test run. Output during a passing test is discarded. Output is echoed normally on test fail or error and is added to the failure messages.

- **-c, --catch**
  
  Control-C during the test run waits for the current test to end and then reports all the results so far. A second Control-C raises the normal `KeyboardInterrupt` exception.

  See [Signal Handling](#) for the functions that provide this functionality.

- **-f, --failfast**
  
  Stop the test run on the first error or failure.

- **--locals**
  
  Show local variables in tracebacks.

*New in version 3.2:* The command-line options `-b`, `-c` and `-f` were added.
New in version 3.5: The command-line option `--locals`.

The command line can also be used for test discovery, for running all of the tests in a project or just a subset.
26.4.3. Test Discovery

New in version 3.2.

unittest supports simple test discovery. In order to be compatible with test discovery, all of the test files must be modules or packages (including namespace packages) importable from the top-level directory of the project (this means that their filenames must be valid identifiers).

Test discovery is implemented in TestLoader.discover(), but can also be used from the command line. The basic command-line usage is:

```
cd project_directory
python -m unittest discover
```

**Note:** As a shortcut, python -m unittest is the equivalent of python -m unittest discover. If you want to pass arguments to test discovery the discover sub-command must be used explicitly.

The discover sub-command has the following options:

- **-v, --verbose**
 Verbose output

- **-s, --start-directory directory**
  Directory to start discovery (. default)

- **-p, --pattern pattern**
  Pattern to match test files (test*.py default)
-t, --top-level-directory directory
Top level directory of project (defaults to start directory)

The -s, -p, and -t options can be passed in as positional arguments in that order. The following two command lines are equivalent:

```
python -m unittest discover -s project_directory -p
python -m unittest discover project_directory "*_test.py"
```

As well as being a path it is possible to pass a package name, for example myproject.subpackage.test, as the start directory. The package name you supply will then be imported and its location on the filesystem will be used as the start directory.

**Caution:** Test discovery loads tests by importing them. Once test discovery has found all the test files from the start directory you specify it turns the paths into package names to import. For example foo/bar/baz.py will be imported as foo.bar.baz.

If you have a package installed globally and attempt test discovery on a different copy of the package then the import *could* happen from the wrong place. If this happens test discovery will warn you and exit.

If you supply the start directory as a package name rather than a path to a directory then discover assumes that whichever location it imports from is the location you intended, so you will not get the warning.

Test modules and packages can customize test loading and discovery by through the load_tests protocol.

*Changed in version 3.4:* Test discovery supports namespace
packages.
26.4.4. Organizing test code

The basic building blocks of unit testing are test cases — single scenarios that must be set up and checked for correctness. In unittest, test cases are represented by unittest.TestCase instances. To make your own test cases you must write subclasses of TestCase or use FunctionTestCase.

The testing code of a TestCase instance should be entirely self contained, such that it can be run either in isolation or in arbitrary combination with any number of other test cases.

The simplest TestCase subclass will simply implement a test method (i.e. a method whose name starts with test) in order to perform specific testing code:

```python
import unittest
class DefaultWidgetSizeTestCase(unittest.TestCase):
    def test_default_widget_size(self):
        widget = Widget('The widget')
        self.assertEqual(widget.size(), (50, 50))
```

Note that in order to test something, we use one of the assert*() methods provided by the TestCase base class. If the test fails, an exception will be raised, and unittest will identify the test case as a failure. Any other exceptions will be treated as errors.

Tests can be numerous, and their set-up can be repetitive. Luckily, we can factor out set-up code by implementing a method called setUp(), which the testing framework will automatically call for every single test we run:
import unittest

class SimpleWidgetTestCase(unittest.TestCase):
    def setUp(self):
        self.widget = Widget('The widget')

    def test_default_widget_size(self):
        self.assertEqual(self.widget.size(), (50, 50), 'incorrect default size')

    def test_widget_resize(self):
        self.widget.resize(100, 150)
        self.assertEqual(self.widget.size(), (100, 150), 'wrong size after resize')

Note: The order in which the various tests will be run is determined by sorting the test method names with respect to the built-in ordering for strings.

If the setUp() method raises an exception while the test is running, the framework will consider the test to have suffered an error, and the test method will not be executed.

Similarly, we can provide a tearDown() method that tidies up after the test method has been run:

import unittest

class SimpleWidgetTestCase(unittest.TestCase):
    def setUp(self):
        self.widget = Widget('The widget')

    def tearDown(self):
        self.widget.dispose()
If `setUp()` succeeded, `tearDown()` will be run whether the test method succeeded or not.

Such a working environment for the testing code is called a *fixture*.

Test case instances are grouped together according to the features they test. *unittest* provides a mechanism for this: the *test suite*, represented by `unittest`'s `TestSuite` class. In most cases, calling `unittest.main()` will do the right thing and collect all the module’s test cases for you, and then execute them.

However, should you want to customize the building of your test suite, you can do it yourself:

```python
def suite():
    suite = unittest.TestSuite()
    suite.addTest(WidgetTestCase('test_default_size'))
    suite.addTest(WidgetTestCase('test_resize'))
    return suite
```

You can place the definitions of test cases and test suites in the same modules as the code they are to test (such as `widget.py`), but there are several advantages to placing the test code in a separate module, such as `test_widget.py`:

- The test module can be run standalone from the command line.
- The test code can more easily be separated from shipped code.
- There is less temptation to change test code to fit the code it tests without a good reason.
- Test code should be modified much less frequently than the code it tests.
- Tested code can be refactored more easily.
- Tests for modules written in C must be in separate modules
anyway, so why not be consistent?
• If the testing strategy changes, there is no need to change the source code.
26.4.5. Re-using old test code

Some users will find that they have existing test code that they would like to run from unittest, without converting every old test function to a TestCase subclass.

For this reason, unittest provides a FunctionTestCase class. This subclass of TestCase can be used to wrap an existing test function. Set-up and tear-down functions can also be provided.

Given the following test function:

```python
def testSomething():
    something = makeSomething()
    assert something.name is not None
    # ...
```

one can create an equivalent test case instance as follows, with optional set-up and tear-down methods:

```python
testcase = unittest.FunctionTestCase(testSomething, setUp=makeSomethingDB, tearDown=deleteSomethingDB)
```

**Note:** Even though FunctionTestCase can be used to quickly convert an existing test base over to a unittest-based system, this approach is not recommended. Taking the time to set up proper TestCase subclasses will make future test refactorings infinitely easier.

In some cases, the existing tests may have been written using the
doctest module. If so, doctest provides a DocTestSuite class that can automatically build unittest.TestSuite instances from the existing doctest-based tests.
26.4.6. Skipping tests and expected failures

*New in version 3.1.*

Unittest supports skipping individual test methods and even whole classes of tests. In addition, it supports marking a test as an “expected failure,” a test that is broken and will fail, but shouldn’t be counted as a failure on a `TestResult`.

Skipping a test is simply a matter of using the `skip()` decorator or one of its conditional variants.

Basic skipping looks like this:

```python
class MyTestCase(unittest.TestCase):
    @unittest.skip("demonstrating skipping")
    def test_nothing(self):
        self.fail("shouldn't happen")

    @unittest.skipIf(mylib.__version__ < (1, 3),
                     "not supported in this library")
    def test_format(self):
        # Tests that work for only a certain version
        pass

    @unittest.skipUnless(sys.platform.startswith("win"),
                         "windows specific testing code")
    def test_windows_support(self):
        # windows specific testing code
        pass
```

This is the output of running the example above in verbose mode:
test_format (__main__.MyTestCase) ... skipped 'not supported in this library version'

Ran 3 tests in 0.005s

OK (skipped=3)

Classes can be skipped just like methods:

```python
@unittest.skip("showing class skipping")
class MySkippedTestCase(unittest.TestCase):
    def test_not_run(self):
        pass
```

`TestCase.setUp()` can also skip the test. This is useful when a resource that needs to be set up is not available.

Expected failures use the `expectedFailure()` decorator:

```python
class ExpectedFailureTestCase(unittest.TestCase):
    @unittest.expectedFailure
    def test_fail(self):
        self.assertEqual(1, 0, "broken")
```

It's easy to roll your own skipping decorators by making a decorator that calls `skip()` on the test when it wants it to be skipped. This decorator skips the test unless the passed object has a certain attribute:

```python
def skipUnlessHasattr(obj, attr):
    if hasattr(obj, attr):
        return lambda func: func
```
The following decorators implement test skipping and expected failures:

```python
return unittest.skip("{!r} doesn't have {!r}".format(name, error))
```

@unittest.skip(reason)
Unconditionally skip the decorated test. reason should describe why the test is being skipped.

@unittest.skipIf(condition, reason)
Skip the decorated test if condition is true.

@unittest.skipUnless(condition, reason)
Skip the decorated test unless condition is true.

@unittest.expectedFailure
Mark the test as an expected failure. If the test fails when run, the test is not counted as a failure.

```python
exception unittest.SkipTest(reason)
This exception is raised to skip a test.
```

Usually you can use `TestCase.skipTest()` or one of the skipping decorators instead of raising this directly.

Skipped tests will not have `setUp()` or `tearDown()` run around them. Skipped classes will not have `setUpClass()` or `tearDownClass()` run. Skipped modules will not have `setUpModule()` or `tearDownModule()` run.
26.4.7. Distinguishing test iterations using subtests

New in version 3.4.

When some of your tests differ only by a some very small differences, for instance some parameters, unittest allows you to distinguish them inside the body of a test method using the `subTest()` context manager.

For example, the following test:

```python
class NumbersTest(unittest.TestCase):
    def test_even(self):
        """
        Test that numbers between 0 and 5 are all even
        """
        for i in range(0, 6):
            with self.subTest(i=i):
                self.assertEqual(i % 2, 0)
```

will produce the following output:

```
FAIL: test_even (__main__.NumbersTest) (i=1)

Traceback (most recent call last):
  File "subtests.py", line 32, in test_even
    self.assertEqual(i % 2, 0)
AssertionError: 1 != 0
```

FAIL: test_even (__main__.NumbersTest) (i=3)

Traceback (most recent call last):
  File "subtests.py", line 32, in test_even
    self.assertEqual(i % 2, 0)
AssertionError: 1 != 0

FAIL: test_even (__main__.NumbersTest) (i=5)

Traceback (most recent call last):
  File "subtests.py", line 32, in test_even
    self.assertEqual(i % 2, 0)
AssertionError: 1 != 0

Without using a subtest, execution would stop after the first failure, and the error would be less easy to diagnose because the value of i wouldn’t be displayed:
26.4.8. Classes and functions

This section describes in depth the API of unittest.

26.4.8.1. Test cases

class unittest.TestCase(methodName='runTest')

Instances of the TestCase class represent the logical test units in the unittest universe. This class is intended to be used as a base class, with specific tests being implemented by concrete subclasses. This class implements the interface needed by the test runner to allow it to drive the tests, and methods that the test code can use to check for and report various kinds of failure.

Each instance of TestCase will run a single base method: the method named methodName. In most uses of TestCase, you will neither change the methodName nor reimplement the default runTest() method.

Changed in version 3.2: TestCase can be instantiated successfully without providing a methodName. This makes it easier to experiment with TestCase from the interactive interpreter.

TestCase instances provide three groups of methods: one group used to run the test, another used by the test implementation to check conditions and report failures, and some inquiry methods allowing information about the test itself to be gathered.

Methods in the first group (running the test) are:

setUp()
Method called to prepare the test fixture. This is called immediately before calling the test method; other than \texttt{AssertionError} or \texttt{SkipTest}, any exception raised by this method will be considered an error rather than a test failure. The default implementation does nothing.

\texttt{tearDown()}

Method called immediately after the test method has been called and the result recorded. This is called even if the test method raised an exception, so the implementation in subclasses may need to be particularly careful about checking internal state. Any exception, other than \texttt{AssertionError} or \texttt{SkipTest}, raised by this method will be considered an error rather than a test failure. This method will only be called if the \texttt{setUp()} succeeds, regardless of the outcome of the test method. The default implementation does nothing.

\texttt{setUpClass()}

A class method called before tests in an individual class run. \texttt{setUpClass} is called with the class as the only argument and must be decorated as a \texttt{classmethod}:

\begin{verbatim}
@classmethod
def setUpClass(cls):
    ...
\end{verbatim}

See \texttt{Class and Module Fixtures} for more details.

\textit{New in version 3.2.}

\texttt{tearDownClass()}

A class method called after tests in an individual class have run.
tearDownClass is called with the class as the only argument and must be decorated as a `classmethod()`:  

```python
@classmethod
def tearDownClass(cls):
    ...
```

See [Class and Module Fixtures](#) for more details.

_New in version 3.2._

**run**(result=None)

Run the test, collecting the result into the `TestResult` object passed as `result`. If `result` is omitted or None, a temporary result object is created (by calling the `defaultTestResult()` method) and used. The result object is returned to `run()`'s caller.

The same effect may be had by simply calling the `TestCase` instance.

_Changed in version 3.3:_ Previous versions of `run` did not return the result. Neither did calling an instance.

**skipTest**(reason)

Calling this during a test method or `setUp()` skips the current test. See [Skipping tests and expected failures](#) for more information.

_New in version 3.1._

**subTest**(msg=None, **params)

Return a context manager which executes the enclosed code
block as a subtest. msg and params are optional, arbitrary values which are displayed whenever a subtest fails, allowing you to identify them clearly.

A test case can contain any number of subtest declarations, and they can be arbitrarily nested.

See Distinguishing test iterations using subtests for more information.

New in version 3.4.

debug()
Run the test without collecting the result. This allows exceptions raised by the test to be propagated to the caller, and can be used to support running tests under a debugger.

The TestCase class provides a number of methods to check for and report failures, such as:

<table>
<thead>
<tr>
<th>Method</th>
<th>Checks that</th>
<th>New in</th>
</tr>
</thead>
<tbody>
<tr>
<td>assertEqual(a, b)</td>
<td>a == b</td>
<td></td>
</tr>
<tr>
<td>assertNotEqual(a, b)</td>
<td>a != b</td>
<td></td>
</tr>
<tr>
<td>assertTrue(x)</td>
<td>bool(x) is True</td>
<td></td>
</tr>
<tr>
<td>assertFalse(x)</td>
<td>bool(x) is False</td>
<td></td>
</tr>
<tr>
<td>assertIs(a, b)</td>
<td>a is b</td>
<td>3.1</td>
</tr>
<tr>
<td>assertIsNot(a, b)</td>
<td>a is not b</td>
<td>3.1</td>
</tr>
<tr>
<td>assertIsNone(x)</td>
<td>x is None</td>
<td>3.1</td>
</tr>
<tr>
<td>assertIsNotNone(x)</td>
<td>x is not None</td>
<td>3.1</td>
</tr>
<tr>
<td>assertIn(a, b)</td>
<td>a in b</td>
<td>3.1</td>
</tr>
</tbody>
</table>
assertNotIn(a, b)

a not in b 3.1

assertIsInstance(a, b)

isinstance(a, b) 3.2

assertNotIsInstance(a, b)

not isinstance(a, b) 3.2

All the assert methods accept a msg argument that, if specified, is used as the error message on failure (see also longMessage). Note that the msg keyword argument can be passed to assertRaises(), assertRaisesRegex(), assertWarns(), assertWarnsRegex() only when they are used as a context manager.

**assertEqual(first, second, msg=None)**

Test that first and second are equal. If the values do not compare equal, the test will fail.

In addition, if first and second are the exact same type and one of list, tuple, dict, set, frozenset or str or any type that a subclass registers with addTypeEqualityFunc() the type-specific equality function will be called in order to generate a more useful default error message (see also the list of type-specific methods).

*Changed in version 3.1:* Added the automatic calling of type-specific equality function.

*Changed in version 3.2:* assertMultiLineEqual() added as the default type equality function for comparing strings.

**assertNotEqual(first, second, msg=None)**

Test that first and second are not equal. If the values do
compare equal, the test will fail.

**assertTrue**(expr, msg=None)
**assertFalse**(expr, msg=None)

Test that *expr* is true (or false).

Note that this is equivalent to `bool(expr)` is True and not to `expr` is True (use `assertIs(expr, True)` for the latter). This method should also be avoided when more specific methods are available (e.g. `assertEqual(a, b)` instead of `assertTrue(a == b)`), because they provide a better error message in case of failure.

**assertIs**(first, second, msg=None)
**assertIsNot**(first, second, msg=None)

Test that *first* and *second* evaluate (or don’t evaluate) to the same object.

*New in version 3.1.*

**assertIsNone**(expr, msg=None)
**assertIsNotNone**(expr, msg=None)

Test that *expr* is (or is not) None.

*New in version 3.1.*

**assertIn**(first, second, msg=None)
**assertNotIn**(first, second, msg=None)

Test that *first* is (or is not) in *second*.

*New in version 3.1.*

**assertIsInstance**(obj, cls, msg=None)
**assertNotIsInstance**(obj, cls, msg=None)

Test that *obj* is (or is not) an instance of *cls* (which can be a class or a tuple of classes, as supported by `isinstance()`). To check for the exact type, use `assertIs(type(obj), cls)`.

*New in version 3.2.*

It is also possible to check the production of exceptions, warnings and log messages using the following methods:

<table>
<thead>
<tr>
<th>Method</th>
<th>Checks that</th>
<th>New in</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>assertRaises(exc, fun, *args, **kwds)</code></td>
<td><code>fun(*args, **kwds) raises exc</code></td>
<td></td>
</tr>
<tr>
<td><code>assertRaisesRegexp(exc, r, fun, *args, **kwds)</code></td>
<td><code>fun(*args, **kwds) raises exc</code> and the message matches regex <em>r</em></td>
<td>3.1</td>
</tr>
<tr>
<td><code>assertWarns(warn, fun, *args, **kwds)</code></td>
<td><code>fun(*args, **kwds) raises warn</code></td>
<td>3.2</td>
</tr>
<tr>
<td><code>assertWarnsRegexp(warn, r, fun, *args, **kwds)</code></td>
<td><code>fun(*args, **kwds) raises warn</code> and the message matches regex <em>r</em></td>
<td>3.2</td>
</tr>
<tr>
<td><code>assertLogs(logger, level)</code></td>
<td>The with block logs on <em>logger</em> with minimum <em>level</em></td>
<td>3.4</td>
</tr>
</tbody>
</table>

**assertRaises**(exception, callable, *args, **kwds)

**assertRaises**(exception, msg=None)

Test that an exception is raised when *callable* is called with any positional or keyword arguments that are also passed to
**assertRaises()**. The test passes if *exception* is raised, is an error if another exception is raised, or fails if no exception is raised. To catch any of a group of exceptions, a tuple containing the exception classes may be passed as *exception*.

If only the *exception* and possibly the *msg* arguments are given, return a context manager so that the code under test can be written inline rather than as a function:

```python
with self.assertRaises(SomeException):
    do_something()
```

When used as a context manager, **assertRaises()** accepts the additional keyword argument *msg*.

The context manager will store the caught exception object in its exception attribute. This can be useful if the intention is to perform additional checks on the exception raised:

```python
with self.assertRaises(SomeException) as cm:
    do_something()
the_exception = cm.exception
self.assertEqual(the_exception.error_code, 3)
```

*Changed in version 3.1:* Added the ability to use **assertRaises()** as a context manager.

*Changed in version 3.2:* Added the exception attribute.

*Changed in version 3.3:* Added the *msg* keyword argument when used as a context manager.

**assertRaisesRegex**(*exception*, *regex*, *callable*, *args*, *kwargs*, *match*):

.. automethod:: unittest.TestCase.assertRaisesRegex
**kwds)

`assertRaisesRegex(exception, regex, msg=None)`

Like `assertRaises()` but also tests that `regex` matches on the string representation of the raised exception. `regex` may be a regular expression object or a string containing a regular expression suitable for use by `re.search()`. Examples:

```
self.assertRaisesRegex(ValueError, "invalid literal for \.
int, 'XYZ'")
```

or:

```
with self.assertRaisesRegex(ValueError, 'literal'
int('XYZ')
```

*New in version 3.1:* under the name `assertRaisesRegexp`.

*Changed in version 3.2:* Renamed to `assertRaisesRegex()`.

*Changed in version 3.3:* Added the `msg` keyword argument when used as a context manager.

`assertWarns(warning, callable, *args, **kwds)`

`assertWarns(warning, msg=None)`

Test that a warning is triggered when `callable` is called with any positional or keyword arguments that are also passed to `assertWarns()`. The test passes if `warning` is triggered and fails if it isn’t. Any exception is an error. To catch any of a group of warnings, a tuple containing the warning classes may be passed as `warnings`.

If only the `warning` and possibly the `msg` arguments are given,
return a context manager so that the code under test can be written inline rather than as a function:

```python
with self.assertWarns(SomeWarning):
    do_something()
```

When used as a context manager, `assertWarns()` accepts the additional keyword argument `msg`.

The context manager will store the caught warning object in its `warning` attribute, and the source line which triggered the warnings in the `filename` and `lineno` attributes. This can be useful if the intention is to perform additional checks on the warning caught:

```python
with self.assertWarns(SomeWarning) as cm:
    do_something()

self.assertIn('myfile.py', cm.filename)
self.assertEqual(320, cm.lineno)
```

This method works regardless of the warning filters in place when it is called.

*New in version 3.2.*

*Changed in version 3.3:* Added the `msg` keyword argument when used as a context manager.

```python
assertWarnsRegex(warning, regex, callable, *args, **kwds)
assertWarnsRegex(warning, regex, msg=None)
```

Like `assertWarns()` but also tests that `regex` matches on the message of the triggered warning. `regex` may be a regular expression object or a string containing a regular expression
suitable for use by `re.search()`. Example:

```python
self.assertWarnsRegex(DeprecationWarning, r'legacy_function\([^()]*\) is legacy_function, 'XYZ')
```

or:

```python
with self.assertWarnsRegex(RuntimeWarning, 'unsfrobnicate(\'/etc/passwd\')
```

New in version 3.2.

Changed in version 3.3: Added the `msg` keyword argument when used as a context manager.

**assertLogs**(logger=None, level=None)

A context manager to test that at least one message is logged on the `logger` or one of its children, with at least the given `level`.

If given, `logger` should be a `logging.Logger` object or a `str` giving the name of a logger. The default is the root logger, which will catch all messages.

If given, `level` should be either a numeric logging level or its string equivalent (for example either "ERROR" or `logging.ERROR`). The default is `logging.INFO`.

The test passes if at least one message emitted inside the with block matches the `logger` and `level` conditions, otherwise it fails.

The object returned by the context manager is a recording
helper which keeps tracks of the matching log messages. It has two attributes:

**records**

A list of `logging.LogRecord` objects of the matching log messages.

**output**

A list of `str` objects with the formatted output of matching messages.

Example:

```python
with self.assertLogs('foo', level='INFO') as cm:
    logging.getLogger('foo').info('first message')
    logging.getLogger('foo.bar').error('second message')
self.assertEqual(cm.output, ['INFO:foo:first message', 'ERROR:foo.bar:second message'])
```

*New in version 3.4.*

There are also other methods used to perform more specific checks, such as:

<table>
<thead>
<tr>
<th>Method</th>
<th>Checks that</th>
<th>New in</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>assertAlmostEqual(a, b)</code></td>
<td><code>round(a-b, 7) == 0</code></td>
<td></td>
</tr>
<tr>
<td><code>assertNotAlmostEqual(a, b)</code></td>
<td><code>round(a-b, 7) != 0</code></td>
<td></td>
</tr>
<tr>
<td><code>assertGreater(a, b)</code></td>
<td><code>a &gt; b</code></td>
<td>3.1</td>
</tr>
<tr>
<td><code>assertGreaterEqual(a, b)</code></td>
<td><code>a &gt;= b</code></td>
<td>3.1</td>
</tr>
<tr>
<td><code>assertLess(a, b)</code></td>
<td><code>a &lt; b</code></td>
<td>3.1</td>
</tr>
<tr>
<td>Method</td>
<td>Description</td>
<td>Python Code</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>assertLess(a, b)</td>
<td>a &lt; b</td>
<td></td>
</tr>
<tr>
<td>assertLessEqual(a, b)</td>
<td>a &lt;= b</td>
<td></td>
</tr>
<tr>
<td>assertRegex(s, r)</td>
<td>r.search(s)</td>
<td></td>
</tr>
<tr>
<td>assertNotRegex(s, r)</td>
<td>not r.search(s)</td>
<td></td>
</tr>
<tr>
<td>assertCountEqual(a, b)</td>
<td>a and b have the same elements in the same number, regardless of their order</td>
<td></td>
</tr>
</tbody>
</table>

| assertAlmostEqual(first, second, places=7, msg=None, delta=None) | Test that first and second are approximately (or not approximately) equal by computing the difference, rounding to the given number of decimal places (default 7), and comparing to zero. Note that these methods round the values to the given number of decimal places (i.e. like the `round()` function) and not significant digits. If delta is supplied instead of places then the difference between first and second must be less or equal to (or greater than) delta. Supplying both delta and places raises a TypeError. |
| assertNotAlmostEqual(first, second, places=7, msg=None, delta=None) | Changed in version 3.2: assertAlmostEqual() automatically considers almost equal objects that compare equal. assertNotAlmostEqual() automatically fails if the objects compare equal. Added the delta keyword argument. |

| assertGreater(first, second, msg=None) | |


assertGreaterEqual(first, second, msg=None)
assertLess(first, second, msg=None)
assertLessEqual(first, second, msg=None)

Test that first is respectively >, >=, < or <= than second depending on the method name. If not, the test will fail:

```python
>>> self.assertGreaterEqual(3, 4)
AssertionError: "3" unexpectedly not greater than or equal to "4"
```

New in version 3.1.

assertRegex(text, regex, msg=None)
assertNotRegex(text, regex, msg=None)

Test that a regex search matches (or does not match) text. In case of failure, the error message will include the pattern and the text (or the pattern and the part of text that unexpectedly matched). regex may be a regular expression object or a string containing a regular expression suitable for use by re.search().

New in version 3.1: under the name assertRegexpMatches.

Changed in version 3.2: The method assertRegexpMatches() has been renamed to assertRegex().

New in version 3.2: assertNotRegex().

assertCountEqual(first, second, msg=None)

Test that sequence first contains the same elements as second, regardless of their order. When they don't, an error message listing the differences between the sequences will be
Duplicate elements are not ignored when comparing first and second. It verifies whether each element has the same count in both sequences. Equivalent to:
```
assertEqual(Counter(list(first)), Counter(list(second)))
```
but works with sequences of unhashable objects as well.

*New in version 3.2.*

The `assertEqual()` method dispatches the equality check for objects of the same type to different type-specific methods. These methods are already implemented for most of the built-in types, but it's also possible to register new methods using `addTypeEqualityFunc()`:

```
addTypeEqualityFunc(typeobj, function)
```

Registers a type-specific method called by `assertEqual()` to check if two objects of exactly the same `typeobj` (not subclasses) compare equal. `function` must take two positional arguments and a third `msg=None` keyword argument just as `assertEqual()` does. It must raise `self.failureException(msg)` when inequality between the first two parameters is detected – possibly providing useful information and explaining the inequalities in details in the error message.

*New in version 3.1.*

The list of type-specific methods automatically used by `assertEqual()` are summarized in the following table. Note that it's usually not necessary to invoke these methods directly.
<table>
<thead>
<tr>
<th>Method</th>
<th>Used to compare</th>
<th>New in</th>
</tr>
</thead>
<tbody>
<tr>
<td>assertMultiLineEqual(a, b)</td>
<td>strings</td>
<td>3.1</td>
</tr>
<tr>
<td>assertSequenceEqual(a, b)</td>
<td>sequences</td>
<td>3.1</td>
</tr>
<tr>
<td>assertListEqual(a, b)</td>
<td>lists</td>
<td>3.1</td>
</tr>
<tr>
<td>assertTupleEqual(a, b)</td>
<td>tuples</td>
<td>3.1</td>
</tr>
<tr>
<td>assertSetEqual(a, b)</td>
<td>sets or frozensets</td>
<td>3.1</td>
</tr>
<tr>
<td>assertDictEqual(a, b)</td>
<td>dicts</td>
<td>3.1</td>
</tr>
</tbody>
</table>

assertMultiLineEqual(first, second, msg=None)

Test that the multiline string first is equal to the string second. When not equal a diff of the two strings highlighting the differences will be included in the error message. This method is used by default when comparing strings with assertEqual().

*New in version 3.1.*

assertSequenceEqual(first, second, msg=None, seq_type=None)

Tests that two sequences are equal. If a seq_type is supplied, both first and second must be instances of seq_type or a failure will be raised. If the sequences are different an error message is constructed that shows the difference between the two.

This method is not called directly by assertEqual(), but it's used to implement assertListEqual() and assertTupleEqual().

*New in version 3.1.*
assertListEqual\( (first, second, msg=None) \)

assertTupleEqual\( (first, second, msg=None) \)

Tests that two lists or tuples are equal. If not, an error message is constructed that shows only the differences between the two. An error is also raised if either of the parameters are of the wrong type. These methods are used by default when comparing lists or tuples with `assertEqual()`.

*New in version 3.1.*

assertSetEqual\( (first, second, msg=None) \)

Tests that two sets are equal. If not, an error message is constructed that lists the differences between the sets. This method is used by default when comparing sets or frozensets with `assertEqual()`.

Fails if either of `first` or `second` does not have a `set.difference()` method.

*New in version 3.1.*

assertDictEqual\( (first, second, msg=None) \)

Test that two dictionaries are equal. If not, an error message is constructed that shows the differences in the dictionaries. This method will be used by default to compare dictionaries in calls to `assertEqual()`.

*New in version 3.1.*

Finally the `TestCase` provides the following methods and attributes:

fail\( (msg=None) \)
Signals a test failure unconditionally, with `msg` or `None` for the error message.

**failureException**

This class attribute gives the exception raised by the test method. If a test framework needs to use a specialized exception, possibly to carry additional information, it must subclass this exception in order to “play fair” with the framework. The initial value of this attribute is `AssertionError`.

**longMessage**

If set to `True` then any explicit failure message you pass in to the assert methods will be appended to the end of the normal failure message. The normal messages contain useful information about the objects involved, for example the message from `assertEqual` shows you the repr of the two unequal objects. Setting this attribute to `True` allows you to have a custom error message in addition to the normal one.

This attribute defaults to `True`. If set to `False` then a custom message passed to an assert method will silence the normal message.

The class setting can be overridden in individual tests by assigning an instance attribute to `True` or `False` before calling the assert methods.

*New in version 3.1.*

**maxDiff**

This attribute controls the maximum length of diffs output by assert methods that report diffs on failure. It defaults to 80*8
characters. Assert methods affected by this attribute are `assertSequenceEqual()` (including all the sequence comparison methods that delegate to it), `assertDictEqual()` and `assertMultiLineEqual()`.

Setting `maxDiff` to `None` means that there is no maximum length of diffs.

*New in version 3.2.*

Testing frameworks can use the following methods to collect information on the test:

**countTestCases()**

Return the number of tests represented by this test object. For `TestCase` instances, this will always be 1.

**defaultTestResult()**

Return an instance of the test result class that should be used for this test case class (if no other result instance is provided to the `run()` method).

For `TestCase` instances, this will always be an instance of `TestResult`; subclasses of `TestCase` should override this as necessary.

**id()**

Return a string identifying the specific test case. This is usually the full name of the test method, including the module and class name.

**shortDescription()**

Returns a description of the test, or `None` if no description has
been provided. The default implementation of this method returns the first line of the test method's docstring, if available, or None.

*Changed in version 3.1:* In 3.1 this was changed to add the test name to the short description even in the presence of a docstring. This caused compatibility issues with unittest extensions and adding the test name was moved to the `TextTestResult` in Python 3.2.

**addCleanup**(function, *args, **kwargs)

Add a function to be called after `tearDown()` to cleanup resources used during the test. Functions will be called in reverse order to the order they are added (LIFO). They are called with any arguments and keyword arguments passed into `addCleanup()` when they are added.

If `setUp()` fails, meaning that `tearDown()` is not called, then any cleanup functions added will still be called.

*New in version 3.1.*

**doCleanups()**

This method is called unconditionally after `tearDown()`, or after `setUp()` if `setUp()` raises an exception.

It is responsible for calling all the cleanup functions added by `addCleanup()`. If you need cleanup functions to be called *prior* to `tearDown()` then you can call `doCleanups()` yourself.

`doCleanups()` pops methods off the stack of cleanup functions one at a time, so it can be called at any time.
New in version 3.1.

```python
class unittest.FunctionTestCase(testFunc, setUp=None, tearDown=None, description=None)
```

This class implements the portion of the `TestCase` interface which allows the test runner to drive the test, but does not provide the methods which test code can use to check and report errors. This is used to create test cases using legacy test code, allowing it to be integrated into a `unittest`-based test framework.

### 26.4.8.1.1. Deprecated aliases

For historical reasons, some of the `TestCase` methods had one or more aliases that are now deprecated. The following table lists the correct names along with their deprecated aliases:

<table>
<thead>
<tr>
<th>Method Name</th>
<th>Deprecated alias</th>
<th>Deprecated since version 3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>assertEqual()</code></td>
<td><code>failUnlessEqual</code></td>
<td><code>assertEqual</code></td>
</tr>
<tr>
<td><code>assertNotEqual()</code></td>
<td><code>failIfEqual</code></td>
<td><code>assertNotEqual</code></td>
</tr>
<tr>
<td><code>assertTrue()</code></td>
<td><code>failUnless</code></td>
<td><code>assertTrue</code></td>
</tr>
<tr>
<td><code>assertFalse()</code></td>
<td><code>failIf</code></td>
<td><code>assertFalse</code></td>
</tr>
<tr>
<td><code>assertRaises()</code></td>
<td><code>failUnlessRaises</code></td>
<td><code>assertRaises</code></td>
</tr>
<tr>
<td><code>assertAlmostEqual()</code></td>
<td><code>failUnlessAlmostEqual</code></td>
<td><code>assertAlmostEqual</code></td>
</tr>
<tr>
<td><code>assertNotAlmostEqual()</code></td>
<td><code>failIfAlmostEqual</code></td>
<td><code>assertNotAlmostEqual</code></td>
</tr>
<tr>
<td><code>assertRegex()</code></td>
<td></td>
<td><code>assertRegex</code></td>
</tr>
<tr>
<td><code>assertRaisesRegex()</code></td>
<td></td>
<td><code>assertRaisesRegex</code></td>
</tr>
</tbody>
</table>

*Deprecated since version 3.1:* the `fail*` aliases listed in the second column.
Deprecated since version 3.2: the assert* aliases listed in the third column.

Deprecated since version 3.2: assertRegexpMatches and assertRaisesRegexp have been renamed to assertRegex() and assertRaisesRegex()

26.4.8.2. Grouping tests

class unittest.TestSuite(tests=())

This class represents an aggregation of individual tests cases and test suites. The class presents the interface needed by the test runner to allow it to be run as any other test case. Running a TestSuite instance is the same as iterating over the suite, running each test individually.

If tests is given, it must be an iterable of individual test cases or other test suites that will be used to build the suite initially. Additional methods are provided to add test cases and suites to the collection later on.

TestSuite objects behave much like TestCase objects, except they do not actually implement a test. Instead, they are used to aggregate tests into groups of tests that should be run together. Some additional methods are available to add tests to TestSuite instances:

addTest(test)

Add a TestCase or TestSuite to the suite.

addTests(tests)

Add all the tests from an iterable of TestCase and TestSuite
instances to this test suite.

This is equivalent to iterating over tests, calling `addTest()` for each element.

`TestSuite` shares the following methods with `TestCase`:

`run(result)`
Run the tests associated with this suite, collecting the result into the test result object passed as `result`. Note that unlike `TestCase.run()`, `TestSuite.run()` requires the result object to be passed in.

`debug()`
Run the tests associated with this suite without collecting the result. This allows exceptions raised by the test to be propagated to the caller and can be used to support running tests under a debugger.

`countTestCases()`
Return the number of tests represented by this test object, including all individual tests and sub-suites.

`__iter__()`
Tests grouped by a `TestSuite` are always accessed by iteration. Subclasses can lazily provide tests by overriding `__iter__()`. Note that this method may be called several times on a single suite (for example when counting tests or comparing for equality) so the tests returned by repeated iterations before `TestSuite.run()` must be the same for each call iteration. After `TestSuite.run()`, callers should not rely on the tests returned by this method unless the caller uses
a subclass that overrides TestSuite._removeTestAtIndex() to preserve test references.

*Changed in version 3.2:* In earlier versions the TestSuite accessed tests directly rather than through iteration, so overriding `__iter__()` wasn't sufficient for providing tests.

*Changed in version 3.4:* In earlier versions the TestSuite held references to each TestCase after TestSuite.run(). Subclasses can restore that behavior by overriding TestSuite._removeTestAtIndex().

In the typical usage of a TestSuite object, the run() method is invoked by a TestRunner rather than by the end-user test harness.

### 26.4.8.3. Loading and running tests

class unittest.TestLoader

The TestLoader class is used to create test suites from classes and modules. Normally, there is no need to create an instance of this class; the unittest module provides an instance that can be shared as unittest.defaultTestLoader. Using a subclass or instance, however, allows customization of some configurable properties.

TestLoader objects have the following attributes:

**errors**

A list of the non-fatal errors encountered while loading tests. Not reset by the loader at any point. Fatal errors are signalled
by the relevant a method raising an exception to the caller. Non-fatal errors are also indicated by a synthetic test that will raise the original error when run.

*New in version 3.5.*

**TestLoader** objects have the following methods:

**loadTestsFromTestCase**(**testCaseClass**)  
Return a suite of all tests cases contained in the **TestCase**-derived testCaseClass.

A test case instance is created for each method named by **getTestCaseNames()**. By default these are the method names beginning with test. If **getTestCaseNames()** returns no methods, but the **runTest()** method is implemented, a single test case is created for that method instead.

**loadTestsFromModule**(**module, pattern=None**)  
Return a suite of all tests cases contained in the given module. This method searches **module** for classes derived from **TestCase** and creates an instance of the class for each test method defined for the class.

**Note:** While using a hierarchy of **TestCase**-derived classes can be convenient in sharing fixtures and helper functions, defining test methods on base classes that are not intended to be instantiated directly does not play well with this method. Doing so, however, can be useful when the fixtures are different and defined in subclasses.

If a module provides a **load_tests** function it will be called to load the tests. This allows modules to customize test loading.
This is the load_tests protocol. The pattern argument is passed as the third argument to load_tests.

*Changed in version 3.2:* Support for load_tests added.

*Changed in version 3.5:* The undocumented and unofficial use_load_tests default argument is deprecated and ignored, although it is still accepted for backward compatibility. The method also now accepts a keyword-only argument pattern which is passed to load_tests as the third argument.

**loadTestsFromName**(name, module=None)

Return a suite of all tests cases given a string specifier.

The specifier name is a “dotted name” that may resolve either to a module, a test case class, a test method within a test case class, a TestSuite instance, or a callable object which returns a TestCase or TestSuite instance. These checks are applied in the order listed here; that is, a method on a possible test case class will be picked up as “a test method within a test case class”, rather than “a callable object”.

For example, if you have a module SampleTests containing a TestCase-derived class SampleTestCase with three test methods (test_one(), test_two(), and test_three()), the specifier 'SampleTests.SampleTestCase' would cause this method to return a suite which will run all three test methods. Using the specifier 'SampleTests.SampleTestCase.test_two' would cause it to return a test suite which will run only the test_two() test method. The specifier can refer to modules and packages which have not been imported; they will be imported as a side-
The method optionally resolves name relative to the given module.

Changed in version 3.5: If an ImportError or AttributeError occurs while traversing name then a synthetic test that raises that error when run will be returned. These errors are included in the errors accumulated by self.errors.

**loadTestsFromNames(names, module=None)**

Similar to loadTestsFromName(), but takes a sequence of names rather than a single name. The return value is a test suite which supports all the tests defined for each name.

**getTestCaseNames(testCaseClass)**

Return a sorted sequence of method names found within testCaseClass; this should be a subclass of `TestCase`.

**discover(start_dir, pattern='test*.py', top_level_dir=None)**

Find all the test modules by recursing into subdirectories from the specified start directory, and return a TestSuite object containing them. Only test files that match pattern will be loaded. (Using shell style pattern matching.) Only module names that are importable (i.e. are valid Python identifiers) will be loaded.

All test modules must be importable from the top level of the project. If the start directory is not the top level directory then the top level directory must be specified separately.

If importing a module fails, for example due to a syntax error, then this will be recorded as a single error and discovery will
continue. If the import failure is due to `SkipTest` being raised, it will be recorded as a skip instead of an error.

If a package (a directory containing a file named `__init__.py`) is found, the package will be checked for a `load_tests` function. If this exists then it will be called `package.load_tests(loader, tests, pattern)`. Test discovery takes care to ensure that a package is only checked for tests once during an invocation, even if the `load_tests` function itself calls `loader.discover`.

If `load_tests` exists then discovery does not recurse into the package, `load_tests` is responsible for loading all tests in the package.

The pattern is deliberately not stored as a loader attribute so that packages can continue discovery themselves. `top_level_dir` is stored so `load_tests` does not need to pass this argument in to `loader.discover()`.

`start_dir` can be a dotted module name as well as a directory.

*New in version 3.2.*

*Changed in version 3.4:* Modules that raise `SkipTest` on import are recorded as skips, not errors. Discovery works for *namespace packages*. Paths are sorted before being imported so that execution order is the same even if the underlying file system’s ordering is not dependent on file name.

*Changed in version 3.5:* Found packages are now checked for `load_tests` regardless of whether their path matches `pattern`, because it is impossible for a package name to match the
The following attributes of a TestLoader can be configured either by subclassing or assignment on an instance:

**testMethodPrefix**
String giving the prefix of method names which will be interpreted as test methods. The default value is 'test'.

This affects **getTestCaseNames()** and all the loadTestsFrom*() methods.

**sortTestMethodsUsing**
Function to be used to compare method names when sorting them in getTestCaseNames() and all the loadTestsFrom*() methods.

**suiteClass**
Callable object that constructs a test suite from a list of tests. No methods on the resulting object are needed. The default value is the TestSuite class.

This affects all the loadTestsFrom*() methods.

*class* unittest.TestResult
This class is used to compile information about which tests have succeeded and which have failed.

A TestResult object stores the results of a set of tests. The TestCase and TestSuite classes ensure that results are properly recorded; test authors do not need to worry about recording the outcome of tests.
Testing frameworks built on top of unittest may want access to the TestResult object generated by running a set of tests for reporting purposes; a TestResult instance is returned by the TestRunner.run() method for this purpose.

TestResult instances have the following attributes that will be of interest when inspecting the results of running a set of tests:

**errors**
A list containing 2-tuples of TestCase instances and strings holding formatted tracebacks. Each tuple represents a test which raised an unexpected exception.

**failures**
A list containing 2-tuples of TestCase instances and strings holding formatted tracebacks. Each tuple represents a test where a failure was explicitly signalled using the TestCase.assert*() methods.

**skipped**
A list containing 2-tuples of TestCase instances and strings holding the reason for skipping the test.

*New in version 3.1.*

**expectedFailures**
A list containing 2-tuples of TestCase instances and strings holding formatted tracebacks. Each tuple represents an expected failure of the test case.

**unexpectedSuccesses**
A list containing TestCase instances that were marked as expected failures, but succeeded.
**shouldStop**
Set to True when the execution of tests should stop by `stop()`.

**testsRun**
The total number of tests run so far.

**buffer**
If set to true, `sys.stdout` and `sys.stderr` will be buffered in between `startTest()` and `stopTest()` being called. Collected output will only be echoed onto the real `sys.stdout` and `sys.stderr` if the test fails or errors. Any output is also attached to the failure / error message.

*New in version 3.2.*

**failfast**
If set to true `stop()` will be called on the first failure or error, halting the test run.

*New in version 3.2.*

**tb_locals**
If set to true then local variables will be shown in tracebacks.

*New in version 3.5.*

**wasSuccessful()**
Return True if all tests run so far have passed, otherwise returns False.

*Changed in version 3.4: Returns False if there were any*
unexpectedSuccesses from tests marked with the expectedFailure() decorator.

**stop()**

This method can be called to signal that the set of tests being run should be aborted by setting the shouldStop attribute to True. TestRunner objects should respect this flag and return without running any additional tests.

For example, this feature is used by the TextTestRunner class to stop the test framework when the user signals an interrupt from the keyboard. Interactive tools which provide TestRunner implementations can use this in a similar manner.

The following methods of the TestResult class are used to maintain the internal data structures, and may be extended in subclasses to support additional reporting requirements. This is particularly useful in building tools which support interactive reporting while tests are being run.

**startTest**(test)

Called when the test case test is about to be run.

**stopTest**(test)

Called after the test case test has been executed, regardless of the outcome.

**startTestRun()**

Called once before any tests are executed.

*New in version 3.1.*

**stopTestRun()**
Called once after all tests are executed.

New in version 3.1.

addError(test, err)
Called when the test case test raises an unexpected exception. err is a tuple of the form returned by sys.exc_info(): (type, value, traceback).

The default implementation appends a tuple (test, formatted_err) to the instance's errors attribute, where formatted_err is a formatted traceback derived from err.

addFailure(test, err)
Called when the test case test signals a failure. err is a tuple of the form returned by sys.exc_info(): (type, value, traceback).

The default implementation appends a tuple (test, formatted_err) to the instance's failures attribute, where formatted_err is a formatted traceback derived from err.

addSuccess(test)
Called when the test case test succeeds.

The default implementation does nothing.

addSkip(test, reason)
Called when the test case test is skipped. reason is the reason the test gave for skipping.

The default implementation appends a tuple (test, reason) to the instance's skipped attribute.
addExpectedFailure(test, err)
Called when the test case test fails, but was marked with the expectedFailure() decorator.

The default implementation appends a tuple (test, formatted_err) to the instance's expectedFailures attribute, where formatted_err is a formatted traceback derived from err.

addUnexpectedSuccess(test)
Called when the test case test was marked with the expectedFailure() decorator, but succeeded.

The default implementation appends the test to the instance's unexpectedSuccesses attribute.

addSubTest(test, subtest, outcome)
Called when a subtest finishes. test is the test case corresponding to the test method. subtest is a custom TestCase instance describing the subtest.

If outcome is None, the subtest succeeded. Otherwise, it failed with an exception where outcome is a tuple of the form returned by sys.exc_info(): (type, value, traceback).

The default implementation does nothing when the outcome is a success, and records subtest failures as normal failures.

New in version 3.4.

class unittest.TextTestResult(stream, descriptions, verbosity)
A concrete implementation of TestResult used by the
**TextTestRunner.**

*New in version 3.2:* This class was previously named `_TextTestResult`. The old name still exists as an alias but is deprecated.

`unittest.defaultTestLoader`

Instance of the `TestLoader` class intended to be shared. If no customization of the `TestLoader` is needed, this instance can be used instead of repeatedly creating new instances.

```python
class unittest.TextTestRunner(stream=None, descriptions=True, verbosity=1, failfast=False, buffer=False, resultclass=None, warnings=None, *, tb_locals=False)
```

A basic test runner implementation that outputs results to a stream. If `stream` is None, the default, `sys.stderr` is used as the output stream. This class has a few configurable parameters, but is essentially very simple. Graphical applications which run test suites should provide alternate implementations. Such implementations should accept **kwargs as the interface to construct runners changes when features are added to unittest.

By default this runner shows `DeprecationWarning`, `PendingDeprecationWarning`, `ResourceWarning` and `ImportWarning` even if they are ignored by default. Deprecation warnings caused by deprecated unittest methods are also special-cased and, when the warning filters are 'default' or 'always', they will appear only once per-module, in order to avoid too many warning messages. This behavior can be overridden using the `-Wd` or `-Wa` options and leaving `warnings` to None.

*Changed in version 3.2:* Added the `warnings` argument.
Changed in version 3.2: The default stream is set to `sys.stderr` at instantiation time rather than import time.

Changed in version 3.5: Added the `tb_locals` parameter.

_makeResult()

This method returns the instance of `TestResult` used by `run()`. It is not intended to be called directly, but can be overridden in subclasses to provide a custom `TestResult`.

_makeResult() instantiates the class or callable passed in the `TextTestRunner` constructor as the `resultclass` argument. It defaults to `TextTestResult` if no `resultclass` is provided. The result class is instantiated with the following arguments:

```
stream, descriptions, verbosity
```

run(test)

This method is the main public interface to the `TextTestRunner`. This method takes a `TestSuite` or `TestCase` instance. A `TestResult` is created by calling `_makeResult()` and the test(s) are run and the results printed to stdout.

```
unittest.main(module='__main__', defaultTest=None, argv=None,
testRunner=None, testLoader=unittest.defaultTestLoader, exit=True,
verbosity=1, failfast=None, catchbreak=None, buffer=None,
warnings=None)
```

A command-line program that loads a set of tests from `module` and runs them; this is primarily for making test modules conveniently executable. The simplest use for this function is to include the following line at the end of a test script:
if __name__ == '__main__':
    unittest.main()

You can run tests with more detailed information by passing in the verbosity argument:

if __name__ == '__main__':
    unittest.main(verbosity=2)

The `defaultTest` argument is either the name of a single test or an iterable of test names to run if no test names are specified via `argv`. If not specified or `None` and no test names are provided via `argv`, all tests found in `module` are run.

The `argv` argument can be a list of options passed to the program, with the first element being the program name. If not specified or `None`, the values of `sys.argv` are used.

The `testRunner` argument can either be a test runner class or an already created instance of it. By default `main` calls `sys.exit()` with an exit code indicating success or failure of the tests run.

The `testLoader` argument has to be a `TestLoader` instance, and defaults to `defaultTestLoader`.

`main` supports being used from the interactive interpreter by passing in the argument `exit=False`. This displays the result on standard output without calling `sys.exit()`:

```python
>>> from unittest import main
>>> main(module='test_module', exit=False)
```

The `failfast`, `catchbreak` and `buffer` parameters have the same
effect as the same-name command-line options.

The warning argument specifies the warning filter that should be used while running the tests. If it's not specified, it will remain None if a -W option is passed to python, otherwise it will be set to 'default'.

Calling main actually returns an instance of the TestProgram class. This stores the result of the tests run as the result attribute.

Changed in version 3.1: The exit parameter was added.

Changed in version 3.2: The verbosity, failfast, catchbreak, buffer and warnings parameters were added.

Changed in version 3.4: The defaultTest parameter was changed to also accept an iterable of test names.

26.4.8.3.1. load_tests Protocol

New in version 3.2.

Modules or packages can customize how tests are loaded from them during normal test runs or test discovery by implementing a function called load_tests.

If a test module defines load_tests it will be called by TestLoader.loadTestsFromModule() with the following arguments:

load_tests(loader, standard_tests, pattern)
where \textit{pattern} is passed straight through from \texttt{loadTestsFromModule}. It defaults to \texttt{None}.

It should return a \texttt{TestSuite}.

\texttt{loader} is the instance of \texttt{TestLoader} doing the loading. \texttt{standard_tests} are the tests that would be loaded by default from the module. It is common for test modules to only want to add or remove tests from the standard set of tests. The third argument is used when loading packages as part of test discovery.

A typical \texttt{load_tests} function that loads tests from a specific set of \texttt{TestCase} classes may look like:

```python
test_cases = (TestCase1, TestCase2, TestCase3)

def load_tests(loader, tests, pattern):
    suite = TestSuite()
    for test_class in test_cases:
        tests = loader.loadTestsFromTestCase(test_class)
        suite.addTests(tests)
    return suite
```

If discovery is started in a directory containing a package, either from the command line or by calling \texttt{TestLoader.discover()}, then the package \texttt{__init__.py} will be checked for \texttt{load_tests}. If that function does not exist, discovery will recurse into the package as though it were just another directory. Otherwise, discovery of the package's tests will be left up to \texttt{load_tests} which is called with the following arguments:

```python
load_tests(loader, standard_tests, pattern)
```
This should return a `TestSuite` representing all the tests from the package. (`standard_tests` will only contain tests collected from `__init__.py`.)

Because the pattern is passed into `load_tests` the package is free to continue (and potentially modify) test discovery. A ‘do nothing’ `load_tests` function for a test package would look like:

```python
def load_tests(loader, standard_tests, pattern):
    # top level directory cached on loader instance
    this_dir = os.path.dirname(__file__)
    package_tests = loader.discover(start_dir=this_dir)
    standard_tests.addTests(package_tests)
    return standard_tests
```

*Changed in version 3.5:* Discovery no longer checks package names for matching `pattern` due to the impossibility of package names matching the default pattern.
26.4.9. Class and Module Fixtures

Class and module level fixtures are implemented in `TestSuite`. When the test suite encounters a test from a new class then `tearDownClass()` from the previous class (if there is one) is called, followed by `setUpClass()` from the new class.

Similarly if a test is from a different module from the previous test then `tearDownModule` from the previous module is run, followed by `setUpModule` from the new module.

After all the tests have run the final `tearDownClass` and `tearDownModule` are run.

Note that shared fixtures do not play well with [potential] features like test parallelization and they break test isolation. They should be used with care.

The default ordering of tests created by the unittest test loaders is to group all tests from the same modules and classes together. This will lead to `setUpClass / setUpModule` (etc) being called exactly once per class and module. If you randomize the order, so that tests from different modules and classes are adjacent to each other, then these shared fixture functions may be called multiple times in a single test run.

Shared fixtures are not intended to work with suites with non-standard ordering. A `BaseTestSuite` still exists for frameworks that don’t want to support shared fixtures.

If there are any exceptions raised during one of the shared fixture functions the test is reported as an error. Because there is no
corresponding test instance an _ErrorHolder object (that has the same interface as a TestCase) is created to represent the error. If you are just using the standard unittest test runner then this detail doesn’t matter, but if you are a framework author it may be relevant.

26.4.9.1. setUpClass and tearDownClass

These must be implemented as class methods:

```python
import unittest
class Test(unittest.TestCase):
    @classmethod
    def setUpClass(cls):
        cls._connection = createExpensiveConnectionObject

    @classmethod
    def tearDownClass(cls):
        cls._connection.destroy()
```

If you want the setUpClass and tearDownClass on base classes called then you must call up to them yourself. The implementations in testCase are empty.

If an exception is raised during a setUpClass then the tests in the class are not run and the tearDownClass is not run. Skipped classes will not have setUpClass or tearDownClass run. If the exception is a SkipTest exception then the class will be reported as having been skipped instead of as an error.

26.4.9.2. setUpModule and tearDownModule
These should be implemented as functions:

```python
def setUpModule():
    createConnection()

def tearDownModule():
    closeConnection()
```

If an exception is raised in a setUpModule then none of the tests in the module will be run and the tearDownModule will not be run. If the exception is a `SkipTest` exception then the module will be reported as having been skipped instead of as an error.
26.4.10. Signal Handling

*New in version 3.2.*

The `-c/--catch` command-line option to unittest, along with the `catchbreak` parameter to `unittest.main()`, provide more friendly handling of control-C during a test run. With catch break behavior enabled control-C will allow the currently running test to complete, and the test run will then end and report all the results so far. A second control-c will raise a `KeyboardInterrupt` in the usual way.

The control-c handling signal handler attempts to remain compatible with code or tests that install their own `signal.SIGINT` handler. If the `unittest` handler is called but *isn’t* the installed `signal.SIGINT` handler, i.e. it has been replaced by the system under test and delegated to, then it calls the default handler. This will normally be the expected behavior by code that replaces an installed handler and delegates to it. For individual tests that need unittest control-c handling disabled the `removeHandler()` decorator can be used.

There are a few utility functions for framework authors to enable control-c handling functionality within test frameworks.

`unittest.installHandler()`

Install the control-c handler. When a `signal.SIGINT` is received (usually in response to the user pressing control-c) all registered results have `stop()` called.

`unittest.registerResult(result)`

Register a `TestResult` object for control-c handling. Registering a result stores a weak reference to it, so it doesn’t prevent the
result from being garbage collected.

Registering a TestResult object has no side-effects if control-c handling is not enabled, so test frameworks can unconditionally register all results they create independently of whether or not handling is enabled.

unittest.removeResult(result)
Remove a registered result. Once a result has been removed then stop() will no longer be called on that result object in response to a control-c.

unittest.removeHandler(function=None)
When called without arguments this function removes the control-c handler if it has been installed. This function can also be used as a test decorator to temporarily remove the handler whilst the test is being executed:

```python
@unittest.removeHandler
def test_signal_handling(self):
    ...
```
26.5. `unittest.mock` — mock object library

*New in version 3.3.*

`unittest.mock` is a library for testing in Python. It allows you to replace parts of your system under test with mock objects and make assertions about how they have been used.

`unittest.mock` provides a core `Mock` class removing the need to create a host of stubs throughout your test suite. After performing an action, you can make assertions about which methods / attributes were used and arguments they were called with. You can also specify return values and set needed attributes in the normal way.

Additionally, mock provides a `patch()` decorator that handles patching module and class level attributes within the scope of a test, along with `sentinel` for creating unique objects. See the quick guide for some examples of how to use `Mock`, `MagicMock` and `patch()`.

Mock is very easy to use and is designed for use with `unittest`. Mock is based on the ‘action -> assertion’ pattern instead of ‘record -> replay’ used by many mocking frameworks.

There is a backport of `unittest.mock` for earlier versions of Python, available as `mock` on PyPI.

**Source code:** `Lib/unittest/mock.py`
26.5.1. Quick Guide

Mock and MagicMock objects create all attributes and methods as you access them and store details of how they have been used. You can configure them, to specify return values or limit what attributes are available, and then make assertions about how they have been used:

```python
>>> from unittest.mock import MagicMock
>>> thing = ProductionClass()
>>> thing.method = MagicMock(return_value=3)
>>> thing.method(3, 4, 5, key='value')
3
>>> thing.method.assert_called_with(3, 4, 5, key='value')
```

side_effect allows you to perform side effects, including raising an exception when a mock is called:

```python
>>> mock = Mock(side_effect=KeyError('foo'))
>>> mock()
Traceback (most recent call last):
...  
  KeyError: 'foo'
```

```python
>>> values = {'a': 1, 'b': 2, 'c': 3}
>>> def side_effect(arg):
...   return values[arg]
...
>>> mock.side_effect = side_effect
>>> mock('a'), mock('b'), mock('c')
(1, 2, 3)
>>> mock.side_effect = [5, 4, 3, 2, 1]
>>> mock(), mock(), mock()
(5, 4, 3)
```
Mock has many other ways you can configure it and control its behaviour. For example the `spec` argument configures the mock to take its specification from another object. Attempting to access attributes or methods on the mock that don’t exist on the spec will fail with an `AttributeError`.

The `patch()` decorator / context manager makes it easy to mock classes or objects in a module under test. The object you specify will be replaced with a mock (or other object) during the test and restored when the test ends:

```python
>>> from unittest.mock import patch
>>> @patch('module.ClassName2')
... @patch('module.ClassName1')
... def test(MockClass1, MockClass2):
...     module.ClassName1()
...     module.ClassName2()
...     assert MockClass1 is module.ClassName1
...     assert MockClass2 is module.ClassName2
...     assert MockClass1.called
...     assert MockClass2.called
... >>> test()
```

**Note:** When you nest patch decorators the mocks are passed in to the decorated function in the same order they applied (the normal `python` order that decorators are applied). This means from the bottom up, so in the example above the mock for `module.ClassName1` is passed in first.

With `patch()` it matters that you patch objects in the namespace where they are looked up. This is normally straightforward, but for a quick guide read [where to patch](#).
As well as a decorator `patch()` can be used as a context manager in a with statement:

```python
>>> with patch.object(ProductionClass, 'method', return_value=... thing = ProductionClass()
... thing.method(1, 2, 3)

>>> mock_method.assert_called_once_with(1, 2, 3)
```

There is also `patch.dict()` for setting values in a dictionary just during a scope and restoring the dictionary to its original state when the test ends:

```python
>>> foo = {'key': 'value'}
>>> original = foo.copy()

>>> with patch.dict(foo, {'newkey': 'newvalue'}, clear=True):
...     assert foo == {'newkey': 'newvalue'}

>>> assert foo == original
```

Mock supports the mocking of Python magic methods. The easiest way of using magic methods is with the `MagicMock` class. It allows you to do things like:

```python
>>> mock = MagicMock()
>>> mock.__str__.return_value = 'foobazbar'
>>> str(mock)
'foobazbar'
>>> mock.__str__.assert_called_with()
```

Mock allows you to assign functions (or other Mock instances) to magic methods and they will be called appropriately. The `MagicMock` class is just a Mock variant that has all of the magic methods pre-
created for you (well, all the useful ones anyway).

The following is an example of using magic methods with the ordinary Mock class:

```python
>>> mock = Mock()
>>> mock.__str__ = Mock(return_value='wheeeeee')
>>> str(mock)
'wheeeeee'
```

For ensuring that the mock objects in your tests have the same api as the objects they are replacing, you can use auto-speccing. Auto-speccing can be done through the autospec argument to patch, or the create_autospec() function. Auto-speccing creates mock objects that have the same attributes and methods as the objects they are replacing, and any functions and methods (including constructors) have the same call signature as the real object.

This ensures that your mocks will fail in the same way as your production code if they are used incorrectly:

```python
>>> from unittest.mock import create_autospec
>>> def function(a, b, c):
...     pass
...
>>> mock_function = create_autospec(function, return_value='fishy')
>>> mock_function(1, 2, 3)
'fishy'
>>> mock_function.assert_called_once_with(1, 2, 3)
>>> mock_function('wrong arguments')
Traceback (most recent call last):
  File "<lambda>", line 1, in <lambda>
TypeError: <lambda>() takes exactly 3 arguments (1 given)
```
`create_autospec()` can also be used on classes, where it copies the signature of the `__init__` method, and on callable objects where it copies the signature of the `__call__` method.
26.5.2. The Mock Class

Mock is a flexible mock object intended to replace the use of stubs and test doubles throughout your code.Mocks are callable and create attributes as new mocks when you access them [1]. Accessing the same attribute will always return the same mock.Mocks record how you use them, allowing you to make assertions about what your code has done to them.

MagicMock is a subclass of Mock with all the magic methods pre-created and ready to use. There are also non-callable variants, useful when you are mocking out objects that aren’t callable: NonCallableMock and NonCallableMagicMock.

The patch() decorators makes it easy to temporarily replace classes in a particular module with a Mock object. By default patch() will create a MagicMock for you. You can specify an alternative class of Mock using the new_callable argument to patch().

class unittest.mock.Mock(spec=None, side_effect=None, return_value=DEFAULT, wraps=None, name=None, spec_set=None, unsafe=False, **kwargs)

Create a new Mock object. Mock takes several optional arguments that specify the behaviour of the Mock object:

- spec: This can be either a list of strings or an existing object (a class or instance) that acts as the specification for the mock object. If you pass in an object then a list of strings is formed by calling dir on the object (excluding unsupported magic attributes and methods). Accessing any attribute not in this list will raise an AttributeError.
If `spec` is an object (rather than a list of strings) then `__class__` returns the class of the `spec` object. This allows mocks to pass `isinstance()` tests.

- **`spec_set`:** A stricter variant of `spec`. If used, attempting to set or get an attribute on the mock that isn't on the object passed as `spec_set` will raise an `AttributeError`.

- **`side_effect`:** A function to be called whenever the Mock is called. See the `side_effect` attribute. Useful for raising exceptions or dynamically changing return values. The function is called with the same arguments as the mock, and unless it returns `DEFAULT`, the return value of this function is used as the return value.

  Alternatively `side_effect` can be an exception class or instance. In this case the exception will be raised when the mock is called.

  If `side_effect` is an iterable then each call to the mock will return the next value from the iterable.

  A `side_effect` can be cleared by setting it to `None`.

- **`return_value`:** The value returned when the mock is called. By default this is a new Mock (created on first access). See the `return_value` attribute.

- **`unsafe`:** By default if any attribute starts with `assert` or `assert` will raise an `AttributeError`. Passing `unsafe=True` will allow access to these attributes.

  *New in version 3.5.*
• **wraps**: Item for the mock object to wrap. If *wraps* is not None then calling the Mock will pass the call through to the wrapped object (returning the real result). Attribute access on the mock will return a Mock object that wraps the corresponding attribute of the wrapped object (so attempting to access an attribute that doesn’t exist will raise an *AttributeError*).

If the mock has an explicit *return_value* set then calls are not passed to the wrapped object and the *return_value* is returned instead.

• **name**: If the mock has a name then it will be used in the repr of the mock. This can be useful for debugging. The name is propagated to child mocks.

Mocks can also be called with arbitrary keyword arguments. These will be used to set attributes on the mock after it is created. See the *configure_mock()* method for details.

**assert_called_with(***args, **kwargs)**

This method is a convenient way of asserting that calls are made in a particular way:

```python
>>> mock = Mock()
>>> mock.method(1, 2, 3, test='wow')
<Mock name='mock.method()' id='...'>
>>> mock.method.assert_called_with(1, 2, 3, test='wow')
```

**assert_called_once_with(***args, **kwargs)**

Assert that the mock was called exactly once and with the specified arguments.

```python
>>> mock = Mock(return_value=None)
```
>>> mock('foo', bar='baz')
>>> mock.assert_called_once_with('foo', bar='baz')
>>> mock('foo', bar='baz')
>>> mock.assert_called_once_with('foo', bar='baz')
Traceback (most recent call last):
...
AssertionError: Expected 'mock' to be called once. Called 2 times.

assert_any_call(*args, **kwargs)
assert the mock has been called with the specified arguments.

The assert passes if the mock has ever been called, unlike
assert_called_with() and
assert_called_once_with() that only pass if the call is
the most recent one.

>>> mock = Mock(return_value=None)
>>> mock(1, 2, arg='thing')
>>> mock('some', 'thing', 'else')
>>> mock.assert_any_call(1, 2, arg='thing')

assert_has_calls(calls, any_order=False)
assert the mock has been called with the specified calls. The
mock_calls list is checked for the calls.

If any_order is false (the default) then the calls must be
sequential. There can be extra calls before or after the specified
calls.

If any_order is true then the calls can be in any order, but they
must all appear in mock_calls.

>>> mock = Mock(return_value=None)
>>> mock(1)
mock(2)
mock(3)
mock(4)
calls = [call(2), call(3)]
mock.assert_has_calls(calls)
calls = [call(4), call(2), call(3)]
mock.assert_has_calls(calls, any_order=True)
mock.assert_not_called(*args, **kwargs)

assert_not_called(*args, **kwargs)
Assert the mock was never called.

m = Mock()
m.hello.assert_not_called()
obj = m.hello()
m.hello.assert_not_called()
Traceback (most recent call last):
...
AssertionError: Expected 'hello' to not have been called.

New in version 3.5.

reset_mock()
The reset_mock method resets all the call attributes on a mock object:

mock = Mock(return_value=None)
m('hello')
m.called
True
mock.reset_mock()
m.called
False

This can be useful where you want to make a series of
assertions that reuse the same object. Note that `reset_mock()` doesn't clear the return value, `side_effect` or any child attributes you have set using normal assignment. Child mocks and the return value mock (if any) are reset as well.

**mock_add_spec**(spec, spec_set=False)

Add a spec to a mock. `spec` can either be an object or a list of strings. Only attributes on the `spec` can be fetched as attributes from the mock.

If `spec_set` is true then only attributes on the spec can be set.

**attach_mock**(mock, attribute)

Attach a mock as an attribute of this one, replacing its name and parent. Calls to the attached mock will be recorded in the `method_calls` and `mock_calls` attributes of this one.

**configure_mock**(**kwargs)

Set attributes on the mock through keyword arguments.

Attributes plus return values and side effects can be set on child mocks using standard dot notation and unpacking a dictionary in the method call:

```python
>>> mock = Mock()
>>> attrs = {'method.return_value': 3, 'other.side_effect': 3}
>>> mock.configure_mock(**attrs)
>>> mock.method()
3
>>> mock.other()
Traceback (most recent call last):
  ...
  KeyError
```
The same thing can be achieved in the constructor call to mocks:

```python
g>>> attrs = {'method.return_value': 3, 'other.side_effect': }
>>> mock = Mock(some_attribute='eggs', **attrs)
>>> mock.some_attribute
'eggs'
>>> mock.method()
3
>>> mock.other()
Traceback (most recent call last):
  ...
  KeyError
```

configure_mock() exists to make it easier to do configuration after the mock has been created.

__dir__()

Mock objects limit the results of dir(some_mock) to useful results. For mocks with a spec this includes all the permitted attributes for the mock.

See FILTER_DIR for what this filtering does, and how to switch it off.

__get_child_mock__(**kw)

Create the child mocks for attributes and return value. By default child mocks will be the same type as the parent. Subclasses of Mock may want to override this to customize the way child mocks are made.

For non-callable mocks the callable variant will be used (rather
than any custom subclass).

**called**
A boolean representing whether or not the mock object has been called:

```python
>>> mock = Mock(return_value=None)
>>> mock.called
False
>>> mock()
>>> mock.called
True
```

**call_count**
An integer telling you how many times the mock object has been called:

```python
>>> mock = Mock(return_value=None)
>>> mock.call_count
0
>>> mock()
>>> mock()
>>> mock.call_count
2
```

**return_value**
Set this to configure the value returned by calling the mock:

```python
>>> mock = Mock()
>>> mock.return_value = 'fish'
>>> mock()
'fish'
```

The default return value is a mock object and you can configure it in the normal way:
**ReturnValue** can also be set in the constructor:

```python
>>> mock = Mock(return_value=3)
>>> mock.return_value
3
>>> mock()
3
```

### side_effect

This can either be a function to be called when the mock is called, an iterable or an exception (class or instance) to be raised.

If you pass in a function, it will be called with the same arguments as the mock and unless the function returns the `DEFAULT` singleton, the call to the mock will then return whatever the function returns. If the function returns `DEFAULT`, then the mock will return its normal value (from the `return_value`).

If you pass in an iterable, it is used to retrieve an iterator which must yield a value on every call. This value can either be an exception instance to be raised, or a value to be returned from the call to the mock (`DEFAULT` handling is identical to the function case).

An example of a mock that raises an exception (to test exception handling of an API):
```python
>>> mock = Mock()
>>> mock.side_effect = Exception('Boom!')
>>> mock()
Traceback (most recent call last):
...
Exception: Boom!
```

Using `side_effect` to return a sequence of values:

```python
>>> mock = Mock()
>>> mock.side_effect = [3, 2, 1]
>>> mock(), mock(), mock()
(3, 2, 1)
```

Using a callable:

```python
>>> mock = Mock(return_value=3)
>>> def side_effect(*args, **kwargs):
...     return DEFAULT
...
>>> mock.side_effect = side_effect
>>> mock()
3
```

`sides_effect` can be set in the constructor. Here’s an example that adds one to the value the mock is called with and returns it:

```python
>>> side_effect = lambda value: value + 1
>>> mock = Mock(side_effect=side_effect)
>>> mock(3)
4
>>> mock(-8)
-7
```

Setting `side_effect` to None clears it:
>>> m = Mock(side_effect=KeyError, return_value=None)
>>> m()
Traceback (most recent call last):
  ...
KeyError

>>> m.side_effect = None
>>> m()
3

**call_args**

This is either None (if the mock hasn’t been called), or the arguments that the mock was last called with. This will be in the form of a tuple: the first member is any ordered arguments the mock was called with (or an empty tuple) and the second member is any keyword arguments (or an empty dictionary).

```python
>>> mock = Mock(return_value=None)
>>> print(mock.call_args)
None
>>> mock()
>>> mock.call_args
call()
>>> mock.call_args == ()
True
>>> mock(3, 4)
>>> mock.call_args
call(3, 4)
>>> mock.call_args == ((3, 4),)
True
>>> mock(3, 4, 5, key='fish', next='w00t!')
>>> mock.call_args
call(3, 4, 5, key='fish', next='w00t!')
```

call_args, along with members of the lists
call_args_list, method_calls and mock_calls are call objects. These are tuples, so they can be unpacked to get at the individual arguments and make more complex assertions. See calls as tuples.

**call_args_list**

This is a list of all the calls made to the mock object in sequence (so the length of the list is the number of times it has been called). Before any calls have been made it is an empty list. The call object can be used for conveniently constructing lists of calls to compare with call_args_list.

```python
>>> mock = Mock(return_value=None)
>>> mock()
>>> mock(3, 4)
>>> mock(key='fish', next='w00t!')
>>> mock.call_args_list
[call(), call(3, 4), call(key='fish', next='w00t!')]
>>> expected = [(), ((3, 4),), ({'key': 'fish', 'next': 'w00t!'},)]
>>> mock.call_args_list == expected
True
```

Members of call_args_list are call objects. These can be unpacked as tuples to get at the individual arguments. See calls as tuples.

**method_calls**

As well as tracking calls to themselves, mocks also track calls to methods and attributes, and their methods and attributes:

```python
>>> mock = Mock()
>>> mock.method()  # this is a special method.
<Mock name='mock.method()' id='...'>
```
>>> mock.property.method.attribute()
<Mock name='mock.property.method.attribute()' id='...'>
>>> mock.method_calls
[call.method(), call.property.method.attribute()]

Members of method_calls are call objects. These can be unpacked as tuples to get at the individual arguments. See calls as tuples.

mock_calls

mock_calls records all calls to the mock object, its methods, magic methods and return value mocks.

>>> mock = MagicMock()
>>> result = mock(1, 2, 3)
>>> mock.first(a=3)
<MagicMock name='mock.first()' id='...'>
>>> mock.second()
<MagicMock name='mock.second()' id='...'>
>>> int(mock)
1
>>> result(1)
<MagicMock name='mock()' id='...'>
>>> expected = [call(1, 2, 3), call.first(a=3), ... call.__int__(), call(1)]
>>> mock.mock_calls == expected
True

Members of mock_calls are call objects. These can be unpacked as tuples to get at the individual arguments. See calls as tuples.

__class__
Normally the \_\_class\_\_ attribute of an object will return its type. For a mock object with a spec, \_\_class\_\_ returns the spec class instead. This allows mock objects to pass \_\_isinstance\_\_ tests for the object they are replacing / masquerading as:

```python
>>> mock = Mock(spec=3)
>>> \_\_isinstance\_\_(mock, int)
True
```

\_\_class\_\_ is assignable to, this allows a mock to pass an \_\_isinstance\_\_ check without forcing you to use a spec:

```python
>>> mock = Mock()
>>> mock.\_\_class\_\_ = dict
>>> \_\_isinstance\_\_(mock, dict)
True
```

class unittest.mock.NonCallableMock(spec=None, wraps=None, name=None, spec_set=None, **kwargs)

A non-callable version of Mock. The constructor parameters have the same meaning of Mock, with the exception of \_\_return\_\_value and \_\_side\_\_effect which have no meaning on a non-callable mock.

Mock objects that use a class or an instance as a spec or spec\_set are able to pass \_\_isinstance\_\_ tests:

```python
>>> mock = Mock(spec=SomeClass)
>>> \_\_isinstance\_\_(mock, SomeClass)
True
>>> mock = Mock(spec_set=SomeClass())
>>> \_\_isinstance\_\_(mock, SomeClass)
True
```
The Mock classes have support for mocking magic methods. See magic methods for the full details.

The mock classes and the patch() decorators all take arbitrary keyword arguments for configuration. For the patch() decorators the keywords are passed to the constructor of the mock being created. The keyword arguments are for configuring attributes of the mock:

```python
>>> m = MagicMock(attribute=3, other='fish')
>>> m.attribute
3
>>> m.other
'fish'
```

The return value and side effect of child mocks can be set in the same way, using dotted notation. As you can't use dotted names directly in a call you have to create a dictionary and unpack it using **:

```python
>>> attrs = {'method.return_value': 3, 'other.side_effect': lambda: 'eggs'}
>>> mock = Mock(some_attribute='eggs', **attrs)
>>> mock.some_attribute
'eggs'
>>> mock.method()
3
>>> mock.other()
Traceback (most recent call last):
  ...
KeyError
```

A callable mock which was created with a spec (or a spec_set) will introspect the specification object's signature when matching calls to the mock. Therefore, it can match the actual call's arguments regardless of whether they were passed positionally or by name:
```python
def f(a, b, c): pass
...
mock = Mock(spec=f)
mock(1, 2, c=3)
<Mock name='mock()' id='140161580456576'>
mock.assert_called_with(1, 2, 3)
mock.assert_called_with(a=1, b=2, c=3)
```

This applies to `assert_called_with()`, `assert_called_once_with()`, `assert_has_calls()` and `assert_any_call()`. When Autospeccing, it will also apply to method calls on the mock object.

*Changed in version 3.4:* Added signature introspection on specced and autospecced mock objects.

```python
class unittest.mock.PropertyMock(*args, **kwargs)
```

A mock intended to be used as a property, or other descriptor, on a class. `PropertyMock` provides `__get__()` and `__set__()` methods so you can specify a return value when it is fetched.

Fetching a `PropertyMock` instance from an object calls the mock, with no args. Setting it calls the mock with the value being set.

```python
>>> class Foo:
...     @property
...     def foo(self):
...         return 'something'
...     @foo.setter
...     def foo(self, value):
...         pass
...
>>> with patch('__main__.Foo.foo', new_callable=PropertyMock):
...     mock_foo.return_value = 'mockity-mock'
...     this_foo = Foo()
```
Because of the way mock attributes are stored you can’t directly attach a `PropertyMock` to a mock object. Instead you can attach it to the mock type object:

```
>>> m = MagicMock()
>>> p = PropertyMock(return_value=3)
>>> type(m).foo = p
>>> m.foo
3
>>> p.assert_called_once_with()
```

### 26.5.2.1. Calling

Mock objects are callable. The call will return the value set as the `return_value` attribute. The default return value is a new Mock object; it is created the first time the return value is accessed (either explicitly or by calling the Mock) - but it is stored and the same one returned each time.

Calls made to the object will be recorded in the attributes like `call_args` and `call_args_list`.

If `side_effect` is set then it will be called after the call has been recorded, so if `side_effect` raises an exception the call is still recorded.
The simplest way to make a mock raise an exception when called is to make `side_effect` an exception class or instance:

```python
>>> m = MagicMock(side_effect=IndexError)
>>> m(1, 2, 3)
Traceback (most recent call last):
...  
IndexError
```

```python
>>> m.mock_calls
[call(1, 2, 3)]
>>> m.side_effect = KeyError('Bang!')
>>> m('two', 'three', 'four')
Traceback (most recent call last):
...  
KeyError: 'Bang!'
```

If `side_effect` is a function then whatever that function returns is what calls to the mock return. The `side_effect` function is called with the same arguments as the mock. This allows you to vary the return value of the call dynamically, based on the input:

```python
>>> def side_effect(value):
...     return value + 1
...
```  

```python
>>> m = MagicMock(side_effect=side_effect)
>>> m(1)
2
>>> m(2)
3
>>> m.mock_calls
[call(1), call(2)]
```

If you want the mock to still return the default return value (a new
mock), or any set return value, then there are two ways of doing this. Either return mock.return_value from inside side_effect, or return DEFAULT:

```python
>>> m = MagicMock()
>>> def side_effect(*args, **kwargs):
...     return m.return_value
... >>> m.side_effect = side_effect
... >>> m.return_value = 3
... >>> m()
3
>>> def side_effect(*args, **kwargs):
...     return DEFAULT
... >>> m.side_effect = side_effect
... >>> m()
3
```

To remove a side_effect, and return to the default behaviour, set the side_effect to None:

```python
>>> m = MagicMock(return_value=6)
>>> def side_effect(*args, **kwargs):
...     return 3
... >>> m.side_effect = side_effect
... >>> m()
3
>>> m.side_effect = None
>>> m()
6
```

The side_effect can also be any iterable object. Repeated calls to the mock will return values from the iterable (until the iterable is
exhausted and a `StopIteration` is raised):

```python
>>> m = MagicMock(side_effect=[1, 2, 3])
>>> m()
1
>>> m()
2
>>> m()
3
>>> m()
Traceback (most recent call last):
  ... 
StopIteration
```

If any members of the iterable are exceptions they will be raised instead of returned:

```python
>>> iterable = (33, ValueError, 66)
>>> m = MagicMock(side_effect=iterable)
>>> m()
33
>>> m()
Traceback (most recent call last):
  ... 
ValueError
>>> m()
66
```

### 26.5.2.2. Deleting Attributes

Mock objects create attributes on demand. This allows them to pretend to be objects of any type.

You may want a mock object to return False to a `hasattr()` call, or raise an `AttributeError` when an attribute is fetched. You can do
this by providing an object as a spec for a mock, but that isn't always convenient.

You “block” attributes by deleting them. Once deleted, accessing an attribute will raise an `AttributeError`.

```python
>>> mock = MagicMock()
>>> hasattr(mock, 'm')
True
>>> del mock.m
>>> hasattr(mock, 'm')
False
>>> del mock.f
>>> mock.f
Traceback (most recent call last):
  ... AttributeError: f
```

26.5.2.3. Mock names and the name attribute

Since “name” is an argument to the `Mock` constructor, if you want your mock object to have a “name” attribute you can’t just pass it in at creation time. There are two alternatives. One option is to use `configure_mock()`:

```python
>>> mock = MagicMock()
>>> mock.configure_mock(name='my_name')
>>> mock.name
'my_name'
```

A simpler option is to simply set the “name” attribute after mock creation:

```python
>>> mock = MagicMock()
```
26.5.2.4. Attaching Mocks as Attributes

When you attach a mock as an attribute of another mock (or as the return value) it becomes a “child” of that mock. Calls to the child are recorded in the `method_calls` and `mock_calls` attributes of the parent. This is useful for configuring child mocks and then attaching them to the parent, or for attaching mocks to a parent that records all calls to the children and allows you to make assertions about the order of calls between mocks:

```python
>>> parent = MagicMock()
>>> child1 = MagicMock(return_value=None)
>>> child2 = MagicMock(return_value=None)
>>> parent.child1 = child1
>>> parent.child2 = child2
>>> child1(1)
>>> child2(2)
>>> parent.mock_calls
[call.child1(1), call.child2(2)]
```

The exception to this is if the mock has a name. This allows you to prevent the “parenting” if for some reason you don’t want it to happen.

```python
>>> mock = MagicMock()
>>> not_a_child = MagicMock(name='not-a-child')
>>> mock.attribute = not_a_child
>>> mock.attribute()
<MagicMock name='not-a-child()' id='...'>
>>> mock.mock_calls
[]
```

Mocks created for you by `patch()` are automatically given names. To
attach mocks that have names to a parent you use the
attach_mock() method:

```python
>>> thing1 = object()
>>> thing2 = object()
>>> parent = MagicMock()
>>> with patch('__main__.thing1', return_value=None)
...     with patch('__main__.thing2', return_value=None)
...         parent.attach_mock(child1, 'child1')
...         parent.attach_mock(child2, 'child2')
...         child1('one')
...         child2('two')

>>> parent.mock_calls
[call.child1('one'), call.child2('two')]
```

The only exceptions are magic methods and attributes (those that have leading and trailing double underscores). Mock doesn't create these but instead raises an `AttributeError`.

[1] This is because the interpreter will often implicitly request these methods, and gets very confused to get a new Mock object when it expects a magic method. If you need magic method support see magic methods.
26.5.3. The patchers

The patch decorators are used for patching objects only within the scope of the function they decorate. They automatically handle the unpatching for you, even if exceptions are raised. All of these functions can also be used in with statements or as class decorators.

26.5.3.1. patch

**Note:** `patch()` is straightforward to use. The key is to do the patching in the right namespace. See the section *where to patch.*

```
unittest.mock.patch(target, new=DEFAULT, spec=None, create=False, spec_set=None, autospec=None, new_callable=None, **kwargs)
```

`patch()` acts as a function decorator, class decorator or a context manager. Inside the body of the function or with statement, the `target` is patched with a `new` object. When the function/with statement exits the patch is undone.

If `new` is omitted, then the target is replaced with a `MagicMock`. If `patch()` is used as a decorator and `new` is omitted, the created mock is passed in as an extra argument to the decorated function. If `patch()` is used as a context manager the created mock is returned by the context manager.

`target` should be a string in the form 'package.module.ClassName'. The `target` is imported and the specified object replaced with the `new` object, so the `target` must be importable from the environment you are calling `patch()` from. The target is imported when the decorated function is executed,
not at decoration time.

The `spec` and `spec_set` keyword arguments are passed to the `MagicMock` if patch is creating one for you.

In addition you can pass `spec=True` or `spec_set=True`, which causes patch to pass in the object being mocked as the `spec/spec_set` object.

`new_callable` allows you to specify a different class, or callable object, that will be called to create the `new` object. By default `MagicMock` is used.

A more powerful form of `spec` is `autospec`. If you set `autospec=True` then the mock will be created with a spec from the object being replaced. All attributes of the mock will also have the spec of the corresponding attribute of the object being replaced. Methods and functions being mocked will have their arguments checked and will raise a `TypeError` if they are called with the wrong signature. For mocks replacing a class, their return value (the ‘instance’) will have the same spec as the class. See the `create_autospec()` function and Autospeccing.

Instead of `autospec=True` you can pass `autospec=some_object` to use an arbitrary object as the spec instead of the one being replaced.

By default `patch()` will fail to replace attributes that don’t exist. If you pass in `create=True`, and the attribute doesn’t exist, patch will create the attribute for you when the patched function is called, and delete it again afterwards. This is useful for writing tests against attributes that your production code creates at runtime. It is off by default because it can be dangerous. With it switched on you
can write passing tests against APIs that don’t actually exist!

Note:
*Changed in version 3.5:* If you are patching builtins in a module then you don’t need to pass create=True, it will be added by default.

Patch can be used as a TestCase class decorator. It works by decorating each test method in the class. This reduces the boilerplate code when your test methods share a common patchings set. `patch()` finds tests by looking for method names that start with `patch.TEST_PREFIX`. By default this is 'test', which matches the way `unittest` finds tests. You can specify an alternative prefix by setting `patch.TEST_PREFIX`.

Patch can be used as a context manager, with the with statement. Here the patching applies to the indented block after the with statement. If you use “as” then the patched object will be bound to the name after the “as”; very useful if `patch()` is creating a mock object for you.

`patch()` takes arbitrary keyword arguments. These will be passed to the `Mock` (or `new_callable`) on construction.

`patch.dict(...)`, `patch.multiple(...)` and `patch.object(...)` are available for alternate use-cases.

`patch()` as function decorator, creating the mock for you and passing it into the decorated function:

```python
g>>> @patch('__main__.SomeClass')
... def function(normal_argument, mock_class):
...     print(mock_class is SomeClass)
g```
Patching a class replaces the class with a `MagicMock instance`. If the class is instantiated in the code under test then it will be the `return_value` of the mock that will be used.

If the class is instantiated multiple times you could use `side_effect` to return a new mock each time. Alternatively you can set the `return_value` to be anything you want.

To configure return values on methods of `instances` on the patched class you must do this on the `return_value`. For example:

```python
>>> class Class:
...     def method(self):
...         pass
...>>> with patch('__main__.Class') as MockClass:
...     instance = MockClass.return_value
...     instance.method.return_value = 'foo'
...     assert Class() is instance
...     assert Class().method() == 'foo'
```

If you use `spec` or `spec_set` and `patch()` is replacing a `class`, then the return value of the created mock will have the same spec.

```python
>>> Original = Class
>>> patcher = patch('__main__.Class', spec=True)
>>> MockClass = patcher.start()
>>> instance = MockClass()
>>> assert isinstance(instance, Original)
>>> patcher.stop()
```
The `new_callable` argument is useful where you want to use an alternative class to the default `MagicMock` for the created mock. For example, if you wanted a `NonCallableMock` to be used:

```python
>>> thing = object()
>>> with patch('__main__.thing', new_callable=NonCallableMock)
...    assert thing is mock_thing
...    thing()
...
Traceback (most recent call last):
...
TypeError: 'NonCallableMock' object is not callable
```

Another use case might be to replace an object with an `io.StringIO` instance:

```python
>>> from io import StringIO
>>> def foo():
...    print('Something')
...
>>> @patch('sys.stdout', new_callable=StringIO)
...    def test(mock_stdout):
...        foo()
...        assert mock_stdout.getvalue() == 'Something'
...
>>> test()
```

When `patch()` is creating a mock for you, it is common that the first thing you need to do is to configure the mock. Some of that configuration can be done in the call to `patch`. Any arbitrary keywords you pass into the call will be used to set attributes on the created mock:
As well as attributes on the created mock attributes, like the `return_value` and `side_effect`, of child mocks can also be configured. These aren't syntactically valid to pass in directly as keyword arguments, but a dictionary with these as keys can still be expanded into a `patch()` call using **:

```
>>> config = {'method.return_value': 3, 'other.side_effect': None}
>>> patcher = patch('__main__.thing', **config)
>>> mock_thing = patcher.start()
>>> mock_thing.method()
3
>>> mock_thing.other()
Traceback (most recent call last):
 ...  
KeyError
```

### 26.5.3.2. `patch.object`

`patch.object(target, attribute, new=DEFAULT, spec=None, create=False, spec_set=None, autospec=None, new_callable=None, **kwargs)`

patch the named member (`attribute`) on an object (`target`) with a mock object.

`patch.object()` can be used as a decorator, class decorator or
a context manager. Arguments new, spec, create, spec_set, autospec and new_callable have the same meaning as for patch(). Like patch(), patch.object() takes arbitrary keyword arguments for configuring the mock object it creates.

When used as a class decorator patch.object() honours patch.TEST_PREFIX for choosing which methods to wrap.

You can either call patch.object() with three arguments or two arguments. The three argument form takes the object to be patched, the attribute name and the object to replace the attribute with.

When calling with the two argument form you omit the replacement object, and a mock is created for you and passed in as an extra argument to the decorated function:

```python
>>> @patch.object(SomeClass, 'class_method')
... def test(mock_method):
...     SomeClass.class_method(3)
...     mock_method.assert_called_with(3)
... >>> test()
```

spec, create and the other arguments to patch.object() have the same meaning as they do for patch().

26.5.3.3. patch.dict

patch.dict(in_dict, values=(), clear=False, **kwargs)

Patch a dictionary, or dictionary like object, and restore the dictionary to its original state after the test.

in_dict can be a dictionary or a mapping like container. If it is a
mapping then it must at least support getting, setting and deleting
items plus iterating over keys.

`in_dict` can also be a string specifying the name of the dictionary,
which will then be fetched by importing it.

`values` can be a dictionary of values to set in the dictionary. `values`
can also be an iterable of (key, value) pairs.

If `clear` is true then the dictionary will be cleared before the new
values are set.

`patch.dict()` can also be called with arbitrary keyword
arguments to set values in the dictionary.

`patch.dict()` can be used as a context manager, decorator or
class decorator. When used as a class decorator `patch.dict()`
honours `patch.TEST_PREFIX` for choosing which methods to
wrap.

`patch.dict()` can be used to add members to a dictionary, or
simply let a test change a dictionary, and ensure the dictionary is
restored when the test ends.

```python
>>> foo = {}
>>> with patch.dict(foo, {'newkey': 'newvalue'}):
...    assert foo == {'newkey': 'newvalue'}
...
>>> assert foo == {}
```

```python
>>> import os
>>> with patch.dict('os.environ', {'newkey': 'newval'}):
...    print(os.environ['newkey'])
...```

newvalue
>>> assert 'newkey' not in os.environ

Keywords can be used in the `patch.dict()` call to set values in the dictionary:

```python
>>> mymodule = MagicMock()
>>> mymodule.function.return_value = 'fish'
>>> with patch.dict('sys.modules', mymodule=mymodule)
...    import mymodule
...    mymodule.function('some', 'args')
... 'fish'
```

`patch.dict()` can be used with dictionary like objects that aren't actually dictionaries. At the very minimum they must support item getting, setting, deleting and either iteration or membership test. This corresponds to the magic methods `__getitem__`, `__setitem__`, `__delitem__` and either `__iter__` or `__contains__`.

```python
>>> class Container:
...    def __init__(self):
...        self.values = {}
...    def __getitem__(self, name):
...        return self.values[name]
...    def __setitem__(self, name, value):
...        self.values[name] = value
...    def __delitem__(self, name):
...        del self.values[name]
...    def __iter__(self):
...        return iter(self.values)
...    >>> thing = Container()
```
>>> thing['one'] = 1
>>> with patch.dict(thing, one=2, two=3):
...   assert thing['one'] == 2
...   assert thing['two'] == 3
...  
>>> assert thing['one'] == 1
>>> assert list(thing) == ['one']

26.5.3.4. patch.multiple

`patch.multiple(target, spec=None, create=False, spec_set=None, autospec=None, new_callable=None, **kwargs)`

Perform multiple patches in a single call. It takes the object to be patched (either as an object or a string to fetch the object by importing) and keyword arguments for the patches:

```python
with patch.multiple(settings, FIRST_PATCH='one', ...
```

Use `DEFAULT` as the value if you want `patch.multiple()` to create mocks for you. In this case the created mocks are passed into a decorated function by keyword, and a dictionary is returned when `patch.multiple()` is used as a context manager.

`patch.multiple()` can be used as a decorator, class decorator or a context manager. The arguments `spec`, `spec_set`, `create`, `autospec` and `new_callable` have the same meaning as for `patch()`. These arguments will be applied to all patches done by `patch.multiple()`.

When used as a class decorator `patch.multiple()` honours `patch.TEST_PREFIX` for choosing which methods to wrap.
If you want `patch.multiple()` to create mocks for you, then you can use `DEFAULT` as the value. If you use `patch.multiple()` as a decorator then the created mocks are passed into the decorated function by keyword.

```python
>>> thing = object()
>>> other = object()

>>> @patch.multiple('__main__', thing=DEFAULT, other)
... def test_function(thing, other):
...    assert isinstance(thing, MagicMock)
...    assert isinstance(other, MagicMock)
...    >>> test_function()
```

`patch.multiple()` can be nested with other patch decorators, but put arguments passed by keyword after any of the standard arguments created by `patch()`:

```python
>>> @patch('sys.exit')
... @patch.multiple('__main__', thing=DEFAULT, other)
... def test_function(mock_exit, other, thing):
...    assert 'other' in repr(other)
...    assert 'thing' in repr(thing)
...    assert 'exit' in repr(mock_exit)
...    >>> test_function()
```

If `patch.multiple()` is used as a context manager, the value returned by the context manager is a dictionary where created mocks are keyed by name:

```python
>>> with patch.multiple('__main__', thing=DEFAULT, o
26.5.3.5. patch methods: start and stop

All the patchers have start() and stop() methods. These make it simpler to do patching in setUp methods or where you want to do multiple patches without nesting decorators or with statements.

To use them call patch(), patch.object() or patch.dict() as normal and keep a reference to the returned patcher object. You can then call start() to put the patch in place and stop() to undo it.

If you are using patch() to create a mock for you then it will be returned by the call to patcher.start.

```python
>>> patcher = patch('package.module.ClassName')
>>> from package import module
>>> original = module.ClassName
>>> new_mock = patcher.start()
>>> assert module.ClassName is not original
>>> assert module.ClassName is new_mock
>>> patcher.stop()
>>> assert module.ClassName is original
>>> assert module.ClassName is not new_mock
```

A typical use case for this might be for doing multiple patches in the setUp method of a TestCase:

```python
>>> class MyTest(TestCase):
```
Caution: If you use this technique you must ensure that the patching is “undone” by calling stop. This can be fiddlier than you might think, because if an exception is raised in the setUp then tearDown is not called. `unittest.TestCase.addCleanup()` makes this easier:

As an added bonus you no longer need to keep a reference to the patcher object.
It is also possible to stop all patches which have been started by using `patch.stopall()`.

`patch.stopall()`  
Stop all active patches. Only stops patches started with `start`.

### 26.5.3.6. patch builtins

You can patch any builtins within a module. The following example patches builtin `ord()`:

```python
>>> @patch('__main__.ord')
... def test(mock_ord):
...     mock_ord.return_value = 101
...     print(ord('c'))
...
>>> test()
101
```

### 26.5.3.7. TEST_PREFIX

All of the patchers can be used as class decorators. When used in this way they wrap every test method on the class. The patchers recognise methods that start with 'test' as being test methods. This is the same way that the `unittest.TestLoader` finds test methods by default.

It is possible that you want to use a different prefix for your tests. You can inform the patchers of the different prefix by setting `patch.TEST_PREFIX`:
>>> patch.TEST_PREFIX = 'foo'
>>> value = 3

>>> @patch('__main__.value', 'not three')
...     class Thing:
...         def foo_one(self):
...             print(value)
...         def foo_two(self):
...             print(value)

>>> Thing().foo_one()
not three
>>> Thing().foo_two()
not three
>>> value
3

26.5.3.8. Nesting Patch Decorators

If you want to perform multiple patches then you can simply stack up the decorators.

You can stack up multiple patch decorators using this pattern:

>>> @patch.object(SomeClass, 'class_method')
>>> @patch.object(SomeClass, 'static_method')
...     def test(mock1, mock2):
...         assert SomeClass.static_method is mock1
...         assert SomeClass.class_method is mock2
...         SomeClass.static_method('foo')
...         SomeClass.class_method('bar')
...         return mock1, mock2

>>> mock1, mock2 = test()
Note that the decorators are applied from the bottom upwards. This is the standard way that Python applies decorators. The order of the created mocks passed into your test function matches this order.

26.5.3.9. Where to patch

`patch()` works by (temporarily) changing the object that a name points to with another one. There can be many names pointing to any individual object, so for patching to work you must ensure that you patch the name used by the system under test.

The basic principle is that you patch where an object is looked up, which is not necessarily the same place as where it is defined. A couple of examples will help to clarify this.

Imagine we have a project that we want to test with the following structure:

```
a.py
   -> Defines SomeClass

b.py
   -> from a import SomeClass
   -> some_function instantiates SomeClass
```

Now we want to test `some_function` but we want to mock out `SomeClass` using `patch()`. The problem is that when we import module `b`, which we will have to do then it imports `SomeClass` from module `a`. If we use `patch()` to mock out `a.SomeClass` then it will have no effect on our test; module `b` already has a reference to the
real SomeClass and it looks like our patching had no effect.

The key is to patch out SomeClass where it is used (or where it is looked up). In this case some_function will actually look up SomeClass in module b, where we have imported it. The patching should look like:

```python
@patch('b.SomeClass')
```

However, consider the alternative scenario where instead of from a import SomeClass module b does import a and some_function uses a.SomeClass. Both of these import forms are common. In this case the class we want to patch is being looked up in the module and so we have to patch a.SomeClass instead:

```python
@patch('a.SomeClass')
```

### 26.5.3.10. Patching Descriptors and Proxy Objects

Both `patch` and `patch.object` correctly patch and restore descriptors: class methods, static methods and properties. You should patch these on the `class` rather than an instance. They also work with `some` objects that proxy attribute access, like the `django settings object`.
26.5.4. MagicMock and magic method support

26.5.4.1. Mocking Magic Methods

Mock supports mocking the Python protocol methods, also known as “magic methods”. This allows mock objects to replace containers or other objects that implement Python protocols.

Because magic methods are looked up differently from normal methods [2], this support has been specially implemented. This means that only specific magic methods are supported. The supported list includes almost all of them. If there are any missing that you need please let us know.

You mock magic methods by setting the method you are interested in to a function or a mock instance. If you are using a function then it must take self as the first argument [3].

```python
>>> def __str__(self):
...     return 'fooble'
...
>>> mock = Mock()
>>> mock.__str__ = __str__
>>> str(mock)
'fooble'
```

```python
>>> mock = Mock()
>>> mock.__str__ = Mock()
>>> mock.__str__.return_value = 'fooble'
>>> str(mock)
'fooble'
```
One use case for this is for mocking objects used as context managers in a `with` statement:

```python
>>> mock = Mock()
>>> mock.__enter__ = Mock(return_value='foo')
>>> mock.__exit__ = Mock(return_value=False)
>>> with mock as m:
...    assert m == 'foo'
...
>>> mock.__enter__.assert_called_with()
>>> mock.__exit__.assert_called_with(None, None, None)
```

Calls to magic methods do not appear in `method_calls`, but they are recorded in `mock_calls`.

**Note:** If you use the `spec` keyword argument to create a mock then attempting to set a magic method that isn't in the spec will raise an `AttributeError`.

The full list of supported magic methods is:

- `__hash__`, `__sizeof__`, `__repr__` and `__str__`
- `__dir__`, `__format__` and `__subclasses__`
- `__floor__`, `__trunc__` and `__ceil__`
- Comparisons: `__lt__`, `__gt__`, `__le__`, `__ge__`, `__eq__` and `__ne__`
- Container methods: `__getitem__`, `__setitem__`, `__delitem__`, `__contains__`, `__len__`, `__iter__`,
__reversed__ and __missing__

- Context manager: __enter__ and __exit__
- Unary numeric methods: __neg__, __pos__ and __invert__
- The numeric methods (including right hand and in-place variants): __add__, __sub__, __mul__, __matmul__, __div__, __truediv__, __floordiv__, __mod__, __divmod__, __lshift__, __rshift__, __and__, __xor__, __or__, and __pow__
- Numeric conversion methods: __complex__, __int__, __float__ and __index__
- Descriptor methods: __get__, __set__ and __delete__
- Pickling: __reduce__, __reduce_ex__, __getinitargs__, __getnewargs__, __getstate__ and __setstate__

The following methods exist but are not supported as they are either in use by mock, can't be set dynamically, or can cause problems:

- __getattr__, __setattr__, __init__ and __new__
- __prepare__, __instancecheck__, __subclasscheck__, __del__

### 26.5.4.2. Magic Mock

There are two MagicMock variants: MagicMock and NonCallableMagicMock.

```
class unittest.mock.MagicMock(*args, **kw)
```

MagicMock is a subclass of Mock with default implementations of most of the magic methods. You can use MagicMock without having to configure the magic methods yourself.

The constructor parameters have the same meaning as for Mock.
If you use the `spec` or `spec_set` arguments then only magic methods that exist in the spec will be created.

```python
class unittest.mock.NonCallableMagicMock(*args, **kw)
    A non-callable version of MagicMock.
```

The constructor parameters have the same meaning as for `MagicMock`, with the exception of `return_value` and `side_effect` which have no meaning on a non-callable mock.

The magic methods are setup with `MagicMock` objects, so you can configure them and use them in the usual way:

```python
>>> mock = MagicMock()
>>> mock[3] = 'fish'
>>> mock.__setitem__.assert_called_with(3, 'fish')
>>> mock.__getitem__.return_value = 'result'
>>> mock[2]
'result'
```

By default many of the protocol methods are required to return objects of a specific type. These methods are preconfigured with a default return value, so that they can be used without you having to do anything if you aren't interested in the return value. You can still set the return value manually if you want to change the default.

Methods and their defaults:

- `__lt__`: NotImplemented
- `__gt__`: NotImplemented
- `__le__`: NotImplemented
- `__ge__`: NotImplemented
- `__int__`: 1
- `__contains__`: False
• `__len__`: 1
• `__iter__`: `iter([])`
• `__exit__`: `False`
• `__complex__`: `1j`
• `__float__`: `1.0`
• `__bool__`: `True`
• `__index__`: `1`
• `__hash__`: default hash for the mock
• `__str__`: default str for the mock
• `__sizeof__`: default sizeof for the mock

For example:

```python
g>>> mock = MagicMock()
g>>> int(mock)
1
g>>> len(mock)
0
g>>> list(mock)
[]
g>>> object() in mock
False
```

The two equality methods, `__eq__()` and `__ne__()`, are special. They do the default equality comparison on identity, using the `side_effect` attribute, unless you change their return value to return something else:

```python
g>>> MagicMock() == 3
False
g>>> MagicMock() != 3
True
g>>> mock = MagicMock()
g>>> mock.__eq__.return_value = True
```
The return value of `MagicMock.__iter__()` can be any iterable object and isn't required to be an iterator:

```python
>>> mock = MagicMock()
>>> mock.__iter__.return_value = ['a', 'b', 'c']
>>> list(mock)
['a', 'b', 'c']
>>> list(mock)
['a', 'b', 'c']
```

If the return value is an iterator, then iterating over it once will consume it and subsequent iterations will result in an empty list:

```python
>>> mock.__iter__.return_value = iter(['a', 'b', 'c'])
>>> list(mock)
['a', 'b', 'c']
>>> list(mock)
[]
```

`MagicMock` has all of the supported magic methods configured except for some of the obscure and obsolete ones. You can still set these up if you want.

Magic methods that are supported but not setup by default in `MagicMock` are:

- `__subclasses__`
- `__dir__`
- `__format__`
- `__get__, __set__ and __delete__`
- `__reversed__` and `__missing__`
Magic methods should be looked up on the class rather than the instance. Different versions of Python are inconsistent about applying this rule. The supported protocol methods should work with all supported versions of Python.

The function is basically hooked up to the class, but each Mock instance is kept isolated from the others.
26.5.5. Helpers

26.5.5.1. sentinel

The `sentinel` object provides a convenient way of providing unique objects for your tests.

Attributes are created on demand when you access them by name. Accessing the same attribute will always return the same object. The objects returned have a sensible `repr` so that test failure messages are readable.

Sometimes when testing you need to test that a specific object is passed as an argument to another method, or returned. It can be common to create named `sentinel` objects to test this. `sentinel` provides a convenient way of creating and testing the identity of objects like this.

In this example we monkey patch method to return `sentinel.some_object`:

```python
>>> real = ProductionClass()
>>> real.method = Mock(name="method")
>>> real.method.return_value = sentinel.some_object
>>> result = real.method()
>>> assert result is sentinel.some_object
>>> sentinel.some_object
sentinel.some_object
```

26.5.5.2. DEFAULT
unittest.mock.DEFAULT

The DEFAULT object is a pre-created sentinel (actually sentinel.DEFAULT). It can be used by side_effect functions to indicate that the normal return value should be used.

26.5.5.3. call

unittest.mock.call(*args, **kwargs)

call() is a helper object for making simpler assertions, for comparing with call_args, call_args_list, mock_calls and method_calls. call() can also be used with assert_has_calls().

```python
>>> m = MagicMock(return_value=None)
>>> m(1, 2, a='foo', b='bar')
>>> m()
>>> m.call_args_list == [call(1, 2, a='foo', b='bar')
True
```

call.call_list()

For a call object that represents multiple calls, call_list() returns a list of all the intermediate calls as well as the final call.

call_list is particularly useful for making assertions on “chained calls”. A chained call is multiple calls on a single line of code. This results in multiple entries in mock_calls on a mock. Manually constructing the sequence of calls can be tedious.

call_list() can construct the sequence of calls from the same chained call:
A call object is either a tuple of (positional args, keyword args) or (name, positional args, keyword args) depending on how it was constructed. When you construct them yourself this isn’t particularly interesting, but the call objects that are in the `Mock.call_args`, `Mock.call_args_list` and `Mock.mock_calls` attributes can be introspected to get at the individual arguments they contain.

The call objects in `Mock.call_args` and `Mock.call_args_list` are two-tuples of (positional args, keyword args) whereas the call objects in `Mock.mock_calls`, along with ones you construct yourself, are three-tuples of (name, positional args, keyword args).

You can use their “tupleness” to pull out the individual arguments for more complex introspection and assertions. The positional arguments are a tuple (an empty tuple if there are no positional arguments) and the keyword arguments are a dictionary:
>>> args
(1, 2, 3)
>>> kwargs
{'arg2': 'two', 'arg': 'one'}
>>> args is kall[0]
True
>>> kwargs is kall[1]
True

>>> m = MagicMock()
>>> m.foo(4, 5, 6, arg='two', arg2='three')
<MockMock name='mock.foo()' id='...'>
>>> kall = m.mock_calls[0]
>>> name, args, kwargs = kall
>>> name
'foo'
>>> args
(4, 5, 6)
>>> kwargs
{'arg2': 'three', 'arg': 'two'}
>>> name is m.mock_calls[0][0]
True

26.5.5.4. create_autospec

unittest.mock.create_autospec(spec, spec_set=False, instance=False, **kwargs)

Create a mock object using another object as a spec. Attributes on the mock will use the corresponding attribute on the spec object as their spec.

Functions or methods being mocked will have their arguments checked to ensure that they are called with the correct signature.
If `spec_set` is `True` then attempting to set attributes that don’t exist on the spec object will raise an `AttributeError`.

If a class is used as a spec then the return value of the mock (the instance of the class) will have the same spec. You can use a class as the spec for an instance object by passing `instance=True`. The returned mock will only be callable if instances of the mock are callable.

`create_autospec()` also takes arbitrary keyword arguments that are passed to the constructor of the created mock.

See `Autospeccing` for examples of how to use auto-speccing with `create_autospec()` and the `autospec` argument to `patch()`.

26.5.5.5. ANY

`unittest.mock.ANY`

Sometimes you may need to make assertions about some of the arguments in a call to mock, but either not care about some of the arguments or want to pull them individually out of `call_args` and make more complex assertions on them.

To ignore certain arguments you can pass in objects that compare equal to `everything`. Calls to `assert_called_with()` and `assert_called_once_with()` will then succeed no matter what was passed in.

```python
>>> mock = Mock(return_value=None)
>>> mock('foo', bar=object())
>>> mock.assert_called_once_with('foo', bar=ANY)
```
ANY can also be used in comparisons with call lists like mock_calls:

```python
>>> m = MagicMock(return_value=None)
>>> m(1)
>>> m(1, 2)
>>> m(object())
>>> m.mock_calls == [call(1), call(1, 2), ANY]
True
```

### 26.5.5.6. FILTER_DIR

`unittest.mock.FILTER_DIR`

FILTER_DIR is a module level variable that controls the way mock objects respond to `dir()` (only for Python 2.6 or more recent). The default is True, which uses the filtering described below, to only show useful members. If you dislike this filtering, or need to switch it off for diagnostic purposes, then set `mock.FILTER_DIR = False`.

With filtering on, `dir(some_mock)` shows only useful attributes and will include any dynamically created attributes that wouldn’t normally be shown. If the mock was created with a `spec` (or `autospec` of course) then all the attributes from the original are shown, even if they haven’t been accessed yet:

```python
>>> dir(Mock())
['assert_any_call',
 'assert_called_once_with',
 'assert_called_with',
 'assert_has_calls',
 'attach_mock',
 ...
>>> from urllib import request
>>> dir(Mock(spec=request))
```
Many of the not-very-useful (private to Mock rather than the thing being mocked) underscore and double underscore prefixed attributes have been filtered from the result of calling dir() on a Mock. If you dislike this behaviour you can switch it off by setting the module level switch FILTER_DIR:

```python
>>> from unittest import mock
>>> mock.FILTER_DIR = False
>>> dir(mock.Mock())
['_NonCallableMock__get_return_value',
'_NonCallableMock__get_side_effect',
'_NonCallableMock__return_value_doc',
'_NonCallableMock__set_return_value',
'_NonCallableMock__set_side_effect',
'__call__',
'__class__',
...]
```

Alternatively you can just use vars(my_mock) (instance members) and dir(type(my_mock)) (type members) to bypass the filtering irrespective of mock.FILTER_DIR.

### 26.5.5.7. mock_open

unittest.mock.mock_open(mock=None, read_data=None)

A helper function to create a mock to replace the use of open(). It works for open() called directly or used as a
context manager.

The mock argument is the mock object to configure. If None (the default) then a MagicMock will be created for you, with the API limited to methods or attributes available on standard file handles.

read_data is a string for the read(), readline(), and readlines() methods of the file handle to return. Calls to those methods will take data from read_data until it is depleted. The mock of these methods is pretty simplistic: every time the mock is called, the read_data is rewound to the start. If you need more control over the data that you are feeding to the tested code you will need to customize this mock for yourself. When that is insufficient, one of the in-memory filesystem packages on PyPI can offer a realistic filesystem for testing.

Changed in version 3.4: Added readline() and readlines() support. The mock of read() changed to consume read_data rather than returning it on each call.

Changed in version 3.5: read_data is now reset on each call to the mock.

Using open() as a context manager is a great way to ensure your file handles are closed properly and is becoming common:

```python
with open('/some/path', 'w') as f:
    f.write('something')
```

The issue is that even if you mock out the call to open() it is the returned object that is used as a context manager (and has
Mocking context managers with a `MagicMock` is common enough and fiddly enough that a helper function is useful.

```python
def mock_open():
    return io.StringIO()

with patch('__main__.open', mock_open):
    with open('foo', 'w') as h:
        h.write('some stuff')

>>> handle = m()

>>> handle.write.assert_called_once_with('some stuff')
```

And for reading files:

```python
>>> with patch('__main__.open', mock_open(read_data='bibble')):
    with open('foo') as h:
        result = h.read()

>>> m.assert_called_once_with('foo')

>>> assert result == 'bibble'
```

### 26.5.5.8. Autospeccing

Autospeccing is based on the existing spec feature of mock. It limits the api of mocks to the api of an original object (the spec), but it is recursive (implemented lazily) so that attributes of mocks only have
the same api as the attributes of the spec. In addition mocked functions / methods have the same call signature as the original so they raise a `TypeError` if they are called incorrectly.

Before I explain how auto-speccing works, here's why it is needed.

`Mock` is a very powerful and flexible object, but it suffers from two flaws when used to mock out objects from a system under test. One of these flaws is specific to the `Mock` api and the other is a more general problem with using mock objects.

First the problem specific to `Mock`. `Mock` has two assert methods that are extremely handy: `assert_called_with()` and `assert_called_once_with()`.

```python
>>> mock = Mock(name='Thing', return_value=None)
>>> mock(1, 2, 3)
>>> mock.assert_called_once_with(1, 2, 3)
>>> mock(1, 2, 3)
>>> mock.assert_called_once_with(1, 2, 3)
Traceback (most recent call last):
...
AssertionError: Expected 'mock' to be called once. Called 2 times.
```

Because mocks auto-create attributes on demand, and allow you to call them with arbitrary arguments, if you misspell one of these assert methods then your assertion is gone:

```python
>>> mock = Mock(name='Thing', return_value=None)
>>> mock(1, 2, 3)
>>> mock.assert_called_once_with(4, 5, 6)
```

Your tests can pass silently and incorrectly because of the typo.
The second issue is more general to mocking. If you refactor some of your code, rename members and so on, any tests for code that is still using the old api but uses mocks instead of the real objects will still pass. This means your tests can all pass even though your code is broken.

Note that this is another reason why you need integration tests as well as unit tests. Testing everything in isolation is all fine and dandy, but if you don’t test how your units are “wired together” there is still lots of room for bugs that tests might have caught.

mock already provides a feature to help with this, called speccing. If you use a class or instance as the spec for a mock then you can only access attributes on the mock that exist on the real class:

```python
>>> from urllib import request
>>> mock = Mock(spec=request.Request)
>>> mock.assret_called_with
Traceback (most recent call last):
  ... AttributeError: Mock object has no attribute 'assret
```

The spec only applies to the mock itself, so we still have the same issue with any methods on the mock:

```python
>>> mock.has_data()
<mock.Mock object at 0x...>
>>> mock.has_data.assret_called_with()
```

Auto-speccing solves this problem. You can either pass autospec=True to `patch()` / `patch.object()` or use the `create_autospec()` function to create a mock with a spec. If you use the autospec=True argument to `patch()` then the object that is
being replaced will be used as the spec object. Because the speccing is done “lazily” (the spec is created as attributes on the mock are accessed) you can use it with very complex or deeply nested objects (like modules that import modules that import modules) without a big performance hit.

Here’s an example of it in use:

```python
golden_tip from urllib import request
golden_tip patcher = patch('__main__.request', autospec=True)
golden_tip mock_request = patcher.start()
golden_tip request is mock_request
golden_tip True
golden_tip mock_request.Request
<MagicMock name='request.Request' spec='Request' id='...'>
```

You can see that request.Request has a spec. request.Request takes two arguments in the constructor (one of which is self). Here’s what happens if we try to call it incorrectly:

```python
golden_tip req = request.Request()
Traceback (most recent call last):
... TypeError: <lambda>() takes at least 2 arguments (1)
```

The spec also applies to instantiated classes (i.e. the return value of specced mocks):

```python
golden_tip req = request.Request('foo')
golden_tip req
<NonCallableMagicMock name='request.Request()' spec=
```
Request objects are not callable, so the return value of instantiating our mocked out request.Request is a non-callable mock. With the spec in place any typos in our asserts will raise the correct error:

```python
>>> req.add_header('spam', 'eggs')
<MagicMock name='request.Request().add_header()' id='...'>
>>> req.add_header().assert_called_with
Traceback (most recent call last):
  ... AttributeError: Mock object has no attribute 'assert_called_with'
```  

In many cases you will just be able to add autospec=True to your existing `patch()` calls and then be protected against bugs due to typos and api changes.

As well as using `autospec` through `patch()` there is a `create_autospec()` for creating autospecced mocks directly:

```python
>>> from urllib import request
>>> mock_request = create_autospec(request)
>>> mock_request.Request('foo', 'bar')
<NonCallableMagicMock name='mock.Request()' spec='Request'>
```  

This isn't without caveats and limitations however, which is why it is not the default behaviour. In order to know what attributes are available on the spec object, autospec has to introspect (access attributes) the spec. As you traverse attributes on the mock a corresponding traversal of the original object is happening under the hood. If any of your specced objects have properties or descriptors that can trigger code execution then you may not be able to use autospec. On the other hand it is much better to design your objects
so that introspection is safe [4].

A more serious problem is that it is common for instance attributes to be created in the __init__() method and not to exist on the class at all. autospec can't know about any dynamically created attributes and restricts the api to visible attributes.

```python
>>> class Something:
...     def __init__(self):
...         self.a = 33
...
>>> with patch('__main__.Something', autospec=True):
...     thing = Something()
...     thing.a
...
Traceback (most recent call last):
...
AttributeError: Mock object has no attribute 'a'
```

There are a few different ways of resolving this problem. The easiest, but not necessarily the least annoying, way is to simply set the required attributes on the mock after creation. Just because autospec doesn't allow you to fetch attributes that don't exist on the spec it doesn't prevent you setting them:

```python
>>> with patch('__main__.Something', autospec=True):
...     thing = Something()
...     thing.a = 33
...
```

There is a more aggressive version of both spec and autospec that does prevent you setting non-existent attributes. This is useful if you want to ensure your code only sets valid attributes too, but obviously it
prevents this particular scenario:

```python
>>> with patch('__main__.Something', autospec=True,
...             thing = Something()
...             thing.a = 33
...
Traceback (most recent call last):
...
AttributeError: Mock object has no attribute 'a'
```

Probably the best way of solving the problem is to add class attributes as default values for instance members initialised in `__init__()`.

Note that if you are only setting default attributes in `__init__()` then providing them via class attributes (shared between instances of course) is faster too. e.g.

```python
class Something:
    a = 33
```

This brings up another issue. It is relatively common to provide a default value of `None` for members that will later be an object of a different type. `None` would be useless as a spec because it wouldn’t let you access any attributes or methods on it. As `None` is never going to be useful as a spec, and probably indicates a member that will normally of some other type, autospec doesn’t use a spec for members that are set to `None`. These will just be ordinary mocks (well - MagicMocks):

```python
>>> class Something:
...     member = None
...
>>> mock = create_autospec(Something)
>>> mock.member.foo.bar.baz()
```
If modifying your production classes to add defaults isn't to your liking then there are more options. One of these is simply to use an instance as the spec rather than the class. The other is to create a subclass of the production class and add the defaults to the subclass without affecting the production class. Both of these require you to use an alternative object as the spec. Thankfully `patch()` supports this - you can simply pass the alternative object as the `autospec` argument:

```python
>>> class Something:
    ...   def __init__(self):
    ...     self.a = 33
    ...
>>> class SomethingForTest(Something):
    ...   a = 33
    ...
>>> p = patch('__main__.Something', autospec=SomethingForTest)
>>> mock = p.start()
>>> mock.a
<NonCallableMagicMock name='Something.a' spec='int'
```

This only applies to classes or already instantiated objects. Calling a mocked class to create a mock instance *does not* create a real instance. It is only attribute lookups - along with calls to `dir()` - that are done.

[4]
26.6. `unittest.mock` — getting started

*New in version 3.3.*
26.6.1. Using Mock

26.6.1.1. Mock Patching Methods

Common uses for Mock objects include:

- Patching methods
- Recording method calls on objects

You might want to replace a method on an object to check that it is called with the correct arguments by another part of the system:

```python
>>> real = SomeClass()
>>> real.method = MagicMock(name='method')
>>> real.method(3, 4, 5, key='value')
<MagicMock name='method()' id='...'>
```

Once our mock has been used (real.method in this example) it has methods and attributes that allow you to make assertions about how it has been used.

**Note:** In most of these examples the Mock and MagicMock classes are interchangeable. As the MagicMock is the more capable class it makes a sensible one to use by default.

Once the mock has been called its called attribute is set to True. More importantly we can use the assert_called_with() or assert_called_once_with() method to check that it was called with the correct arguments.

This example tests that calling ProductionClass().method results in a call to the something method:
26.6.1.2. Mock for Method Calls on an Object

In the last example we patched a method directly on an object to check that it was called correctly. Another common use case is to pass an object into a method (or some part of the system under test) and then check that it is used in the correct way.

The simple `ProductionClass` below has a closer method. If it is called with an object then it calls `close` on it.

```python
>>> class ProductionClass:
    ...
    def closer(self, something):
    ...
        something.close()
    ...
```

So to test it we need to pass in an object with a close method and check that it was called correctly.

```python
>>> real = ProductionClass()
>>> mock = Mock()
>>> real.closer(mock)
>>> mock.close.assert_called_with()
```
We don’t have to do any work to provide the ‘close’ method on our mock. Accessing close creates it. So, if ‘close’ hasn’t already been called then accessing it in the test will create it, but `assert_called_with()` will raise a failure exception.

26.6.1.3. Mocking Classes

A common use case is to mock out classes instantiated by your code under test. When you patch a class, then that class is replaced with a mock. Instances are created by *calling the class*. This means you access the “mock instance” by looking at the return value of the mocked class.

In the example below we have a function `some_function` that instantiates `Foo` and calls a method on it. The call to `patch()` replaces the class `Foo` with a mock. The `Foo` instance is the result of calling the mock, so it is configured by modifying the mock `return_value`.

```python
>>> def some_function():
...     instance = module.Foo()
...     return instance.method()
...
>>> with patch('module.Foo') as mock:
...     instance = mock.return_value
...     instance.method.return_value = 'the result'
...     result = some_function()
...     assert result == 'the result'
```

26.6.1.4. Naming your mocks

It can be useful to give your mocks a name. The name is shown in the
repr of the mock and can be helpful when the mock appears in test failure messages. The name is also propagated to attributes or methods of the mock:

```python
>>> mock = MagicMock(name='foo')
>>> mock
<MagicMock name='foo' id='...'>
>>> mock.method
<MagicMock name='foo.method' id='...'>
```

### 26.6.1.5. Tracking all Calls

Often you want to track more than a single call to a method. The `mock_calls` attribute records all calls to child attributes of the mock - and also to their children.

```python
>>> mock = MagicMock()
>>> mock.method()
<MagicMock name='mock.method()' id='...'>
>>> mock.attribute.method(10, x=53)
<MagicMock name='mock.attribute.method()' id='...'>
>>> mock.mock_calls
[call.method(), call.attribute.method(10, x=53)]
```

If you make an assertion about `mock_calls` and any unexpected methods have been called, then the assertion will fail. This is useful because as well as asserting that the calls you expected have been made, you are also checking that they were made in the right order and with no additional calls:

You use the `call` object to construct lists for comparing with `mock_calls`:

```python
>>> mock = MagicMock()
>>> mock.method()
<MagicMock name='mock.method()' id='...'>
>>> mock.attribute.method(10, x=53)
<MagicMock name='mock.attribute.method()' id='...'>
>>> mock.mock_calls
[call.method(), call.attribute.method(10, x=53)]
```
26.6.1.6. Setting Return Values and Attributes

Setting the return values on a mock object is trivially easy:

```python
>>> mock = Mock()
>>> mock.return_value = 3
>>> mock()
3
```

Of course you can do the same for methods on the mock:

```python
>>> mock = Mock()
>>> mock.method.return_value = 3
>>> mock.method()
3
```

The return value can also be set in the constructor:

```python
>>> mock = Mock(return_value=3)
>>> mock()
3
```

If you need an attribute setting on your mock, just do it:

```python
>>> mock = Mock()
>>> mock.x = 3
>>> mock.x
3
```

Sometimes you want to mock up a more complex situation, like for
example mock.connection.cursor().execute("SELECT 1"). If we wanted this call to return a list, then we have to configure the result of the nested call.

We can use call to construct the set of calls in a “chained call” like this for easy assertion afterwards:

```python
>>> mock = Mock()
>>> cursor = mock.connection.cursor.return_value
>>> cursor.execute.return_value = ['foo']
>>> mock.connection.cursor().execute("SELECT 1")
['foo']
>>> expected = call.connection.cursor().execute("SELECT 1")
>>> mock.mock_calls
[call.connection.cursor(), call.connection.cursor().execute("SELECT 1")]
>>> mock.mock_calls == expected
True
```

It is the call to .call_list() that turns our call object into a list of calls representing the chained calls.

26.6.1.7. Raising exceptions with mocks

A useful attribute is side_effect. If you set this to an exception class or instance then the exception will be raised when the mock is called.

```python
>>> mock = Mock(side_effect=Exception('Boom!'))
>>> mock()
Traceback (most recent call last):
  ... Exception: Boom!
```
26.6.1.8. Side effect functions and iterables

side_effect can also be set to a function or an iterable. The use case for side_effect as an iterable is where your mock is going to be called several times, and you want each call to return a different value. When you set side_effect to an iterable every call to the mock returns the next value from the iterable:

```python
>>> mock = MagicMock(side_effect=[4, 5, 6])
>>> mock()
4
>>> mock()
5
>>> mock()
6
```

For more advanced use cases, like dynamically varying the return values depending on what the mock is called with, side_effect can be a function. The function will be called with the same arguments as the mock. Whatever the function returns is what the call returns:

```python
>>> vals = {(1, 2): 1, (2, 3): 2}
>>> def side_effect(*args):
...     return vals[args]
...
>>> mock = MagicMock(side_effect=side_effect)
>>> mock(1, 2)
1
>>> mock(2, 3)
2
```

26.6.1.9. Creating a Mock from an Existing Object
One problem with over use of mocking is that it couples your tests to the implementation of your mocks rather than your real code. Suppose you have a class that implements `some_method`. In a test for another class, you provide a mock of this object that also provides `some_method`. If later you refactor the first class, so that it no longer has `some_method` - then your tests will continue to pass even though your code is now broken!

**Mock** allows you to provide an object as a specification for the mock, using the `spec` keyword argument. Accessing methods / attributes on the mock that don’t exist on your specification object will immediately raise an attribute error. If you change the implementation of your specification, then tests that use that class will start failing immediately without you having to instantiate the class in those tests.

```python
>>> mock = Mock(spec=SomeClass)
>>> mock.old_method()
Traceback (most recent call last):
 ... AttributeError: object has no attribute 'old_method'
```

Using a specification also enables a smarter matching of calls made to the mock, regardless of whether some parameters were passed as positional or named arguments:

```python
>>> def f(a, b, c): pass
 ... >>> mock = Mock(spec=f)
 ... >>> mock(1, 2, 3)
<Mock name='mock()' id='140161580456576'>
 ... >>> mock.assert_called_with(a=1, b=2, c=3)
```

If you want this smarter matching to also work with method calls on the
mock, you can use **auto-speccing**.

If you want a stronger form of specification that prevents the setting of arbitrary attributes as well as the getting of them then you can use `spec_set` instead of `spec`. 
26.6.2. Patch Decorators

**Note:** With `patch()` it matters that you patch objects in the namespace where they are looked up. This is normally straightforward, but for a quick guide read *where to patch.*

A common need in tests is to patch a class attribute or a module attribute, for example patching a builtin or patching a class in a module to test that it is instantiated. Modules and classes are effectively global, so patching on them has to be undone after the test or the patch will persist into other tests and cause hard to diagnose problems.

Mock provides three convenient decorators for this: `patch()`, `patch.object()` and `patch.dict()`. `patch` takes a single string, of the form `package.module.Class.attribute` to specify the attribute you are patching. It also optionally takes a value that you want the attribute (or class or whatever) to be replaced with.

`patch.object` takes an object and the name of the attribute you would like patched, plus optionally the value to patch it with.

```python
>>> original = SomeClass.attribute
>>> @patch.object(SomeClass, 'attribute', sentinel.attribute)
... def test():
...     assert SomeClass.attribute == sentinel.attribute
... test()
>>> assert SomeClass.attribute == original
>>> @patch('package.module.attribute', sentinel.attribute)
```

```python
```
... def test():
...     from package.module import attribute
...     assert attribute is sentinel.attribute
... >>> test()

If you are patching a module (including builtins) then use patch() instead of patch.object():

>>> mock = MagicMock(return_value=sentinel.file_handle)
>>> with patch('builtins.open', mock):
...     handle = open('filename', 'r')
... >>> mock.assert_called_with('filename', 'r')
>>> assert handle == sentinel.file_handle, "incorrect file handle returned"

The module name can be 'dotted', in the form package.module if needed:

>>> @patch('package.module.ClassName.attribute', sentinel)
... def test():
...     from package.module import ClassName
...     assert ClassName.attribute == sentinel.attribute
... >>> test()

A nice pattern is to actually decorate test methods themselves:

>>> class MyTest(unittest2.TestCase):
...     @patch.object(SomeClass, 'attribute', sentinel)
...     def test_something(self):
...         self.assertEqual(SomeClass.attribute, sentinel...
If you want to patch with a Mock, you can use `patch()` with only one argument (or `patch.object()` with two arguments). The mock will be created for you and passed into the test function / method:

```python
>>> original = SomeClass.attribute
>>> MyTest('test_something').test_something()
>>> assert SomeClass.attribute == original
```

You can stack up multiple patch decorators using this pattern:

```python
>>> class MyTest(unittest2.TestCase):
...     @patch('package.module.ClassName1')
...     @patch('package.module.ClassName2')
...     def test_something(self, MockClass2, MockClass1):
...         self.assertIs(package.module.ClassName1, ...
...         self.assertIs(package.module.ClassName2, ...
... >>> MyTest('test_something').test_something()
```

When you nest patch decorators the mocks are passed in to the decorated function in the same order they applied (the normal python order that decorators are applied). This means from the bottom up, so in the example above the mock for test_module.ClassName2 is passed in first.
There is also `patch.dict()` for setting values in a dictionary just during a scope and restoring the dictionary to its original state when the test ends:

```python
>>> foo = {'key': 'value'}
>>> original = foo.copy()
>>> with patch.dict(foo, {'newkey': 'newvalue'}, clear=True):
...    assert foo == {'newkey': 'newvalue'}
...
>>> assert foo == original
```

`patch`, `patch.object` and `patch.dict` can all be used as context managers.

Where you use `patch()` to create a mock for you, you can get a reference to the mock using the “as” form of the with statement:

```python
>>> class ProductionClass:
...    def method(self):
...        pass
...
>>> with patch.object(ProductionClass, 'method') as mock_method:
...    mock_method.return_value = None
...    real = ProductionClass()
...    real.method(1, 2, 3)
...
>>> mock_method.assert_called_with(1, 2, 3)
```

As an alternative `patch`, `patch.object` and `patch.dict` can be used as class decorators. When used in this way it is the same as applying the decorator individually to every method whose name starts with “test”.
26.6.3. Further Examples

Here are some more examples for some slightly more advanced scenarios.

26.6.3.1. Mocking chained calls

Mocking chained calls is actually straightforward with mock once you understand the return_value attribute. When a mock is called for the first time, or you fetch its return_value before it has been called, a new Mock is created.

This means that you can see how the object returned from a call to a mocked object has been used by interrogating the return_value mock:

```python
>>> mock = Mock()
>>> mock().foo(a=2, b=3)
<Mock name='mock().foo()' id='...'>
>>> mock.return_value.foo.assert_called_with(a=2, b=3)
```

From here it is a simple step to configure and then make assertions about chained calls. Of course another alternative is writing your code in a more testable way in the first place...

So, suppose we have some code that looks a little bit like this:

```python
>>> class Something:
...     def __init__(self):
...         self.backend = BackendProvider()
...     def method(self):
...         response = self.backend.get_endpoint('foobar')
```
Assuming that BackendProvider is already well tested, how do we test method()? Specifically, we want to test that the code section # more code uses the response object in the correct way.

As this chain of calls is made from an instance attribute we can monkey patch the backend attribute on a Something instance. In this particular case we are only interested in the return value from the final call to start_call so we don’t have much configuration to do. Let’s assume the object it returns is ‘file-like’, so we’ll ensure that our response object uses the builtin open() as its spec.

To do this we create a mock instance as our mock backend and create a mock response object for it. To set the response as the return value for that final start_call we could do this:

```python
mock_backend.get_endpoint.return_value.create_call.return_value.start_call.return_value
```

We can do that in a slightly nicer way using the configure_mock() method to directly set the return value for us:

```python
>>> something = Something()
>>> mock_response = Mock(spec=open)
>>> mock_backend = Mock()
>>> config = {'get_endpoint.return_value.create_call.return_value.start_call.return_value'}
>>> mock_backend.configure_mock(**config)
```

With these we monkey patch the “mock backend” in place and can make the real call:

```python
>>> something.backend = mock_backend
```
Using mock_calls we can check the chained call with a single assert. A chained call is several calls in one line of code, so there will be several entries in mock_calls. We can use call.call_list() to create this list of calls for us:

```python
>>> chained = call.get_endpoint('foobar').create_call
>>> call_list = chained.call_list()
>>> assert mock_backend.mock_calls == call_list
```

### 26.6.3.2. Partial mocking

In some tests I wanted to mock out a call to datetime.date.today() to return a known date, but I didn’t want to prevent the code under test from creating new date objects. Unfortunately datetime.date is written in C, and so I couldn’t just monkey-patch out the static date.today() method.

I found a simple way of doing this that involved effectively wrapping the date class with a mock, but passing through calls to the constructor to the real class (and returning real instances).

The patch decorator is used here to mock out the date class in the module under test. The side_effect attribute on the mock date class is then set to a lambda function that returns a real date. When the mock date class is called a real date will be constructed and returned by side_effect.

```python
>>> from datetime import date
>>> with patch('mymodule.date') as mock_date:
...     mock_date.today.return_value = date(2010, 10
```
Note that we don’t patch `datetime.date` globally, we patch date in the module that uses it. See where to patch.

When `date.today()` is called a known date is returned, but calls to the `date(...)` constructor still return normal dates. Without this you can find yourself having to calculate an expected result using exactly the same algorithm as the code under test, which is a classic testing anti-pattern.

Calls to the date constructor are recorded in the `mock_date` attributes (call_count and friends) which may also be useful for your tests.

An alternative way of dealing with mocking dates, or other builtin classes, is discussed in this blog entry.

### 26.6.3.3. Mocking a Generator Method

A Python generator is a function or method that uses the `yield` statement to return a series of values when iterated over [1].

A generator method / function is called to return the generator object. It is the generator object that is then iterated over. The protocol method for iteration is `__iter__()`, so we can mock this using a `MagicMock`.

Here’s an example class with an “iter” method implemented as a generator:
How would we mock this class, and in particular its “iter” method?

To configure the values returned from the iteration (implicit in the call to `list`), we need to configure the object returned by the call to `foo.iter()`.

```python
>>> mock_foo = MagicMock()
>>> mock_foo.iter.return_value = iter([1, 2, 3])
>>> list(mock_foo.iter())
[1, 2, 3]
```

There are also generator expressions and more advanced uses of generators, but we aren’t concerned about them here. A very good introduction to generators and how powerful they are is: *Generator Tricks for Systems Programmers*.

26.6.3.4. Applying the same patch to every test method

If you want several patches in place for multiple test methods the obvious way is to apply the patch decorators to every method. This can feel like unnecessary repetition. For Python 2.6 or more recent you can use `patch()` (in all its various forms) as a class decorator. This applies the patches to all test methods on the class. A test method is identified by methods whose names start with `test`:
An alternative way of managing patches is to use the patch methods: start and stop. These allow you to move the patching into your setUp and tearDown methods.
If you use this technique you must ensure that the patching is “undone” by calling stop. This can be fiddlier than you might think, because if an exception is raised in the setUp then tearDown is not called. `unittest.TestCase.addCleanup()` makes this easier:

```python
>>> class MyTest(TestCase):
...     def setUp(self):
...         patcher = patch('mymodule.foo')
...         self.addCleanup(patcher.stop)
...         self.mock_foo = patcher.start()
...
...     def test_foo(self):
...         self.assertEqual(mymodule.foo, self.mock_foo)
...     ...;

>>> MyTest('test_foo').run()
```

26.6.3.5. Mocking Unbound Methods

Whilst writing tests today I needed to patch an *unbound method* (patching the method on the class rather than on the instance). I needed `self` to be passed in as the first argument because I want to make asserts about which objects were calling this particular method. The issue is that you can't patch with a mock for this, because if you replace an unbound method with a mock it doesn't become a bound method when fetched from the instance, and so it doesn't get `self` passed in. The workaround is to patch the unbound method with a real function instead. The `patch()` decorator makes it so simple to patch out methods with a mock that having to create a real function becomes a nuisance.

If you pass `autospec=True` to `patch` then it does the patching with a *real* function object. This function object has the same signature as the
one it is replacing, but delegates to a mock under the hood. You still get your mock auto-created in exactly the same way as before. What it means though, is that if you use it to patch out an unbound method on a class the mocked function will be turned into a bound method if it is fetched from an instance. It will have self passed in as the first argument, which is exactly what I wanted:

```python
>>> class Foo:
...     def foo(self):
...         pass
...
>>> with patch.object(Foo, 'foo', autospec=True) as mock_foo:
...     mock_foo.return_value = 'foo'
...     foo = Foo()
...     foo.foo()
... 'foo'
>>> mock_foo.assert_called_once_with(foo)
```

If we don't use autospec=True then the unbound method is patched out with a Mock instance instead, and isn't called with self.

26.6.3.6. Checking multiple calls with mock

mock has a nice API for making assertions about how your mock objects are used.

```python
>>> mock = Mock()
>>> mock.foo_bar.return_value = None
>>> mock.foo_bar('baz', spam='eggs')
>>> mock.foo_bar.assert_called_with('baz', spam='eggs')
```

If your mock is only being called once you can use the
assert_called_once_with() method that also asserts that the call_count is one.

```python
>>> mock.foo_bar.assert_called_once_with('baz', spam)
>>> mock.foo_bar()
>>> mock.foo_bar.assert_called_once_with('baz', spam)
Traceback (most recent call last):
  ...
AssertionError: Expected to be called once. Called 2
```

Both assert_called_with and assert_called_once_with make assertions about the most recent call. If your mock is going to be called several times, and you want to make assertions about all those calls you can use call_args_list:

```python
>>> mock = Mock(return_value=None)
>>> mock(1, 2, 3)
>>> mock(4, 5, 6)
>>> mock()
>>> mock.call_args_list
[call(1, 2, 3), call(4, 5, 6), call()]
```

The call helper makes it easy to make assertions about these calls. You can build up a list of expected calls and compare it to call_args_list. This looks remarkably similar to the repr of the call_args_list:

```python
>>> expected = [call(1, 2, 3), call(4, 5, 6), call()]
>>> mock.call_args_list == expected
True
```

26.6.3.7. Coping with mutable arguments
Another situation is rare, but can bite you, is when your mock is called with mutable arguments. `call_args` and `call_args_list` store references to the arguments. If the arguments are mutated by the code under test then you can no longer make assertions about what the values were when the mock was called.

Here’s some example code that shows the problem. Imagine the following functions defined in ‘mymodule’:

```python
def frob(val):
    pass

def grob(val):
    "First frob and then clear val"
    frob(val)
    val.clear()
```

When we try to test that `grob` calls `frob` with the correct argument look what happens:

```python
>>> with patch('mymodule.frob') as mock_frob:
...     val = {6}
...     mymodule.grob(val)
... >>> val
set()
>>> mock_frob.assert_called_with({6})
Traceback (most recent call last):
  ... AssertionError: Expected: (({6},), {})
Called with: ((set()), {})```

One possibility would be for mock to copy the arguments you pass in. This could then cause problems if you do assertions that rely on object identity for equality.
Here's one solution that uses the side_effect functionality. If you provide a side_effect function for a mock then side_effect will be called with the same args as the mock. This gives us an opportunity to copy the arguments and store them for later assertions. In this example I'm using another mock to store the arguments so that I can use the mock methods for doing the assertion. Again a helper function sets this up for me.

```python
from copy import deepcopy
from unittest.mock import Mock, patch, DEFAULT

def copy_call_args(mock):
    new_mock = Mock()
    def side_effect(*args, **kwars):
        args = deepcopy(args)
        kwars = deepcopy(kwars)
        new_mock(*args, **kwars)
        return DEFAULT
    mock.side_effect = side_effect
    return new_mock

with patch('mymodule.frob') as mock_frob:
    new_mock = copy_call_args(mock_frob)
    val = {6}
    mymodule.grob(val)

e new_mock.assert_called_with({6})
e new_mock.call_args
    call({6})
```

copy_call_args is called with the mock that will be called. It returns a new mock that we do the assertion on. The side_effect function makes a copy of the args and calls our new_mock with the copy.

**Note:** If your mock is only going to be used once there is an easier
way of checking arguments at the point they are called. You can simply do the checking inside a side_effect function.

```python
>>> def side_effect(arg):
...    assert arg == {6}
...
>>> mock = Mock(side_effect=side_effect)
>>> mock({6})
>>> mock(set())
Traceback (most recent call last):
  ...
AssertionError
```

An alternative approach is to create a subclass of Mock or MagicMock that copies (using copy.deepcopy()) the arguments. Here's an example implementation:

```python
>>> from copy import deepcopy
>>> class CopyingMock(MagicMock):
...    def __call__(self, *args, **kwargs):
...        args = deepcopy(args)
...        kwargs = deepcopy(kwargs)
...        return super(CopyingMock, self).__call__(*args, **kwargs)
...            
>>> c = CopyingMock(return_value=None)
>>> arg = set()
>>> c(arg)
>>> arg.add(1)
>>> c.assert_called_with(set())
>>> c.assert_called_with(arg)
Traceback (most recent call last):
  ...
AssertionError: Expected call: mock({1})
Actual call: mock(set())
>>> c.foo
```
When you subclass Mock or MagicMock all dynamically created attributes, and the return_value will use your subclass automatically. That means all children of a CopyingMock will also have the type CopyingMock.

26.6.3.8. Nesting Patches

Using patch as a context manager is nice, but if you do multiple patches you can end up with nested with statements indenting further and further to the right:

```python
>>> class MyTest(TestCase):
...     ...
...     def test_foo(self):
...         ...
...         with patch('mymodule.Foo') as mock_foo:
...             ...
...             with patch('mymodule.Bar') as mock_bar:
...                 ...
...                 with patch('mymodule.Spam') as mock_spam:
...                     assert mymodule.Foo is mock_foo
...                     assert mymodule.Bar is mock_bar
...                     assert mymodule.Spam is mock_spam
...     ...
...     original = mymodule.Foo
...     MyTest('test_foo').test_foo()
...     assert mymodule.Foo is original
```

With unittest cleanup functions and the patch methods: start and stop we can achieve the same effect without the nested indentation. A simple helper method, create_patch, puts the patch in place and returns the created mock for us:
>>> class MyTest(TestCase):
...    ...
...    def create_patch(self, name):
...        patcher = patch(name)
...        thing = patcher.start()
...        self.addCleanup(patcher.stop)
...        return thing
...    ...
...    def test_foo(self):
...        mock_foo = self.create_patch('mymodule.Foo'
...        mock_bar = self.create_patch('mymodule.Bar'
...        mock_spam = self.create_patch('mymodule.Spam'
...        ...
...        assert mymodule.Foo is mock_foo
...        assert mymodule.Bar is mock_bar
...        assert mymodule.Spam is mock_spam
...        ...

>>> original = mymodule.Foo
>>> MyTest('test_foo').run()
>>> assert mymodule.Foo is original

### 26.6.3.9. Mocking a dictionary with MagicMock

You may want to mock a dictionary, or other container object, recording all access to it whilst having it still behave like a dictionary.

We can do this with MagicMock, which will behave like a dictionary, and using side_effect to delegate dictionary access to a real underlying dictionary that is under our control.

When the __getitem__() and __setitem__() methods of our MagicMock are called (normal dictionary access) then side_effect is called with the key (and in the case of __setitem__ the value too). We can also control what is returned.
After the MagicMock has been used we can use attributes like `call_args_list` to assert about how the dictionary was used:

```python
>>> my_dict = {'a': 1, 'b': 2, 'c': 3}
>>> def getitem(name):
...    return my_dict[name]
...
>>> def setitem(name, val):
...    my_dict[name] = val
...
>>> mock = MagicMock()
>>> mock.__getitem__.side_effect = getitem
>>> mock.__setitem__.side_effect = setitem
```

**Note:** An alternative to using MagicMock is to use Mock and *only* provide the magic methods you specifically want:

```python
>>> mock = Mock()
>>> mock.__getitem__ = Mock(side_effect=getitem)
>>> mock.__setitem__ = Mock(side_effect=setitem)
```

A *third* option is to use MagicMock but passing in `dict` as the `spec` (or `spec_set`) argument so that the MagicMock created only has dictionary magic methods available:

```python
>>> mock = MagicMock(spec_set=dict)
>>> mock.__getitem__.side_effect = getitem
>>> mock.__setitem__.side_effect = setitem
```

With these side effect functions in place, the mock will behave like a normal dictionary but recording the access. It even raises a `KeyError` if you try to access a key that doesn’t exist.
>>> mock['a']
1
>>> mock['c']
3
>>> mock['d']
Traceback (most recent call last):
 ... 
  KeyError: 'd'
>>> mock['b'] = 'fish'
>>> mock['d'] = 'eggs'
>>> mock['b']
'fish'
>>> mock['d']
'eggs'

After it has been used you can make assertions about the access using the normal mock methods and attributes:

>>> mock.__getitem__.call_args_list
[call('a'), call('c'), call('d'), call('b'), call('d')]
>>> mock.__setitem__.call_args_list
[call('b', 'fish'), call('d', 'eggs')]
>>> my_dict
{'a': 1, 'c': 3, 'b': 'fish', 'd': 'eggs'}

26.6.3.10. Mock subclasses and their attributes

There are various reasons why you might want to subclass Mock. One reason might be to add helper methods. Here’s a silly example:

```python
>>> class MyMock(MagicMock):
...     def has_been_called(self):
...         return self.called

...```
The standard behaviour for Mock instances is that attributes and the return value mocks are of the same type as the mock they are accessed on. This ensures that Mock attributes are Mocks and Mock attributes are MagicMocks [2]. So if you're subclassing to add helper methods then they'll also be available on the attributes and return value mock of instances of your subclass.

Sometimes this is inconvenient. For example, one user is subclassing mock to created a Twisted adaptor. Having this applied to attributes too actually causes errors.

Mock (in all its flavours) uses a method called _get_child_mock to create these “sub-mocks” for attributes and return values. You can prevent your subclass being used for attributes by overriding this method. The signature is that it takes arbitrary keyword arguments (**kwargs) which are then passed onto the mock constructor:
An exception to this rule are the non-callable mocks. Attributes use the callable variant because otherwise non-callable mocks couldn't have callable methods.

26.6.3.11. Mocking imports with patch.dict

One situation where mocking can be hard is where you have a local import inside a function. These are harder to mock because they aren’t using an object from the module namespace that we can patch out.

Generally local imports are to be avoided. They are sometimes done to prevent circular dependencies, for which there is usually a much better way to solve the problem (refactor the code) or to prevent “up front costs” by delaying the import. This can also be solved in better ways than an unconditional local import (store the module as a class or module attribute and only do the import on first use).

That aside there is a way to use mock to affect the results of an import. Importing fetches an object from the sys.modules dictionary. Note that it fetches an object, which need not be a module. Importing a module for the first time results in a module object being put in sys.modules, so usually when you import something you get a module back. This need not be the case however.
This means you can use `patch.dict()` to temporarily put a mock in place in `sys.modules`. Any imports whilst this patch is active will fetch the mock. When the patch is complete (the decorated function exits, the with statement body is complete or `patcher.stop()` is called) then whatever was there previously will be restored safely.

Here's an example that mocks out the 'fooble' module.

```python
g>>> mock = Mock()  
g>>> with patch.dict('sys.modules', {'fooble': mock}) 
...     import fooble 
...     fooble.blob() 
...<Mock name='mock.blob()' id='...'>
g>>> assert 'fooble' not in sys.modules 
g>>> mock.blob.assert_called_once_with() 
```

As you can see the `import fooble` succeeds, but on exit there is no 'fooble' left in `sys.modules`.

This also works for the `from module import name` form:

```python
g>>> mock = Mock()  
g>>> with patch.dict('sys.modules', {'fooble': mock}) 
...     from fooble import blob 
...     blob.blip() 
...<Mock name='mock.blob.blip()' id='...'>
g>>> mock.blob.blip.assert_called_once_with() 
```

With slightly more work you can also mock package imports:

```python
g>>> mock = Mock()  
```
26.6.3.12. Tracking order of calls and less verbose call assertions

The Mock class allows you to track the order of method calls on your mock objects through the method_calls attribute. This doesn’t allow you to track the order of calls between separate mock objects, however we can use mock_calls to achieve the same effect.

Because mocks track calls to child mocks in mock_calls, and accessing an arbitrary attribute of a mock creates a child mock, we can create our separate mocks from a parent one. Calls to those child mock will then all be recorded, in order, in the mock_calls of the parent:

```python
>>> manager = Mock()
>>> mock_foo = manager.foo
>>> mock_bar = manager.bar

>>> mock_foo.something()
<Mock name='mock.foo.something()' id='...'>
>>> mock_bar.other.thing()
<Mock name='mock.bar.other.thing()' id='...'>

>>> manager.mock_calls
```
We can then assert about the calls, including the order, by comparing with the mock_calls attribute on the manager mock:

```python
>>> expected_calls = [call.foo.something(), call.bar.other.thing()]
>>> manager.mock_calls == expected_calls
True
```

If patch is creating, and putting in place, your mocks then you can attach them to a manager mock using the `attach_mock()` method. After attaching calls will be recorded in mock_calls of the manager.

```python
>>> manager = MagicMock()
>>> with patch('mymodule.Class1') as MockClass1:
...     with patch('mymodule.Class2') as MockClass2:
...         manager.attach_mock(MockClass1, 'MockClass1')
...         manager.attach_mock(MockClass2, 'MockClass2')
...         MockClass1().foo()
...         MockClass2().bar()
...
<MagicMock name='mock.MockClass1().foo()' id='...'>
<MagicMock name='mock.MockClass2().bar()' id='...'>
>>> manager.mock_calls
[call.MockClass1(),
 call.MockClass1().foo(),
 call.MockClass2(),
 call.MockClass2().bar()]
```

If many calls have been made, but you’re only interested in a particular sequence of them then an alternative is to use the `assert_has_calls()` method. This takes a list of calls (constructed with the `call` object). If that sequence of calls are in `mock_calls`
then the assert succeeds.

```python
>>> m = MagicMock()
>>> m().foo().bar().baz()
<MagicMock name='mock().foo().bar().baz()' id='...'>
>>> m.one().two().three()
<MagicMock name='mock.one().two().three()' id='...'>
>>> calls = call.one().two().three().call_list()
>>> m.assert_has_calls(calls)
```

Even though the chained call `m.one().two().three()` aren't the only calls that have been made to the mock, the assert still succeeds.

Sometimes a mock may have several calls made to it, and you are only interested in asserting about some of those calls. You may not even care about the order. In this case you can pass `any_order=True` to `assert_has_calls`:

```python
>>> m = MagicMock()
>>> m(1), m.two(2, 3), m.seven(7), m.fifty('50')
(...)
>>> calls = [call.fifty('50'), call(1), call.seven(7), call(2, 3)]
>>> m.assert_has_calls(calls, any_order=True)
```

26.6.3.13. More complex argument matching

Using the same basic concept as `ANY` we can implement matchers to do more complex assertions on objects used as arguments to mocks.

Suppose we expect some object to be passed to a mock that by default compares equal based on object identity (which is the Python default for user defined classes). To use `assert_called_with()`
we would need to pass in the exact same object. If we are only interested in some of the attributes of this object then we can create a matcher that will check these attributes for us.

You can see in this example how a ‘standard’ call to assert_called_with isn’t sufficient:

```python
>>> class Foo:
...     def __init__(self, a, b):
...         self.a, self.b = a, b
...
>>> mock = Mock(return_value=None)
>>> mock(Foo(1, 2))
>>> mock.assert_called_with(Foo(1, 2))
Traceback (most recent call last):
  ...  
AssertionError: Expected: call(<__main__.Foo object at 0x...>)
Actual call: call(<__main__.Foo object at 0x...>)
```

A comparison function for our Foo class might look something like this:

```python
>>> def compare(self, other):
...     if not type(self) == type(other):
...         return False
...     if self.a != other.a:
...         return False
...     if self.b != other.b:
...         return False
...     return True
...
```

And a matcher object that can use comparison functions like this for its equality operation would look something like this:

```python
>>> class Matcher:
```
Putting all this together:

```python
>>> match_foo = Matcher(compare, Foo(1, 2))
>>> mock.assert_called_with(match_foo)
```

The Matcher is instantiated with our compare function and the Foo object we want to compare against. In `assert_called_with` the Matcher equality method will be called, which compares the object the mock was called with against the one we created our matcher with. If they match then `assert_called_with` passes, and if they don't an `AssertionError` is raised:

```python
>>> match_wrong = Matcher(compare, Foo(3, 4))
>>> mock.assert_called_with(match_wrong)
Traceback (most recent call last):
  ...
AssertionError: Expected: ((<Matcher object at 0x...>,), {}) Called with: ((<Foo object at 0x...>,), {})
```

With a bit of tweaking you could have the comparison function raise the `AssertionError` directly and provide a more useful failure message.

As of version 1.5, the Python testing library PyHamcrest provides similar functionality, that may be useful here, in the form of its equality matcher (`hamcrest.library.integration.match_equality`).
26.7. 2to3 - Automated Python 2 to 3 code translation

2to3 is a Python program that reads Python 2.x source code and applies a series of fixers to transform it into valid Python 3.x code. The standard library contains a rich set of fixers that will handle almost all code. 2to3 supporting library lib2to3 is, however, a flexible and generic library, so it is possible to write your own fixers for 2to3. lib2to3 could also be adapted to custom applications in which Python code needs to be edited automatically.
26.7.1. Using 2to3

2to3 will usually be installed with the Python interpreter as a script. It is also located in the Tools/scripts directory of the Python root.

2to3’s basic arguments are a list of files or directories to transform. The directories are recursively traversed for Python sources.

Here is a sample Python 2.x source file, example.py:

```python
def greet(name):
    print "Hello, {0}!".format(name)
print "What's your name?"
name = raw_input()
greet(name)
```

It can be converted to Python 3.x code via 2to3 on the command line:

```
$ 2to3 example.py
```

A diff against the original source file is printed. 2to3 can also write the needed modifications right back to the source file. (A backup of the original file is made unless -n is also given.) Writing the changes back is enabled with the -w flag:

```
$ 2to3 -w example.py
```

After transformation, example.py looks like this:

```python
def greet(name):
    print("Hello, {0}!").format(name))
print("What's your name?")
name = input()
```
greet(name)

Comments and exact indentation are preserved throughout the translation process.

By default, 2to3 runs a set of predefined fixers. The -l flag lists all available fixers. An explicit set of fixers to run can be given with -f. Likewise the -x explicitly disables a fixer. The following example runs only the imports and has_key fixers:

$ 2to3 -f imports -f has_key example.py

This command runs every fixer except the apply fixer:

$ 2to3 -x apply example.py

Some fixers are explicit, meaning they aren't run by default and must be listed on the command line to be run. Here, in addition to the default fixers, the idioms fixer is run:

$ 2to3 -f all -f idioms example.py

Notice how passing all enables all default fixers.

Sometimes 2to3 will find a place in your source code that needs to be changed, but 2to3 cannot fix automatically. In this case, 2to3 will print a warning beneath the diff for a file. You should address the warning in order to have compliant 3.x code.

2to3 can also refactor doctests. To enable this mode, use the -d flag. Note that only doctests will be refactored. This also doesn't require the module to be valid Python. For example, doctest like examples in a reST document could also be refactored with this option.
The -v option enables output of more information on the translation process.

Since some print statements can be parsed as function calls or statements, 2to3 cannot always read files containing the print function. When 2to3 detects the presence of the from __future__ import print_function compiler directive, it modifies its internal grammar to interpret \texttt{print()} as a function. This change can also be enabled manually with the -p flag. Use -p to run fixers on code that already has had its print statements converted.

The -o or --output-dir option allows specification of an alternate directory for processed output files to be written to. The -n flag is required when using this as backup files do not make sense when not overwriting the input files.

\textit{New in version 3.2.3}: The -o option was added.

The -W or --write-unchanged-files flag tells 2to3 to always write output files even if no changes were required to the file. This is most useful with -o so that an entire Python source tree is copied with translation from one directory to another. This option implies the -w flag as it would not make sense otherwise.

\textit{New in version 3.2.3}: The -W flag was added.

The --add-suffix option specifies a string to append to all output filenames. The -n flag is required when specifying this as backups are not necessary when writing to different filenames. Example:

\begin{verbatim}
$ 2to3 -n -W --add-suffix=3 example.py
\end{verbatim}

Will cause a converted file named \texttt{example.py3} to be written.
New in version 3.2.3: The `--add-suffix` option was added.

To translate an entire project from one directory tree to another use:

```
$ 2to3 --output-dir=python3-version/mycode -W -n python2-version/mycode
```
26.7.2. Fixers

Each step of transforming code is encapsulated in a fixer. The command `2to3 -l` lists them. As documented above, each can be turned on and off individually. They are described here in more detail.

**apply**

Removes usage of `apply()`. For example `apply(function, *args, **kwargs)` is converted to `function(*args, **kwargs).

**asserts**

Replaces deprecated `unittest` method names with the correct ones.

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>failUnlessEqual(a, b)</code></td>
<td><code>assertEqual(a, b)</code></td>
</tr>
<tr>
<td><code>assertEquals(a, b)</code></td>
<td><code>assertEqual(a, b)</code></td>
</tr>
<tr>
<td><code>failIfEqual(a, b)</code></td>
<td><code>assertNotEqual(a, b)</code></td>
</tr>
<tr>
<td><code>assertNotEquals(a, b)</code></td>
<td><code>assertNotEqual(a, b)</code></td>
</tr>
<tr>
<td><code>failUnless(a)</code></td>
<td><code>assertTrue(a)</code></td>
</tr>
<tr>
<td><code>assert_(a)</code></td>
<td><code>assertTrue(a)</code></td>
</tr>
<tr>
<td><code>failIf(a)</code></td>
<td><code>assertFalse(a)</code></td>
</tr>
<tr>
<td><code>failUnlessRaises(exc, cal)</code></td>
<td><code>assertRaises(exc, cal)</code></td>
</tr>
<tr>
<td><code>failUnlessAlmostEqual(a, b)</code></td>
<td><code>assertAlmostEqual(a, b)</code></td>
</tr>
<tr>
<td><code>assertAlmostEquals(a, b)</code></td>
<td><code>assertAlmostEqual(a, b)</code></td>
</tr>
<tr>
<td><code>assertAlmostEquals(a, b)</code></td>
<td><code>assertAlmostEqual(a, b)</code></td>
</tr>
<tr>
<td>failIfAlmostEqual(a, b)</td>
<td>assertNotAlmostEqual(a, b)</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>assertNotAlmostEquals(a, b)</td>
<td>assertNotAlmostEqual(a, b)</td>
</tr>
</tbody>
</table>

**basestring**

Converts basestring to str.

**buffer**

Converts buffer to memoryview. This fixer is optional because the memoryview API is similar but not exactly the same as that of buffer.

**callable**

Converts callable(x) to isinstance(x, collections.Callable), adding an import to collections if needed. Note callable(x) has returned in Python 3.2, so if you do not intend to support Python 3.1, you can disable this fixer.

**dict**

Fixes dictionary iteration methods. dict.iteritems() is converted to dict.items(), dict.iterkeys() to dict.keys(), and dict.itervalues() to dict.values(). Similarly, dict.viewitems(), dict.viewkeys() and dict.viewvalues() are converted respectively to dict.items(), dict.keys() and dict.values(). It also wraps existing usages of dict.items(), dict.keys(), and dict.values() in a call to list.

**except**

Converts except X, T to except X as T.
exec
Converts the exec statement to the `exec()` function.

execfile
Removes usage of `execfile()`. The argument to `execfile()` is wrapped in calls to `open()`, `compile()`, and `exec()`.

exitfunc
Changes assignment of `sys.exitfunc` to use of the `atexit` module.

filter
Wraps `filter()` usage in a `list` call.

funcattrs
Fixes function attributes that have been renamed. For example, `my_function.func_closure` is converted to `my_function.__closure__`.

future
Removes from `__future__` import `new_feature` statements.

getcwd
Renames `os.getcwdu()` to `os.getcwd()`.

has_key
Changes `dict.has_key(key)` to `key in dict`.

idioms
This optional fixer performs several transformations that make Python code more idiomatic. Type comparisons like `type(x) is`
SomeClass and type(x) == SomeClass are converted to isinstance(x, SomeClass). while 1 becomes while True. This fixer also tries to make use of sorted() in appropriate places. For example, this block

```python
L = list(some_iterable)
L.sort()
```

is changed to

```python
L = sorted(some_iterable)
```

**import**

Detects sibling imports and converts them to relative imports.

**imports**

Handles module renames in the standard library.

**imports2**

Handles other modules renames in the standard library. It is separate from the imports fixer only because of technical limitations.

**input**

Converts input(prompt) to eval(input(prompt)).

**intern**

Converts intern() to sys.intern().

**isinstance**

Fixes duplicate types in the second argument of isinstance(). For example, isinstance(x, (int, int)) is converted to isinstance(x, (int)).
**itertools imports**
Removes imports of `itertools.ifilter()`, `itertools.izip()`, and `itertools.imap()`. Imports of `itertools.ifilterfalse()` are also changed to `itertools.filterfalse()`.

**itertools**
Changes usage of `itertools.ifilter()`, `itertools.izip()`, and `itertools.imap()` to their built-in equivalents. `itertools.ifilterfalse()` is changed to `itertools.filterfalse()`.

**long**
Renames `long` to `int`.

**map**
Wraps `map()` in a `list` call. It also changes `map(None, x)` to `list(x)`. Using from `future_builtins` import `map` disables this fixer.

**metaclass**
Converts the old metaclass syntax (`__metaclass__ = Meta` in the class body) to the new (`class X(metaclass=Meta)`).

**methodattrs**
Fixes old method attribute names. For example, `meth.im_func` is converted to `meth.__func__`.

**ne**
Converts the old not-equal syntax, `<>`, to `!=`.

**next**
Converts the use of iterator’s `next()` methods to the `next()` function. It also renames `next()` methods to `__next__()`.

**nonzero**
Renames `__nonzero__()` to `__bool__()`.

**numliterals**
Converts octal literals into the new syntax.

**operator**
Converts calls to various functions in the `operator` module to other, but equivalent, function calls. When needed, the appropriate import statements are added, e.g. `import collections`. The following mapping are made:

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>operator.isCallable(obj)</code></td>
<td><code>hasattr(obj, '__call__')</code></td>
</tr>
<tr>
<td><code>operator.sequenceIncludes(obj)</code></td>
<td><code>operator.contains</code></td>
</tr>
<tr>
<td><code>operator.isSequenceType(obj)</code></td>
<td><code>isinstance(obj, collections.Sequence)</code></td>
</tr>
<tr>
<td><code>operator.isMappingType(obj)</code></td>
<td><code>isinstance(obj, collections.Mapping)</code></td>
</tr>
<tr>
<td><code>operator.isNumberType(obj)</code></td>
<td><code>isinstance(obj, numbers.Number)</code></td>
</tr>
<tr>
<td><code>operator.repeat(obj, n)</code></td>
<td><code>operator.mul(obj, operator.irepeat(obj, n))</code></td>
</tr>
<tr>
<td><code>operator.irepeat(obj, n)</code></td>
<td><code>operator.imul(obj)</code></td>
</tr>
</tbody>
</table>

**paren**
Add extra parenthesis where they are required in list comprehensions. For example, `[x for x in 1, 2] becomes
[x for x in (1, 2)].

**print**
Converts the print statement to the `print()` function.

**raise**
Converts `raise E, V` to `raise E(V)`, and `raise E, V, T` to `raise E(V).with_traceback(T)`. If `E` is a tuple, the translation will be incorrect because substituting tuples for exceptions has been removed in 3.0.

**raw_input**
Converts `raw_input()` to `input()`.

**reduce**
Handles the move of `reduce()` to `functools.reduce()`.

**reload**
Converts `reload()` to `imp.reload()`.

**renames**
Changes `sys.maxint` to `sys.maxsize`.

**repr**
Replaces backtick `repr` with the `repr()` function.

**set_literal**
Replaces use of the `set` constructor with set literals. This fixer is optional.

**standarderror**
Renames `StandardError` to `Exception`. 
**sys_exc**
Changes the deprecated `sys.exc_value`, `sys.exc_type`, `sys.exc_traceback` to use `sys.exc_info()`.

**throw**
Fixes the API change in generator's `throw()` method.

**tuple_params**
Removes implicit tuple parameter unpacking. This fixer inserts temporary variables.

**types**
Fixes code broken from the removal of some members in the `types` module.

**unicode**
Renames `unicode` to `str`.

**urllib**
Handles the rename of `urllib` and `urllib2` to the `urllib` package.

**ws_comma**
Removes excess whitespace from comma separated items. This fixer is optional.

**xrange**
Renames `xrange()` to `range()` and wraps existing `range()` calls with `list`.

**xreadlines**
Changes for `x in file.xreadlines()` to `for x in file`.
zip
Wraps `zip()` usage in a `list` call. This is disabled when from `future_builtins import zip` appears.
26.7.3. **lib2to3** - 2to3’s library

**Note:** The **lib2to3** API should be considered unstable and may change drastically in the future.
26.8. **test** — Regression tests package for Python

**Note:** The **test** package is meant for internal use by Python only. It is documented for the benefit of the core developers of Python. Any use of this package outside of Python’s standard library is discouraged as code mentioned here can change or be removed without notice between releases of Python.

The **test** package contains all regression tests for Python as well as the modules **test.support** and **test.regrtest**. **test.support** is used to enhance your tests while **test.regrtest** drives the testing suite.

Each module in the **test** package whose name starts with **test_** is a testing suite for a specific module or feature. All new tests should be written using the **unittest** or **doctest** module. Some older tests are written using a “traditional” testing style that compares output printed to `sys.stdout`; this style of test is considered deprecated.

**See also:**

**Module unittest**
   Writing PyUnit regression tests.

**Module doctest**
   Tests embedded in documentation strings.
26.8.1. Writing Unit Tests for the test package

It is preferred that tests that use the unittest module follow a few guidelines. One is to name the test module by starting it with test_ and end it with the name of the module being tested. The test methods in the test module should start with test_ and end with a description of what the method is testing. This is needed so that the methods are recognized by the test driver as test methods. Also, no documentation string for the method should be included. A comment (such as # Tests function returns only True or False) should be used to provide documentation for test methods. This is done because documentation strings get printed out if they exist and thus what test is being run is not stated.

A basic boilerplate is often used:

```python
import unittest
from test import support

class MyTestCase1(unittest.TestCase):
    # Only use setUp() and tearDown() if necessary

    def setUp(self):
        ... code to execute in preparation for tests

    def tearDown(self):
        ... code to execute to clean up after tests

    def test_feature_one(self):
        # Test feature one.
        ... testing code ...
```
def test_feature_two(self):
    # Test feature two.
    ... testing code ...

    ... more test methods ...

class MyTestCase2(unittest.TestCase):
    ... same structure as MyTestCase1 ...

    ... more test classes ...

if __name__ == '__main__':
    unittest.main()

This code pattern allows the testing suite to be run by test.regrtest, on its own as a script that supports the unittest CLI, or via the python -m unittest CLI.

The goal for regression testing is to try to break code. This leads to a few guidelines to be followed:

- The testing suite should exercise all classes, functions, and constants. This includes not just the external API that is to be presented to the outside world but also “private” code.

- Whitebox testing (examining the code being tested when the tests are being written) is preferred. Blackbox testing (testing only the published user interface) is not complete enough to make sure all boundary and edge cases are tested.

- Make sure all possible values are tested including invalid ones. This makes sure that not only all valid values are acceptable but also that improper values are handled correctly.
- Exhaust as many code paths as possible. Test where branching occurs and thus tailor input to make sure as many different paths through the code are taken.

- Add an explicit test for any bugs discovered for the tested code. This will make sure that the error does not crop up again if the code is changed in the future.

- Make sure to clean up after your tests (such as close and remove all temporary files).

- If a test is dependent on a specific condition of the operating system then verify the condition already exists before attempting the test.

- Import as few modules as possible and do it as soon as possible. This minimizes external dependencies of tests and also minimizes possible anomalous behavior from side-effects of importing a module.

- Try to maximize code reuse. On occasion, tests will vary by something as small as what type of input is used. Minimize code duplication by subclassing a basic test class with a class that specifies the input:

```python
class TestFuncAcceptsSequencesMixin:
    func = mySuperWhammyFunction

    def test_func(self):
        self.func(self.arg)

class AcceptLists(TestFuncAcceptsSequencesMixin,
    arg = [1, 2, 3]
```
```python
class AcceptStrings(TestFuncAcceptsSequencesMixin):
    arg = 'abc'

class AcceptTuples(TestFuncAcceptsSequencesMixin):
    arg = (1, 2, 3)
```

When using this pattern, remember that all classes that inherit from `unittest.TestCase` are run as tests. The Mixin class in the example above does not have any data and so can’t be run by itself, thus it does not inherit from `unittest.TestCase`.

See also:

**Test Driven Development**
A book by Kent Beck on writing tests before code.
26.8.2. Running tests using the command-line interface

The test package can be run as a script to drive Python’s regression test suite, thanks to the -m option: python -m test. Under the hood, it uses test.regrtest; the call python -m test.regrtest used in previous Python versions still works. Running the script by itself automatically starts running all regression tests in the test package. It does this by finding all modules in the package whose name starts with test_, importing them, and executing the function test_main() if present or loading the tests via unittest.TestLoader.loadTestsFromModule if test_main does not exist. The names of tests to execute may also be passed to the script. Specifying a single regression test (python -m test test_spam) will minimize output and only print whether the test passed or failed.

Running test directly allows what resources are available for tests to use to be set. You do this by using the -u command-line option. Specifying all as the value for the -u option enables all possible resources: python -m test -uall. If all but one resource is desired (a more common case), a comma-separated list of resources that are not desired may be listed after all. The command python -m test -uall,-audio,-largefile will run test with all resources except the audio and largefile resources. For a list of all resources and more command-line options, run python -m test -h.

Some other ways to execute the regression tests depend on what platform the tests are being executed on. On Unix, you can run make test at the top-level directory where Python was built. On Windows, executing rt.bat from your PCBuild directory will run all regression
tests.
26.9. `test.support` — Utilities for the Python test suite

The `test.support` module provides support for Python’s regression test suite.

**Note:** `test.support` is not a public module. It is documented here to help Python developers write tests. The API of this module is subject to change without backwards compatibility concerns between releases.

This module defines the following exceptions:

- **Exception** `test.support.TestFailed`  
  Exception to be raised when a test fails. This is deprecated in favor of `unittest`-based tests and `unittest.TestCase`'s assertion methods.

- **Exception** `test.support.ResourceDenied`  
  Subclass of `unittest.SkipTest`. Raised when a resource (such as a network connection) is not available. Raised by the `requires()` function.

The `test.support` module defines the following constants:

- **`test.support.verbose`**  
  True when verbose output is enabled. Should be checked when more detailed information is desired about a running test. `verbose` is set by `test.regrtest`. 
test.support.is_jython

True if the running interpreter is Jython.

test.support.TESTFN

Set to a name that is safe to use as the name of a temporary file. Any temporary file that is created should be closed and unlinked (removed).

The test.support module defines the following functions:

test.support.forget(module_name)

Remove the module named module_name from sys.modules and delete any byte-compiled files of the module.

test.support.is_resource_enabled(resource)

Return True if resource is enabled and available. The list of available resources is only set when test.regrtest is executing the tests.

test.support.requires(resource, msg=None)

Raise ResourceDenied if resource is not available. msg is the argument to ResourceDenied if it is raised. Always returns True if called by a function whose __name__ is '__main__'. Used when tests are executed by test.regrtest.

test.support.findfile(filename, subdir=None)

Return the path to the file named filename. If no match is found filename is returned. This does not equal a failure since it could be the path to the file.

    Setting subdir indicates a relative path to use to find the file rather than looking directly in the path directories.
**run_unittest**(*classes*)

Execute **unittest.TestCase** subclasses passed to the function. The function scans the classes for methods starting with the prefix `test_` and executes the tests individually.

It is also legal to pass strings as parameters; these should be keys in `sys.modules`. Each associated module will be scanned by `unittest.TestLoader.loadTestsFromModule()`. This is usually seen in the following `test_main()` function:

```python
def test_main():
    support.run_unittest(__name__)
```

This will run all tests defined in the named module.

**run_doctest**(module, verbosity=None)

Run `doctest.testmod()` on the given `module`. Return `(failure_count, test_count)`.

If `verbosity` is None, `doctest.testmod()` is run with verbosity set to `verbose`. Otherwise, it is run with verbosity set to None.

**check_warnings**(*filters, quiet=True*)

A convenience wrapper for `warnings.catch_warnings()` that makes it easier to test that a warning was correctly raised. It is approximately equivalent to calling `warnings.catch_warnings(record=True)` with `warnings.simplefilter()` set to `always` and with the option to automatically validate the results that are recorded.

`check_warnings` accepts 2-tuples of the form ("message regexp", WarningCategory) as positional arguments. If one
or more filters are provided, or if the optional keyword argument quiet is False, it checks to make sure the warnings are as expected: each specified filter must match at least one of the warnings raised by the enclosed code or the test fails, and if any warnings are raised that do not match any of the specified filters the test fails. To disable the first of these checks, set quiet to True.

If no arguments are specified, it defaults to:

```python
check_warnings(("", Warning), quiet=True)
```

In this case all warnings are caught and no errors are raised.

On entry to the context manager, a WarningRecorder instance is returned. The underlying warnings list from `catch_warnings()` is available via the recorder object's warnings attribute. As a convenience, the attributes of the object representing the most recent warning can also be accessed directly through the recorder object (see example below). If no warning has been raised, then any of the attributes that would otherwise be expected on an object representing a warning will return None.

The recorder object also has a reset() method, which clears the warnings list.

The context manager is designed to be used like this:

```python
with check_warnings(("assertion is always true", "", UserWarning)):
    exec('assert(False, "Hey!")')
    warnings.warn(UserWarning("Hide me!"))
```

In this case if either warning was not raised, or some other warning
was raised, `check_warnings()` would raise an error.

When a test needs to look more deeply into the warnings, rather than just checking whether or not they occurred, code like this can be used:

```
with check_warnings(quiet=True) as w:
    warnings.warn("foo")
    assert str(w.args[0]) == "foo"
    warnings.warn("bar")
    assert str(w.args[0]) == "bar"
    assert str(w.warnings[0].args[0]) == "foo"
    assert str(w.warnings[1].args[0]) == "bar"
    w.reset()
    assert len(w.warnings) == 0
```

Here all warnings will be caught, and the test code tests the captured warnings directly.

*Changed in version 3.2:* New optional arguments `filters` and `quiet`.

test.support.``captured_stdin``
test.support.``captured_stdout``
test.support.``captured_stderr``

A context managers that temporarily replaces the named stream with `io.StringIO` object.

Example use with output streams:

```
with captured_stdout() as stdout, captured_stderr:
    print("hello")
    print("error", file=sys.stderr)
    stdout.getvalue() == "hello\n"
    stderr.getvalue() == "error\n"
```
Example use with input stream:

```python
with captured_stdin() as stdin:
    stdin.write('hello
')
    stdin.seek(0)
    # call test code that consumes from sys.stdin
captured = input()
self.assertEqual(captured, "hello")
```

test.support.temp_dir(path=None, quiet=False)
A context manager that creates a temporary directory at path and yields the directory.

If path is None, the temporary directory is created using `tempfile.mkdtemp()`. If quiet is False, the context manager raises an exception on error. Otherwise, if path is specified and cannot be created, only a warning is issued.

test.support.change_cwd(path, quiet=False)
A context manager that temporarily changes the current working directory to path and yields the directory.

If quiet is False, the context manager raises an exception on error. Otherwise, it issues only a warning and keeps the current working directory the same.

test.support.temp_cwd(name='tempcwd', quiet=False)
A context manager that temporarly creates a new directory and changes the current working directory (CWD).

The context manager creates a temporary directory in the current directory with name name before temporarily changing the current working directory. If name is None, the temporary directory is
created using `tempfile.mkdtemp()`.

If `quiet` is False and it is not possible to create or change the CWD, an error is raised. Otherwise, only a warning is raised and the original CWD is used.

test.support.temp_umask(umask)
A context manager that temporarily sets the process umask.

test.support.can_symlink()
Return True if the OS supports symbolic links, False otherwise.

@test.support.skip_unless_symlink
A decorator for running tests that require support for symbolic links.

@test.support.anticipate_failure(condition)
A decorator to conditionally mark tests with unittest.expectedFailure(). Any use of this decorator should have an associated comment identifying the relevant tracker issue.

@test.support.run_with_locale(catstr, *locales)
A decorator for running a function in a different locale, correctly resetting it after it has finished. `catstr` is the locale category as a string (for example "LC_ALL"). The `locales` passed will be tried sequentially, and the first valid locale will be used.

test.support.make_bad_fd()
Create an invalid file descriptor by opening and closing a temporary file, and returning its descriptor.

test.support.import_module(name, deprecated=False)
This function imports and returns the named module. Unlike a
normal import, this function raises unittest.SkipTest if the module cannot be imported.

Module and package deprecation messages are suppressed during this import if deprecated is True.

New in version 3.1.

test.support.import_fresh_module(name, fresh=(), blocked=(), deprecated=False)

This function imports and returns a fresh copy of the named Python module by removing the named module from sys.modules before doing the import. Note that unlike reload(), the original module is not affected by this operation.

fresh is an iterable of additional module names that are also removed from the sys.modules cache before doing the import.

blocked is an iterable of module names that are replaced with None in the module cache during the import to ensure that attempts to import them raise ImportError.

The named module and any modules named in the fresh and blocked parameters are saved before starting the import and then reinserted into sys.modules when the fresh import is complete.

Module and package deprecation messages are suppressed during this import if deprecated is True.

This function will raise ImportError if the named module cannot be imported.

Example use:
# Get copies of the warnings module for testing without affecting the version being used by the rest of the test suite.
# C implementation, the other is forced to use the pure Python fallback implementation
py_warnings = import_fresh_module('warnings', block_warnings=True)
c_warnings = import_fresh_module('warnings', fresh=True)

New in version 3.1.

test.support.bind_port(sock, host=HOST)

Bind the socket to a free port and return the port number. Relies on ephemeral ports in order to ensure we are using an unbound port. This is important as many tests may be running simultaneously, especially in a buildbot environment. This method raises an exception if the sock.family is AF_INET and sock.type is SOCK_STREAM, and the socket has SO_REUSEADDR or SO_REUSEPORT set on it. Tests should never set these socket options for TCP/IP sockets. The only case for setting these options is testing multicasting via multiple UDP sockets.

Additionally, if the SO_EXCLUSIVEADDRUSE socket option is available (i.e. on Windows), it will be set on the socket. This will prevent anyone else from binding to our host/port for the duration of the test.

test.support.find_unused_port(family=socket.AF_INET, socktype=socket.SOCK_STREAM)

Returns an unused port that should be suitable for binding. This is achieved by creating a temporary socket with the same family and type as the sock parameter (default is AF_INET, SOCK_STREAM), and binding it to the specified host address (defaults to 0.0.0.0) with the port set to 0, eliciting an unused ephemeral port from the
OS. The temporary socket is then closed and deleted, and the ephemeral port is returned.

Either this method or `bind_port()` should be used for any tests where a server socket needs to be bound to a particular port for the duration of the test. Which one to use depends on whether the calling code is creating a python socket, or if an unused port needs to be provided to an constructor or passed to an external program (i.e. the -accept argument to openssl's s_server mode). Always prefer `bind_port()` over `find_unused_port()` where possible. Using a hard coded port is discouraged since it can makes multiple instances of the test impossible to run simultaneously, which is a problem for buildbots.

`test.support.load_package_tests(pkg_dir, loader, standard_tests, pattern)`

Generic implementation of the `unittest` load_tests protocol for use in test packages. `pkg_dir` is the root directory of the package; `loader, standard_tests, and pattern` are the arguments expected by load_tests. In simple cases, the test package's `__init__.py` can be the following:

```python
import os
from test.support import load_package_tests

def load_tests(*args):
    return load_package_tests(os.path.dirname(__file__))
```

detect_api_mismatch(ref_api, other_api, *,
                     ignore=()):

Returns the set of attributes, functions or methods of `ref_api` not found on `other_api`, except for a defined list of items to be ignored
in this check specified in ignore.

By default this skips private attributes beginning with ‘_’ but includes all magic methods, i.e. those starting and ending in ‘__’.

New in version 3.5.

The test.support module defines the following classes:

class test.support.TransientResource(exc, **kwargs)

Instances are a context manager that raises ResourceDenied if the specified exception type is raised. Any keyword arguments are treated as attribute/value pairs to be compared against any exception raised within the with statement. Only if all pairs match properly against attributes on the exception is ResourceDenied raised.

class test.support.EnvironmentVarGuard

Class used to temporarily set or unset environment variables. Instances can be used as a context manager and have a complete dictionary interface for querying/modifying the underlying os.environ. After exit from the context manager all changes to environment variables done through this instance will be rolled back.

    Changed in version 3.1: Added dictionary interface.

EnvironmentVarGuard.set(envvar, value)

Temporarily set the environment variable envvar to the value of value.

EnvironmentVarGuard.unset(envvar)

Temporarily unset the environment variable envvar.
class test.support.SuppressCrashReport

A context manager used to try to prevent crash dialog popups on tests that are expected to crash a subprocess.

On Windows, it disables Windows Error Reporting dialogs using SetErrorMode.

On UNIX, resource.setrlimit() is used to set resource.RLIMIT_CORE's soft limit to 0 to prevent coredump file creation.

On both platforms, the old value is restored by __exit__().

class test.support.WarningsRecorder

Class used to record warnings for unit tests. See documentation of check_warnings() above for more details.
27. Debugging and Profiling

These libraries help you with Python development: the debugger enables you to step through code, analyze stack frames and set breakpoints etc., and the profilers run code and give you a detailed breakdown of execution times, allowing you to identify bottlenecks in your programs.

- 27.1. bdb — Debugger framework
- 27.2. faulthandler — Dump the Python traceback
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27.1. bdb — Debugger framework

Source code: Lib/bdb.py

The bdb module handles basic debugger functions, like setting breakpoints or managing execution via the debugger.

The following exception is defined:

```
exception bdb.BdbQuit

Exception raised by the Bdb class for quitting the debugger.
```

The bdb module also defines two classes:

```
class bdb.Breakpoint(self, file, line, temporary=0, cond=None, funcname=None)

This class implements temporary breakpoints, ignore counts, disabling and (re-)enabling, and conditionals.

Breakpoints are indexed by number through a list called bpbynumber and by (file, line) pairs through bplist. The former points to a single instance of class Breakpoint. The latter points to a list of such instances since there may be more than one breakpoint per line.

When creating a breakpoint, its associated filename should be in canonical form. If a funcname is defined, a breakpoint hit will be counted when the first line of that function is executed. A conditional breakpoint always counts a hit.

Breakpoint instances have the following methods:
deleteMe()
Delete the breakpoint from the list associated to a file/line. If it is the last breakpoint in that position, it also deletes the entry for the file/line.

enable()
Mark the breakpoint as enabled.

disable()
Mark the breakpoint as disabled.

bpformat()
Return a string with all the information about the breakpoint, nicely formatted:

- The breakpoint number.
- If it is temporary or not.
- Its file,line position.
- The condition that causes a break.
- If it must be ignored the next N times.
- The breakpoint hit count.

*New in version 3.2.*

bpprint(out=None)
Print the output of `bpformat()` to the file `out`, or if it is None, to standard output.

class bdb.Bdb(skip=None)
The `Bdb` class acts as a generic Python debugger base class.

This class takes care of the details of the trace facility; a derived class should implement user interaction. The standard debugger class (`pdb.Pdb`) is an example.
The `skip` argument, if given, must be an iterable of glob-style module name patterns. The debugger will not step into frames that originate in a module that matches one of these patterns. Whether a frame is considered to originate in a certain module is determined by the `__name__` in the frame globals.

*New in version 3.1:* The `skip` argument.

The following methods of `Bdb` normally don’t need to be overridden.

**canonic(filename)**

Auxiliary method for getting a filename in a canonical form, that is, as a case-normalized (on case-insensitive filesystems) absolute path, stripped of surrounding angle brackets.

**reset()**

Set the botframe, stopframe, returnframe and quitting attributes with values ready to start debugging.

**trace_dispatch(frame, event, arg)**

This function is installed as the trace function of debugged frames. Its return value is the new trace function (in most cases, that is, itself).

The default implementation decides how to dispatch a frame, depending on the type of event (passed as a string) that is about to be executed. `event` can be one of the following:

- "line": A new line of code is going to be executed.
- "call": A function is about to be called, or another code block entered.
- "return": A function or other code block is about to
return.

- "exception": An exception has occurred.
- "c_call": A C function is about to be called.
- "c_return": A C function has returned.
- "c_exception": A C function has raised an exception.

For the Python events, specialized functions (see below) are called. For the C events, no action is taken.

The arg parameter depends on the previous event.

See the documentation for `sys.settrace()` for more information on the trace function. For more information on code and frame objects, refer to The standard type hierarchy.

**dispatch_line(frame)**

If the debugger should stop on the current line, invoke the `user_line()` method (which should be overridden in subclasses). Raise a `BdbQuit` exception if the Bdb.quitting flag is set (which can be set from `user_line()`). Return a reference to the `trace_dispatch()` method for further tracing in that scope.

**dispatch_call(frame, arg)**

If the debugger should stop on this function call, invoke the `user_call()` method (which should be overridden in subclasses). Raise a `BdbQuit` exception if the Bdb.quitting flag is set (which can be set from `user_call()`). Return a reference to the `trace_dispatch()` method for further tracing in that scope.

**dispatch_return(frame, arg)**

If the debugger should stop on this function return, invoke the
user_return() method (which should be overridden in subclasses). Raise a BdbQuit exception if the Bdb.quitting flag is set (which can be set from user_return()). Return a reference to the trace_dispatch() method for further tracing in that scope.

**dispatch_exception(frame, arg)**

If the debugger should stop at this exception, invokes the user_exception() method (which should be overridden in subclasses). Raise a BdbQuit exception if the Bdb.quitting flag is set (which can be set from user_exception()). Return a reference to the trace_dispatch() method for further tracing in that scope.

Normally derived classes don’t override the following methods, but they may if they want to redefine the definition of stopping and breakpoints.

**stop_here(frame)**

This method checks if the frame is somewhere below botframe in the call stack. botframe is the frame in which debugging started.

**break_here(frame)**

This method checks if there is a breakpoint in the filename and line belonging to frame or, at least, in the current function. If the breakpoint is a temporary one, this method deletes it.

**break_anywhere(frame)**

This method checks if there is a breakpoint in the filename of the current frame.
Derived classes should override these methods to gain control over debugger operation.

**user_call(frame, argument_list)**
This method is called from `dispatch_call()` when there is the possibility that a break might be necessary anywhere inside the called function.

**user_line(frame)**
This method is called from `dispatch_line()` when either `stop_here()` or `break_here()` yields True.

**user_return(frame, return_value)**
This method is called from `dispatch_return()` when `stop_here()` yields True.

**user_exception(frame, exc_info)**
This method is called from `dispatch_exception()` when `stop_here()` yields True.

**do_clear(arg)**
Handle how a breakpoint must be removed when it is a temporary one.

This method must be implemented by derived classes.

Derived classes and clients can call the following methods to affect the stepping state.

**set_step()**
Stop after one line of code.

**set_next(frame)**
Stop on the next line in or below the given frame.

**set_return(frame)**
Stop when returning from the given frame.

**set_until(frame)**
Stop when the line with the line no greater than the current one is reached or when returning from current frame.

**set_trace([frame])**
Start debugging from frame. If frame is not specified, debugging starts from caller's frame.

**set_continue()**
Stop only at breakpoints or when finished. If there are no breakpoints, set the system trace function to None.

**set_quit()**
Set the quitting attribute to True. This raises BdbQuit in the next call to one of the dispatch_*( ) methods.

Derived classes and clients can call the following methods to manipulate breakpoints. These methods return a string containing an error message if something went wrong, or None if all is well.

**set_break(filename, lineno, temporary=0, cond, funcname)**
Set a new breakpoint. If the lineno line doesn’t exist for the filename passed as argument, return an error message. The filename should be in canonical form, as described in the canonic() method.

**clear_break(filename, lineno)**
Delete the breakpoints in *filename* and *lineno*. If none were set, an error message is returned.

**clear_bpbynumber**(arg)
Delete the breakpoint which has the index *arg* in the Breakpoint.bpbynumber. If *arg* is not numeric or out of range, return an error message.

**clear_all_file_breaks**(filename)
Delete all breakpoints in *filename*. If none were set, an error message is returned.

**clear_all_breaks()**
Delete all existing breakpoints.

**get_bpbynumber**(arg)
Return a breakpoint specified by the given number. If *arg* is a string, it will be converted to a number. If *arg* is a non-numeric string, if the given breakpoint never existed or has been deleted, a *ValueError* is raised.

*New in version 3.2.*

**get_break**(filename, lineno)
Check if there is a breakpoint for *lineno* of *filename*.

**get_breaks**(filename, lineno)
Return all breakpoints for *lineno* in *filename*, or an empty list if none are set.

**get_file_breaks**(filename)
Return all breakpoints in *filename*, or an empty list if none are set.
**get_all_breaks()**

Return all breakpoints that are set.

Derived classes and clients can call the following methods to get a data structure representing a stack trace.

**get_stack**(*f, t*)

Get a list of records for a frame and all higher (calling) and lower frames, and the size of the higher part.

**format_stack_entry**(*frame_lineno, lprefix=':')*

Return a string with information about a stack entry, identified by a (frame, lineno) tuple:

- The canonical form of the filename which contains the frame.
- The function name, or "<lambda>".
- The input arguments.
- The return value.
- The line of code (if it exists).

The following two methods can be called by clients to use a debugger to debug a **statement**, given as a string.

**run**(*cmd, globals=None, locals=None*)

Debug a statement executed via the **exec()** function. **globals** defaults to __main__.__dict__, **locals** defaults to **globals**.

**runeval**(*expr, globals=None, locals=None*)

Debug an expression executed via the **eval()** function. **globals** and **locals** have the same meaning as in **run()**.

**runctx**(*cmd, globals, locals*)
For backwards compatibility. Calls the `run()` method.

**runcall**(*func, *args, **kwds*)

Debug a single function call, and return its result.

Finally, the module defines the following functions:

**bdb.checkfuncname**(*b, frame*)

Check whether we should break here, depending on the way the breakpoint *b* was set.

If it was set via line number, it checks if *b.line* is the same as the one in the frame also passed as argument. If the breakpoint was set via function name, we have to check we are in the right frame (the right function) and if we are in its first executable line.

**bdb.effective**(*file, line, frame*)

Determine if there is an effective (active) breakpoint at this line of code. Return a tuple of the breakpoint and a boolean that indicates if it is ok to delete a temporary breakpoint. Return (*None, None*) if there is no matching breakpoint.

**bdb.set_trace()**

Start debugging with a Bdb instance from caller’s frame.
27. Debugging and Profiling
27.2. `faulthandler` — Dump the Python traceback

*New in version 3.3.*

This module contains functions to dump Python tracebacks explicitly, on a fault, after a timeout, or on a user signal. Call `faulthandler.enable()` to install fault handlers for the SIGSEGV, SIGFPE, SIGABRT, SIGBUS, and SIGILL signals. You can also enable them at startup by setting the `PYTHONFAULTHANDLER` environment variable or by using the `-X` `faulthandler` command line option.

The fault handler is compatible with system fault handlers like Apport or the Windows fault handler. The module uses an alternative stack for signal handlers if the `sigaltstack()` function is available. This allows it to dump the traceback even on a stack overflow.

The fault handler is called on catastrophic cases and therefore can only use signal-safe functions (e.g. it cannot allocate memory on the heap). Because of this limitation traceback dumping is minimal compared to normal Python tracebacks:

- Only ASCII is supported. The `backslashreplace` error handler is used on encoding.
- Each string is limited to 500 characters.
- Only the filename, the function name and the line number are displayed. (no source code)
- It is limited to 100 frames and 100 threads.
- The order is reversed: the most recent call is shown first.
By default, the Python traceback is written to `sys.stderr`. To see
tracebacks, applications must be run in the terminal. A log file can
alternatively be passed to `faulthandler.enable()`.

The module is implemented in C, so tracebacks can be dumped on a
crash or when Python is deadlocked.
27.2.1. Dumping the traceback

```
faulthandler.dump_traceback(file=sys.stderr, all_threads=True)
```

Dump the tracebacks of all threads into file. If `all_threads` is False, dump only the current thread.

*Changed in version 3.5:* Added support for passing file descriptor to this function.
27.2.2. Fault handler state

faulthandler.enable(file=sys.stderr, all_threads=True)

Enable the fault handler: install handlers for the SIGSEGV, SIGFPE, SIGABRT, SIGBUS and SIGILL signals to dump the Python traceback. If all_threads is True, produce tracebacks for every running thread. Otherwise, dump only the current thread.

The file must be kept open until the fault handler is disabled: see issue with file descriptors.

Changed in version 3.5: Added support for passing file descriptor to this function.

faulthandler.disable()

Disable the fault handler: uninstall the signal handlers installed by enable().

faulthandler.is_enabled()

Check if the fault handler is enabled.
27.2.3. Dumping the tracebacks after a timeout

```python
faulthandler.dump_traceback_later(timeout, repeat=False, file=sys.stderr, exit=False)
```

Dump the tracebacks of all threads, after a timeout of `timeout` seconds, or every `timeout` seconds if `repeat` is True. If `exit` is True, call `__exit__()` with status=1 after dumping the tracebacks. (Note `__exit__()` exits the process immediately, which means it doesn’t do any cleanup like flushing file buffers.) If the function is called twice, the new call replaces previous parameters and resets the timeout. The timer has a sub-second resolution.

The `file` must be kept open until the traceback is dumped or `cancel_dump_traceback_later()` is called: see issue with file descriptors.

This function is implemented using a watchdog thread and therefore is not available if Python is compiled with threads disabled.

*Changed in version 3.5*: Added support for passing file descriptor to this function.

```python
faulthandler.cancel_dump_traceback_later()
```

Cancel the last call to `dump_traceback_later()`.
27.2.4. Dumping the traceback on a user signal

`faulthandler.register(signum, file=sys.stderr, all_threads=True, chain=False)`

Register a user signal: install a handler for the `signum` signal to dump the traceback of all threads, or of the current thread if `all_threads` is False, into `file`. Call the previous handler if `chain` is True.

The `file` must be kept open until the signal is unregistered by `unregister()`: see issue with file descriptors.

Not available on Windows.

*Changed in version 3.5:* Added support for passing file descriptor to this function.

`faulthandler.unregister(signum)`

Unregister a user signal: uninstall the handler of the `signum` signal installed by `register()`. Return True if the signal was registered, False otherwise.

Not available on Windows.
27.2.5. Issue with file descriptors

`enable()`, `dump_traceback_later()` and `register()` keep the file descriptor of their `file` argument. If the file is closed and its file descriptor is reused by a new file, or if `os.dup2()` is used to replace the file descriptor, the traceback will be written into a different file. Call these functions again each time that the file is replaced.
27.2.6. Example

Example of a segmentation fault on Linux with and without enabling the fault handler:

```
$ python3 -c "import ctypes; ctypes.string_at(0)"
Segmentation fault

$ python3 -q -X faulthandler
>>> import ctypes
>>> ctypes.string_at(0)
Fatal Python error: Segmentation fault
```

Current thread 0x00007fb899f39700 (most recent call first)
  File "'/home/python/cpython/Lib/ctypes/__init__.py"
  File "<stdin>", line 1 in <module>
Segmentation fault
27.3. pdb — The Python Debugger

Source code: Lib/pdb.py

The module pdb defines an interactive source code debugger for Python programs. It supports setting (conditional) breakpoints and single stepping at the source line level, inspection of stack frames, source code listing, and evaluation of arbitrary Python code in the context of any stack frame. It also supports post-mortem debugging and can be called under program control.

The debugger is extensible – it is actually defined as the class Pdb. This is currently undocumented but easily understood by reading the source. The extension interface uses the modules bdb and cmd.

The debugger’s prompt is (Pdb). Typical usage to run a program under control of the debugger is:

```python
>>> import pdb
>>> import mymodule
>>> pdb.run('mymodule.test()')
> <string>(0)?()
(Pdb) continue
> <string>(1)?()
(Pdb) continue
NameError: 'spam'
> <string>(1)?()
(Pdb)
```

*Changed in version 3.3:* Tab-completion via the readline module is available for commands and command arguments, e.g. the current
global and local names are offered as arguments of the p command.

pdb.py can also be invoked as a script to debug other scripts. For example:

```
python3 -m pdb myscript.py
```

When invoked as a script, pdb will automatically enter post-mortem debugging if the program being debugged exits abnormally. After post-mortem debugging (or after normal exit of the program), pdb will restart the program. Automatic restarting preserves pdb’s state (such as breakpoints) and in most cases is more useful than quitting the debugger upon program’s exit.

*New in version 3.2:* pdb.py now accepts a -c option that executes commands as if given in a .pdbrc file, see Debugger Commands.

The typical usage to break into the debugger from a running program is to insert

```
import pdb; pdb.set_trace()
```

at the location you want to break into the debugger. You can then step through the code following this statement, and continue running without the debugger using the continue command.

The typical usage to inspect a crashed program is:

```
>>> import pdb
>>> import mymodule
>>> mymodule.test()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "./mymodule.py", line 4, in test
```
The module defines the following functions; each enters the debugger in a slightly different way:

```python
import pdb

def test2()
    print(spam)
NameError: name 'spam'
```

```
>>> pdb.pm()
> ./mymodule.py(3)test2()
-> print(spam)
(Pdb)
```

**pdb.run**(*statement*, *globals=None*, *locals=None*)

Execute the *statement* (given as a string or a code object) under debugger control. The debugger prompt appears before any code is executed; you can set breakpoints and type `continue`, or you can step through the statement using `step` or `next` (all these commands are explained below). The optional *globals* and *locals* arguments specify the environment in which the code is executed; by default the dictionary of the module `__main__` is used. (See the explanation of the built-in `exec()` or `eval()` functions.)

**pdb.runeval**(*expression*, *globals=None*, *locals=None*)

Evaluate the *expression* (given as a string or a code object) under debugger control. When `runeval()` returns, it returns the value of the expression. Otherwise this function is similar to `run()`

**pdb.runcall**(*function*, *args*, **kwds*)

Call the *function* (a function or method object, not a string) with the given arguments. When `runcall()` returns, it returns whatever the function call returned. The debugger prompt appears as soon as the function is entered.
pdb.set_trace()
    Enter the debugger at the calling stack frame. This is useful to
    hard-code a breakpoint at a given point in a program, even if the
    code is not otherwise being debugged (e.g. when an assertion
    fails).

dbd.post_mortem(traceback=None)
    Enter post-mortem debugging of the given traceback object. If no
    traceback is given, it uses the one of the exception that is currently
    being handled (an exception must be being handled if the default is
    to be used).

dbd.pm()
    Enter post-mortem debugging of the traceback found in
    sys.last_traceback.

The run* functions and set_trace() are aliases for instantiating
the Pdb class and calling the method of the same name. If you want to
access further features, you have to do this yourself:

class pdb.Pdb(completekey='tab', stdin=None, stdout=None,
              skip=None, nosigint=False)
    Pdb is the debugger class.

    The completekey, stdin and stdout arguments are passed to the
underlying cmd.Cmd class; see the description there.

    The skip argument, if given, must be an iterable of glob-style
module name patterns. The debugger will not step into frames that
originate in a module that matches one of these patterns. [1]

    By default, Pdb sets a handler for the SIGINT signal (which is sent
when the user presses Ctrl-C on the console) when you give a
continue command. This allows you to break into the debugger again by pressing Ctrl-C. If you want Pdb not to touch the SIGINT handler, set nosigint tot true.

Example call to enable tracing with skip:

```python
import pdb; pdb.Pdb(skip=['django.*']).set_trace()
```

*New in version 3.1:* The skip argument.

*New in version 3.2:* The nosigint argument. Previously, a SIGINT handler was never set by Pdb.

```python
run(statement, globals=None, locals=None)
runeval(expression, globals=None, locals=None)
runcall(function, *args, **kwds)
set_trace()
```

See the documentation for the functions explained above.
27.3.1. Debugger Commands

The commands recognized by the debugger are listed below. Most commands can be abbreviated to one or two letters as indicated; e.g. h(e1p) means that either h or help can be used to enter the help command (but not he or hel, nor H or Help or HELP). Arguments to commands must be separated by whitespace (spaces or tabs). Optional arguments are enclosed in square brackets ([ ]) in the command syntax; the square brackets must not be typed. Alternatives in the command syntax are separated by a vertical bar (|).

Entering a blank line repeats the last command entered. Exception: if the last command was a list command, the next 11 lines are listed.

Commands that the debugger doesn’t recognize are assumed to be Python statements and are executed in the context of the program being debugged. Python statements can also be prefixed with an exclamation point (!). This is a powerful way to inspect the program being debugged; it is even possible to change a variable or call a function. When an exception occurs in such a statement, the exception name is printed but the debugger’s state is not changed.

The debugger supports aliases. Aliases can have parameters which allows one a certain level of adaptability to the context under examination.

Multiple commands may be entered on a single line, separated by ;;. (A single ; is not used as it is the separator for multiple commands in a line that is passed to the Python parser.) No intelligence is applied to separating the commands; the input is split at the first ;; pair, even if it is in the middle of a quoted string.
If a file .pdbrc exists in the user’s home directory or in the current directory, it is read in and executed as if it had been typed at the debugger prompt. This is particularly useful for aliases. If both files exist, the one in the home directory is read first and aliases defined there can be overridden by the local file.

*Changed in version 3.2:* .pdbrc can now contain commands that continue debugging, such as `continue` or `next`. Previously, these commands had no effect.

**h(elp) [command]**
Without argument, print the list of available commands. With a `command` as argument, print help about that command. `help pdb` displays the full documentation (the docstring of the `pdb` module). Since the `command` argument must be an identifier, `help exec` must be entered to get help on the `!` command.

**w(here)**
Print a stack trace, with the most recent frame at the bottom. An arrow indicates the current frame, which determines the context of most commands.

**d(own) [count]**
Move the current frame `count` (default one) levels down in the stack trace (to a newer frame).

**u(p) [count]**
Move the current frame `count` (default one) levels up in the stack trace (to an older frame).

**b(reak) [([filename:]lineno | function) [, condition]]**
With a `lineno` argument, set a break there in the current file. With a
function argument, set a break at the first executable statement within that function. The line number may be prefixed with a filename and a colon, to specify a breakpoint in another file (probably one that hasn’t been loaded yet). The file is searched on sys.path. Note that each breakpoint is assigned a number to which all the other breakpoint commands refer.

If a second argument is present, it is an expression which must evaluate to true before the breakpoint is honored.

Without argument, list all breaks, including for each breakpoint, the number of times that breakpoint has been hit, the current ignore count, and the associated condition if any.

tbreak [[filename:]lineno | function] [, condition]
Temporary breakpoint, which is removed automatically when it is first hit. The arguments are the same as for break.

clear [filename:lineno | bpnumber [bpnumber ...]]
With a filename:lineno argument, clear all the breakpoints at this line. With a space separated list of breakpoint numbers, clear those breakpoints. Without argument, clear all breaks (but first ask confirmation).

disable [bpnumber [bpnumber ...]]
Disable the breakpoints given as a space separated list of breakpoint numbers. Disabling a breakpoint means it cannot cause the program to stop execution, but unlike clearing a breakpoint, it remains in the list of breakpoints and can be (re-)enabled.

enable [bpnumber [bpnumber ...]]
Enable the breakpoints specified.
**ignore bpnumber [count]**
Set the ignore count for the given breakpoint number. If count is omitted, the ignore count is set to 0. A breakpoint becomes active when the ignore count is zero. When non-zero, the count is decremented each time the breakpoint is reached and the breakpoint is not disabled and any associated condition evaluates to true.

**condition bpnumber [condition]**
Set a new condition for the breakpoint, an expression which must evaluate to true before the breakpoint is honored. If condition is absent, any existing condition is removed; i.e., the breakpoint is made unconditional.

**commands [bpnumber]**
Specify a list of commands for breakpoint number bpnumber. The commands themselves appear on the following lines. Type a line containing just end to terminate the commands. An example:

```
(Pdb) commands 1
(com) p some_variable
(com) end
(Pdb)
```

To remove all commands from a breakpoint, type commands and follow it immediately with end; that is, give no commands.

With no bpnumber argument, commands refers to the last breakpoint set.

You can use breakpoint commands to start your program up again. Simply use the continue command, or step, or any other command that resumes execution.
Specifying any command resuming execution (currently continue, step, next, return, jump, quit and their abbreviations) terminates the command list (as if that command was immediately followed by end). This is because any time you resume execution (even with a simple next or step), you may encounter another breakpoint—which could have its own command list, leading to ambiguities about which list to execute.

If you use the ‘silent’ command in the command list, the usual message about stopping at a breakpoint is not printed. This may be desirable for breakpoints that are to print a specific message and then continue. If none of the other commands print anything, you see no sign that the breakpoint was reached.

**s(step)**

Execute the current line, stop at the first possible occasion (either in a function that is called or on the next line in the current function).

**n(ext)**

Continue execution until the next line in the current function is reached or it returns. (The difference between next and step is that step stops inside a called function, while next executes called functions at (nearly) full speed, only stopping at the next line in the current function.)

**unt(ill) [lineno]**

Without argument, continue execution until the line with a number greater than the current one is reached.

With a line number, continue execution until a line with a number greater or equal to that is reached. In both cases, also stop when the current frame returns.
Changed in version 3.2: Allow giving an explicit line number.

r(eturn)
Continue execution until the current function returns.

c(ont(inue))
Continue execution, only stop when a breakpoint is encountered.

j(ump) lineno
Set the next line that will be executed. Only available in the bottom-most frame. This lets you jump back and execute code again, or jump forward to skip code that you don’t want to run.

It should be noted that not all jumps are allowed – for instance it is not possible to jump into the middle of a for loop or out of a finally clause.

l(ist) [first[, last]]
List source code for the current file. Without arguments, list 11 lines around the current line or continue the previous listing. With . as argument, list 11 lines around the current line. With one argument, list 11 lines around at that line. With two arguments, list the given range; if the second argument is less than the first, it is interpreted as a count.

The current line in the current frame is indicated by ->. If an exception is being debugged, the line where the exception was originally raised or propagated is indicated by >>, if it differs from the current line.

New in version 3.2: The >> marker.

l1 l | longlist
List all source code for the current function or frame. Interesting lines are marked as for `list`.

*New in version 3.2.*

**a(rgs)**
Print the argument list of the current function.

**p** expression
Evaluate the `expression` in the current context and print its value.

**Note:** `print()` can also be used, but is not a debugger command — this executes the Python `print()` function.

**pp** expression
Like the `p` command, except the value of the expression is pretty-printed using the `pprint` module.

**whatis** expression
Print the type of the `expression`.

**source** expression
Try to get source code for the given object and display it.

*New in version 3.2.*

**display** `[expression]`
Display the value of the expression if it changed, each time execution stops in the current frame.

Without expression, list all display expressions for the current frame.
New in version 3.2.

**undisplay** [expression]
Do not display the expression any more in the current frame. Without expression, clear all display expressions for the current frame.

New in version 3.2.

**interact**
Start an interative interpreter (using the code module) whose global namespace contains all the (global and local) names found in the current scope.

New in version 3.2.

**alias** [name [command]]
Create an alias called *name* that executes *command*. The command must *not* be enclosed in quotes. Replaceable parameters can be indicated by %1, %2, and so on, while %* is replaced by all the parameters. If no command is given, the current alias for *name* is shown. If no arguments are given, all aliases are listed.

Aliases may be nested and can contain anything that can be legally typed at the pdb prompt. Note that internal pdb commands *can* be overridden by aliases. Such a command is then hidden until the alias is removed. Aliasing is recursively applied to the first word of the command line; all other words in the line are left alone.

As an example, here are two useful aliases (especially when placed in the .pdbrc file):
unalias name
  Delete the specified alias.

! statement
  Execute the (one-line) statement in the context of the current stack frame. The exclamation point can be omitted unless the first word of the statement resembles a debugger command. To set a global variable, you can prefix the assignment command with a global statement on the same line, e.g.:

  (Pdb) global list_options; list_options = ['-l']
  (Pdb)

run [args ...]
restart [args ...]
  Restart the debugged Python program. If an argument is supplied, it is split with shlex and the result is used as the new sys.argv. History, breakpoints, actions and debugger options are preserved. restart is an alias for run.

q(uit)
  Quit from the debugger. The program being executed is aborted.

Footnotes

[1] Whether a frame is considered to originate in a certain module is determined by the __name__ in the frame globals.
27.4. The Python Profilers

Source code: Lib/profile.py and Lib/pstats.py
27.4.1. Introduction to the profilers

cProfile and profile provide deterministic profiling of Python programs. A profile is a set of statistics that describes how often and for how long various parts of the program executed. These statistics can be formatted into reports via the pstats module.

The Python standard library provides two different implementations of the same profiling interface:

1. cProfile is recommended for most users; it's a C extension with reasonable overhead that makes it suitable for profiling long-running programs. Based on lsprof, contributed by Brett Rosen and Ted Czotter.
2. profile, a pure Python module whose interface is imitated by cProfile, but which adds significant overhead to profiled programs. If you're trying to extend the profiler in some way, the task might be easier with this module. Originally designed and written by Jim Roskind.

**Note:** The profiler modules are designed to provide an execution profile for a given program, not for benchmarking purposes (for that, there is timeit for reasonably accurate results). This particularly applies to benchmarking Python code against C code: the profilers introduce overhead for Python code, but not for C-level functions, and so the C code would seem faster than any Python one.
27.4.2. Instant User’s Manual

This section is provided for users that “don’t want to read the manual.” It provides a very brief overview, and allows a user to rapidly perform profiling on an existing application.

To profile a function that takes a single argument, you can do:

```python
import cProfile
import re

CProfile.run('re.compile("foo|bar")')
```

(Use `profile` instead of `cProfile` if the latter is not available on your system.)

The above action would run `re.compile()` and print profile results like the following:

```
197 function calls (192 primitive calls) in 0.
Ordered by: standard name
ncalls tottime percall cumtime percall filename:lineno
 1    0.000    0.000    0.001    0.001 <string>:1
 1    0.000    0.000    0.001    0.001 re.py:212
 1    0.000    0.000    0.001    0.001 re.py:268
 1    0.000    0.000    0.000    0.000 sre_compile:1
 1    0.000    0.000    0.000    0.000 sre_compile:1
 4    0.000    0.000    0.000    0.000 sre_compile:1
 3/1 0.000    0.000    0.000    0.000 sre_compile:1

```

The first line indicates that 197 calls were monitored. Of those calls, 192 were `primitive`, meaning that the call was not induced via
recursion. The next line: Ordered by: standard name, indicates that the text string in the far right column was used to sort the output. The column headings include:

ncalls
  for the number of calls,
tottime
  for the total time spent in the given function (and excluding time made in calls to sub-functions)
percall
  is the quotient of tottime divided by ncalls
cumtime
  is the cumulative time spent in this and all subfunctions (from invocation till exit). This figure is accurate even for recursive functions.
percall
  is the quotient of cumtime divided by primitive calls
filename:lineno(function)
  provides the respective data of each function

When there are two numbers in the first column (for example 3/1), it means that the function recursed. The second value is the number of primitive calls and the former is the total number of calls. Note that when the function does not recurse, these two values are the same, and only the single figure is printed.

Instead of printing the output at the end of the profile run, you can save the results to a file by specifying a filename to the run() function:

```python
import cProfile
import re
```
cProfile.run('re.compile("foo|bar"), 'restats')

The `pstats.Stats` class reads profile results from a file and formats them in various ways.

The file `cProfile` can also be invoked as a script to profile another script. For example:

```
python -m cProfile [-o output_file] [-s sort_order]
```

- `-o` writes the profile results to a file instead of to stdout
- `-s` specifies one of the `sort_stats()` sort values to sort the output by. This only applies when `-o` is not supplied.

The `pstats` module's `Stats` class has a variety of methods for manipulating and printing the data saved into a profile results file:

```
import pstats
p = pstats.Stats('restats')
p.strip_dirs().sort_stats(-1).print_stats()
```

The `strip_dirs()` method removed the extraneous path from all the module names. The `sort_stats()` method sorted all the entries according to the standard module/line/name string that is printed. The `print_stats()` method printed out all the statistics. You might try the following sort calls:

```
p.sort_stats('name')
p.print_stats()
```

The first call will actually sort the list by function name, and the second call will print out the statistics. The following are some interesting calls
to experiment with:

```
p.sort_stats('cumulative').print_stats(10)
```

This sorts the profile by cumulative time in a function, and then only prints the ten most significant lines. If you want to understand what algorithms are taking time, the above line is what you would use.

If you were looking to see what functions were looping a lot, and taking a lot of time, you would do:

```
p.sort_stats('time').print_stats(10)
```

to sort according to time spent within each function, and then print the statistics for the top ten functions.

You might also try:

```
p.sort_stats('file').print_stats('__init__')
```

This will sort all the statistics by file name, and then print out statistics for only the class init methods (since they are spelled with `__init__` in them). As one final example, you could try:

```
p.sort_stats('time', 'cumulative').print_stats(.5, 'init')
```

This line sorts statistics with a primary key of time, and a secondary key of cumulative time, and then prints out some of the statistics. To be specific, the list is first culled down to 50% (re: .5) of its original size, then only lines containing `init` are maintained, and that sub-sub-list is printed.

If you wondered what functions called the above functions, you could
now (p is still sorted according to the last criteria) do:

```
p.print_callers(.5, 'init')
```

and you would get a list of callers for each of the listed functions.

If you want more functionality, you’re going to have to read the manual, or guess what the following functions do:

```
p.print_callees()
p.add('restats')
```

Invoked as a script, the pstats module is a statistics browser for reading and examining profile dumps. It has a simple line-oriented interface (implemented using cmd) and interactive help.
27.4.3. **profile** and **cProfile** Module Reference

Both the **profile** and **cProfile** modules provide the following functions:

**profile.run**(command, filename=None, sort=-1)

This function takes a single argument that can be passed to the `exec()` function, and an optional file name. In all cases this routine executes:

```
exec(command, __main__.__dict__, __main__.__dict__)
```

and gathers profiling statistics from the execution. If no file name is present, then this function automatically creates a `Stats` instance and prints a simple profiling report. If the sort value is specified it is passed to this `Stats` instance to control how the results are sorted.

**profile.runctx**(command, globals, locals, filename=None)

This function is similar to `run()`, with added arguments to supply the globals and locals dictionaries for the `command` string. This routine executes:

```
exec(command, globals, locals)
```

and gathers profiling statistics as in the `run()` function above.

**class profile.Profile**(timer=None, timeunit=0.0, subcalls=True, builtins=True)
This class is normally only used if more precise control over profiling is needed than what the \texttt{cProfile.run()} function provides.

A custom timer can be supplied for measuring how long code takes to run via the \texttt{timer} argument. This must be a function that returns a single number representing the current time. If the number is an integer, the \texttt{timeunit} specifies a multiplier that specifies the duration of each unit of time. For example, if the timer returns times measured in thousands of seconds, the time unit would be \texttt{.001}.

Directly using the \texttt{Profile} class allows formatting profile results without writing the profile data to a file:

```python
import cProfile, pstats, io
pr = cProfile.Profile()
pr.enable()
# ... do something ...
pr.disable()
s = io.StringIO()
sortby = 'cumulative'
ps = pstats.Stats(pr, stream=s).sort_stats(sortby
ps.print_stats()
print(s.getvalue())
```

\textbf{enable()}

Start collecting profiling data.

\textbf{disable()}

Stop collecting profiling data.

\textbf{create_stats()}

Stop collecting profiling data and record the results internally as
the current profile.

**print_stats**(sort=-1)
Create a *Stats* object based on the current profile and print the results to stdout.

**dump_stats**(filename)
Write the results of the current profile to *filename*.

**run**(cmd)
Profile the cmd via *exec()*.

**runcxtx**(cmd, globals, locals)
Profile the cmd via *exec()* with the specified global and local environment.

**runcall**(func, *args, **kwargs)
Profile *func*(*args, **kwargs*)
27.4.4. The Stats Class

Analysis of the profiler data is done using the Stats class.

```python
class pstats.Stats(*filenames or profile, stream=sys.stdout)
```

This class constructor creates an instance of a “statistics object” from a filename (or list of filenames) or from a Profile instance. Output will be printed to the stream specified by stream.

The file selected by the above constructor must have been created by the corresponding version of profile or cProfile. To be specific, there is no file compatibility guaranteed with future versions of this profiler, and there is no compatibility with files produced by other profilers. If several files are provided, all the statistics for identical functions will be coalesced, so that an overall view of several processes can be considered in a single report. If additional files need to be combined with data in an existing Stats object, the add() method can be used.

Instead of reading the profile data from a file, a cProfile.Profile or profile.Profile object can be used as the profile data source.

Stats objects have the following methods:

**strip_dirs()**

This method for the Stats class removes all leading path information from file names. It is very useful in reducing the size of the printout to fit within (close to) 80 columns. This method modifies the object, and the stripped information is lost. After performing a strip operation, the object is considered to have its
entries in a “random” order, as it was just after object initialization and loading. If \texttt{strip_dirs()} causes two function names to be indistinguishable (they are on the same line of the same filename, and have the same function name), then the statistics for these two entries are accumulated into a single entry.

\textbf{add(\texttt{*filenames})}

This method of the \texttt{Stats} class accumulates additional profiling information into the current profiling object. Its arguments should refer to filenames created by the corresponding version of \texttt{profile.run()} or \texttt{cProfile.run()}. Statistics for identically named (re: file, line, name) functions are automatically accumulated into single function statistics.

\textbf{dump_stats(\texttt{filename})}

Save the data loaded into the \texttt{Stats} object to a file named \texttt{filename}. The file is created if it does not exist, and is overwritten if it already exists. This is equivalent to the method of the same name on the \texttt{profile.Profile} and \texttt{cProfile.Profile} classes.

\textbf{sort_stats(\texttt{*keys})}

This method modifies the \texttt{Stats} object by sorting it according to the supplied criteria. The argument is typically a string identifying the basis of a sort (example: 'time' or 'name').

When more than one key is provided, then additional keys are used as secondary criteria when there is equality in all keys selected before them. For example, \texttt{sort_stats('name', 'file')} will sort all the entries according to their function
name, and resolve all ties (identical function names) by sorting by file name.

Abbreviations can be used for any key names, as long as the abbreviation is unambiguous. The following are the keys currently defined:

<table>
<thead>
<tr>
<th>Valid Arg</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>'calls'</td>
<td>call count</td>
</tr>
<tr>
<td>'cumulative'</td>
<td>cumulative time</td>
</tr>
<tr>
<td>'cumtime'</td>
<td>cumulative time</td>
</tr>
<tr>
<td>'file'</td>
<td>file name</td>
</tr>
<tr>
<td>'filename'</td>
<td>file name</td>
</tr>
<tr>
<td>'module'</td>
<td>file name</td>
</tr>
<tr>
<td>'ncalls'</td>
<td>call count</td>
</tr>
<tr>
<td>'pcalls'</td>
<td>primitive call count</td>
</tr>
<tr>
<td>'line'</td>
<td>line number</td>
</tr>
<tr>
<td>'name'</td>
<td>function name</td>
</tr>
<tr>
<td>'nfl'</td>
<td>name/file/line</td>
</tr>
<tr>
<td>'stdname'</td>
<td>standard name</td>
</tr>
<tr>
<td>'time'</td>
<td>internal time</td>
</tr>
<tr>
<td>'tottime'</td>
<td>internal time</td>
</tr>
</tbody>
</table>

Note that all sorts on statistics are in descending order (placing most time consuming items first), where as name, file, and line number searches are in ascending order (alphabetical). The subtle distinction between 'nfl' and 'stdname' is that the standard name is a sort of the name as printed, which means
that the embedded line numbers get compared in an odd way. For example, lines 3, 20, and 40 would (if the file names were the same) appear in the string order 20, 3 and 40. In contrast, 'nfl' does a numeric compare of the line numbers. In fact, sort_stats('nfl') is the same as sort_stats('name', 'file', 'line').

For backward-compatibility reasons, the numeric arguments -1, 0, 1, and 2 are permitted. They are interpreted as 'stdname', 'calls', 'time', and 'cumulative' respectively. If this old style format (numeric) is used, only one sort key (the numeric key) will be used, and additional arguments will be silently ignored.

**reverse_order()**

This method for the Stats class reverses the ordering of the basic list within the object. Note that by default ascending vs descending order is properly selected based on the sort key of choice.

**print_stats(*restrictions)**

This method for the Stats class prints out a report as described in the profile.run() definition.

The order of the printing is based on the last sort_stats() operation done on the object (subject to caveats in add() and strip_dirs()).

The arguments provided (if any) can be used to limit the list down to the significant entries. Initially, the list is taken to be the complete set of profiled functions. Each restriction is either an integer (to select a count of lines), or a decimal fraction
between 0.0 and 1.0 inclusive (to select a percentage of lines),
or a regular expression (to pattern match the standard name
that is printed. If several restrictions are provided, then they are
applied sequentially. For example:

```
print_stats(.1, 'foo:')
```

would first limit the printing to first 10% of list, and then only
print functions that were part of filename .*foo:. In contrast,
the command:

```
print_stats('foo:', .1)
```

would limit the list to all functions having file names .*foo:,
and then proceed to only print the first 10% of them.

**print_callers(*restrictions)**

This method for the Stats class prints a list of all functions that
called each function in the profiled database. The ordering is
identical to that provided by print_stats(), and the
definition of the restricting argument is also identical. Each
caller is reported on its own line. The format differs slightly
depending on the profiler that produced the stats:

- With profile, a number is shown in parentheses after
each caller to show how many times this specific call was
made. For convenience, a second non-parenthesized
number repeats the cumulative time spent in the function at
the right.
- With cProfile, each caller is preceded by three numbers:
the number of times this specific call was made, and the
total and cumulative times spent in the current function
while it was invoked by this specific caller.
print_callees(*restrictions)

This method for the Stats class prints a list of all function that were called by the indicated function. Aside from this reversal of direction of calls (re: called vs was called by), the arguments and ordering are identical to the print_callers() method.
27.4.5. What Is Deterministic Profiling?

Deterministic profiling is meant to reflect the fact that all function call, function return, and exception events are monitored, and precise timings are made for the intervals between these events (during which time the user’s code is executing). In contrast, statistical profiling (which is not done by this module) randomly samples the effective instruction pointer, and deduces where time is being spent. The latter technique traditionally involves less overhead (as the code does not need to be instrumented), but provides only relative indications of where time is being spent.

In Python, since there is an interpreter active during execution, the presence of instrumented code is not required to do deterministic profiling. Python automatically provides a hook (optional callback) for each event. In addition, the interpreted nature of Python tends to add so much overhead to execution, that deterministic profiling tends to only add small processing overhead in typical applications. The result is that deterministic profiling is not that expensive, yet provides extensive run time statistics about the execution of a Python program.

Call count statistics can be used to identify bugs in code (surprising counts), and to identify possible inline-expansion points (high call counts). Internal time statistics can be used to identify “hot loops” that should be carefully optimized. Cumulative time statistics should be used to identify high level errors in the selection of algorithms. Note that the unusual handling of cumulative times in this profiler allows statistics for recursive implementations of algorithms to be directly compared to iterative implementations.
27.4.6. Limitations

One limitation has to do with accuracy of timing information. There is a fundamental problem with deterministic profilers involving accuracy. The most obvious restriction is that the underlying “clock” is only ticking at a rate (typically) of about .001 seconds. Hence no measurements will be more accurate than the underlying clock. If enough measurements are taken, then the “error” will tend to average out. Unfortunately, removing this first error induces a second source of error.

The second problem is that it “takes a while” from when an event is dispatched until the profiler’s call to get the time actually gets the state of the clock. Similarly, there is a certain lag when exiting the profiler event handler from the time that the clock’s value was obtained (and then squirreled away), until the user’s code is once again executing. As a result, functions that are called many times, or call many functions, will typically accumulate this error. The error that accumulates in this fashion is typically less than the accuracy of the clock (less than one clock tick), but it can accumulate and become very significant.

The problem is more important with profile than with the lower-overhead cProfile. For this reason, profile provides a means of calibrating itself for a given platform so that this error can be probabilistically (on the average) removed. After the profiler is calibrated, it will be more accurate (in a least square sense), but it will sometimes produce negative numbers (when call counts are exceptionally low, and the gods of probability work against you :-). ) Do not be alarmed by negative numbers in the profile. They should only appear if you have calibrated your profiler, and the results are actually
better than without calibration.
27.4.7. Calibration

The profiler of the `profile` module subtracts a constant from each event handling time to compensate for the overhead of calling the time function, and socking away the results. By default, the constant is 0. The following procedure can be used to obtain a better constant for a given platform (see Limitations).

```python
import profile
pr = profile.Profile()
for i in range(5):
    print(pr.calibrate(10000))
```

The method executes the number of Python calls given by the argument, directly and again under the profiler, measuring the time for both. It then computes the hidden overhead per profiler event, and returns that as a float. For example, on a 1.8Ghz Intel Core i5 running Mac OS X, and using Python’s time.clock() as the timer, the magical number is about 4.04e-6.

The object of this exercise is to get a fairly consistent result. If your computer is very fast, or your timer function has poor resolution, you might have to pass 100000, or even 1000000, to get consistent results.

When you have a consistent answer, there are three ways you can use it:

```python
import profile

# 1. Apply computed bias to all Profile instances created thereafter.
profile.Profile.bias = your_computed_bias
```
# 2. Apply computed bias to a specific Profile instance.

```python
pr = profile.Profile()
pr.bias = your_computed_bias
```

# 3. Specify computed bias in instance constructor.

```python
pr = profile.Profile(bias=your_computed_bias)
```

If you have a choice, you are better off choosing a smaller constant, and then your results will “less often” show up as negative in profile statistics.
27.4.8. Using a custom timer

If you want to change how current time is determined (for example, to force use of wall-clock time or elapsed process time), pass the timing function you want to the Profile class constructor:

```python
pr = profile.Profile(your_time_func)
```

The resulting profiler will then call your_time_func. Depending on whether you are using `profile.Profile` or `cProfile.Profile`, your_time_func's return value will be interpreted differently:

**profile.Profile**

your_time_func should return a single number, or a list of numbers whose sum is the current time (like what `os.times()` returns). If the function returns a single time number, or the list of returned numbers has length 2, then you will get an especially fast version of the dispatch routine.

Be warned that you should calibrate the profiler class for the timer function that you choose (see Calibration). For most machines, a timer that returns a lone integer value will provide the best results in terms of low overhead during profiling. (`os.times()` is pretty bad, as it returns a tuple of floating point values). If you want to substitute a a better timer in the cleanest fashion, derive a class and hardwire a replacement dispatch method that best handles your timer call, along with the appropriate calibration constant.

**cProfile.Profile**

your_time_func should return a single number. If it returns integers, you can also invoke the class constructor with a second argument specifying the real duration of one unit of time. For
example, if `your_integer_time_func` returns times measured in thousands of seconds, you would construct the Profile instance as follows:

```python
cpr = cProfile.Profile(your_integer_time_func, 0.0)
```

As the `cProfile.Profile` class cannot be calibrated, custom timer functions should be used with care and should be as fast as possible. For the best results with a custom timer, it might be necessary to hard-code it in the C source of the internal `_lsprof` module.

Python 3.3 adds several new functions in `time` that can be used to make precise measurements of process or wall-clock time. For example, see `time.perf_counter()`.
27. Debugging and Profiling
27.5. `timeit` — Measure execution time of small code snippets

*Source code: Lib/timeit.py*

This module provides a simple way to time small bits of Python code. It has both a Command-Line Interface as well as a callable one. It avoids a number of common traps for measuring execution times. See also Tim Peters’ introduction to the “Algorithms” chapter in the *Python Cookbook*, published by O'Reilly.
27.5.1. Basic Examples

The following example shows how the Command-Line Interface can be used to compare three different expressions:

```bash
$ python3 -m timeit '"-".join(str(n) for n in range(100))'
10000 loops, best of 3: 30.2 usec per loop
$ python3 -m timeit '"-".join([str(n) for n in range(100)])'
10000 loops, best of 3: 27.5 usec per loop
$ python3 -m timeit '"-".join(map(str, range(100)))'
10000 loops, best of 3: 23.2 usec per loop
```

This can be achieved from the Python Interface with:

```python
>>> import timeit
>>> timeit.timeit('"-".join(str(n) for n in range(100))', 0.3018611848820001
>>> timeit.timeit('"-".join([str(n) for n in range(100)])', 0.2727368790656328
>>> timeit.timeit('"-".join(map(str, range(100)))', 0.23702679807320237
```

Note however that `timeit` will automatically determine the number of repetitions only when the command-line interface is used. In the Examples section you can find more advanced examples.
27.5.2. Python Interface

The module defines three convenience functions and a public class:

```python
import timeit

timeit.timeit(stmt='pass', setup='pass', timer=<default timer>, number=1000000, globals=None)
```

Create a `Timer` instance with the given statement, `setup` code and `timer` function and run its `timeit()` method with `number` executions. The optional `globals` argument specifies a namespace in which to execute the code.

*Changed in version 3.5:* The optional `globals` parameter was added.

```python
import timeit

timeit.repeat(stmt='pass', setup='pass', timer=<default timer>, repeat=3, number=1000000, globals=None)
```

Create a `Timer` instance with the given statement, `setup` code and `timer` function and run its `repeat()` method with the given `repeat` count and `number` executions. The optional `globals` argument specifies a namespace in which to execute the code.

*Changed in version 3.5:* The optional `globals` parameter was added.

```python
import timeit

timeit.default_timer()
```

The default timer, which is always `time.perf_counter()`.

*Changed in version 3.3:* `time.perf_counter()` is now the default timer.

```python
class timeit.Timer(stmt='pass', setup='pass', timer=<timer function>, globals=None)
```
Class for timing execution speed of small code snippets.

The constructor takes a statement to be timed, an additional statement used for setup, and a timer function. Both statements default to 'pass'; the timer function is platform-dependent (see the module doc string). \texttt{stmt} and \texttt{setup} may also contain multiple statements separated by ; or newlines, as long as they don't contain multi-line string literals. The statement will by default be executed within timeit's namespace; this behavior can be controlled by passing a namespace to \texttt{globals}.

To measure the execution time of the first statement, use the \texttt{timeit()} method. The \texttt{repeat()} method is a convenience to call \texttt{timeit()} multiple times and return a list of results.

The execution time of \texttt{setup} is excluded from the overall timed execution run.

The \texttt{stmt} and \texttt{setup} parameters can also take objects that are callable without arguments. This will embed calls to them in a timer function that will then be executed by \texttt{timeit()}. Note that the timing overhead is a little larger in this case because of the extra function calls.

\textit{Changed in version 3.5:} The optional \texttt{globals} parameter was added.

\texttt{timeit(number=1000000)}

Time \texttt{number} executions of the main statement. This executes the setup statement once, and then returns the time it takes to execute the main statement a number of times, measured in seconds as a float. The argument is the number of times through the loop, defaulting to one million. The main statement,
the setup statement and the timer function to be used are passed to the constructor.

**Note:** By default, `timeit()` temporarily turns off garbage collection during the timing. The advantage of this approach is that it makes independent timings more comparable. This disadvantage is that GC may be an important component of the performance of the function being measured. If so, GC can be re-enabled as the first statement in the setup string. For example:

```python
timeit.Timer('for i in range(10): oct(i)', 'gc.enable()')
```

**repeat**(repeat=3, number=1000000)

Call `timeit()` a few times.

This is a convenience function that calls the `timeit()` repeatedly, returning a list of results. The first argument specifies how many times to call `timeit()`. The second argument specifies the number argument for `timeit()`.

**Note:** It's tempting to calculate mean and standard deviation from the result vector and report these. However, this is not very useful. In a typical case, the lowest value gives a lower bound for how fast your machine can run the given code snippet; higher values in the result vector are typically not caused by variability in Python’s speed, but by other processes interfering with your timing accuracy. So the `min()` of the result is probably the only number you should be interested in. After that, you should look at the entire vector and apply common sense rather than statistics.
**print_exc**(*file=None*)

Helper to print a traceback from the timed code.

Typical use:

```python
t = Timer(...)  # outside the try/except
try:
    t.timeit(...)  # or t.repeat(...)
except Exception:
    t.print_exc()
```

The advantage over the standard traceback is that source lines in the compiled template will be displayed. The optional *file* argument directs where the traceback is sent; it defaults to `sys.stderr`.
27.5.3. Command-Line Interface

When called as a program from the command line, the following form is used:

```
python -m timeit [-n N] [-r N] [-u U] [-s S] [-t] [---]...
```

Where the following options are understood:

- `-n N`, `--number=N`
  how many times to execute 'statement'

- `-r N`, `--repeat=N`
  how many times to repeat the timer (default 3)

- `-s S`, `--setup=S`
  statement to be executed once initially (default pass)

- `-p`, `--process`
  measure process time, not wallclock time, using `time.process_time()` instead of `time.perf_counter()`, which is the default

  *New in version 3.3.*

- `-t`, `--time`
  use `time.time()` (deprecated)

- `-u`, `--unit=U`
  specify a time unit for timer output; can select usec, msec, or sec
New in version 3.5.

- **c, --clock**
  use `time.clock()` (deprecated)

- **v, --verbose**
  print raw timing results; repeat for more digits precision

- **h, --help**
  print a short usage message and exit

A multi-line statement may be given by specifying each line as a separate statement argument; indented lines are possible by enclosing an argument in quotes and using leading spaces. Multiple `-s` options are treated similarly.

If `-n` is not given, a suitable number of loops is calculated by trying successive powers of 10 until the total time is at least 0.2 seconds.

`default_timer()` measurements can be affected by other programs running on the same machine, so the best thing to do when accurate timing is necessary is to repeat the timing a few times and use the best time. The `-r` option is good for this; the default of 3 repetitions is probably enough in most cases. You can use `time.process_time()` to measure CPU time.

**Note:** There is a certain baseline overhead associated with executing a pass statement. The code here doesn’t try to hide it, but you should be aware of it. The baseline overhead can be measured by invoking the program without arguments, and it might differ between Python versions.
27.5.4. Examples

It is possible to provide a setup statement that is executed only once at the beginning:

```python
$ python -m timeit -s 'text = "sample string"; char = g'
10000000 loops, best of 3: 0.0877 usec per loop
$ python -m timeit -s 'text = "sample string"; char = g'
1000000 loops, best of 3: 0.342 usec per loop

>>> import timeit
timeit.timeit('char in text', setup='text = "sample string"; char = g')
0.41440500499993504
>>> timeit.timeit('text.find(char)', setup='text = "sample string"; char = g')
1.7246671520006203
```

The same can be done using the `Timer` class and its methods:

```python
>>> import timeit
t = timeit.Timer('char in text', setup='text = "sample string"; char = g')
t.timeit()
0.395516149999312
>>> t.repeat()
[0.40193588800002544, 0.3960157959998014, 0.39594301399984033]
```

The following examples show how to time expressions that contain multiple lines. Here we compare the cost of using `hasattr()` vs. `try/except` to test for missing and present object attributes:

```python
$ python -m timeit 'try:' str.__bool__ 'except AttributeError'
100000 loops, best of 3: 15.7 usec per loop
$ python -m timeit 'if hasattr(str, "__bool__")': pass
```
To give the `timeit` module access to functions you define, you can pass a `setup` parameter which contains an import statement:
```python
def test():
    """Stupid test function"""
    L = [i for i in range(100)]

if __name__ == '__main__':
    import timeit
    print(timeit.timeit("test()"), setup="from __main__ import test")
```

Another option is to pass `globals()` to the `globals` parameter, which will cause the code to be executed within your current global namespace. This can be more convenient than individually specifying imports:

```python
def f(x):
    return x**2
def g(x):
    return x**4
def h(x):
    return x**8

import timeit
print(timeit.timeit('[func(42) for func in (f,g,h)]'))
```
27.6. **trace** — Trace or track Python statement execution

**Source code:** [Lib/trace.py](Lib/trace.py)

The **trace** module allows you to trace program execution, generate annotated statement coverage listings, print caller/callee relationships and list functions executed during a program run. It can be used in another program or from the command line.
27.6.1. Command-Line Usage

The `trace` module can be invoked from the command line. It can be as simple as

```
python -m trace --count -C . somefile.py ...
```

The above will execute `somefile.py` and generate annotated listings of all Python modules imported during the execution into the current directory.

**--help**
Display usage and exit.

**--version**
Display the version of the module and exit.

27.6.1.1. Main options

At least one of the following options must be specified when invoking `trace`. The `--listfuncs` option is mutually exclusive with the `--trace` and `--count` options. When `--listfuncs` is provided, neither `--count` nor `--trace` are accepted, and vice versa.

**-c, --count**
Produce a set of annotated listing files upon program completion that shows how many times each statement was executed. See also `--coverdir`, `--file` and `--no-report` below.

**-t, --trace**
Display lines as they are executed.
-l, --listfuncs
Display the functions executed by running the program.

-r, --report
Produce an annotated list from an earlier program run that used the --count and --file option. This does not execute any code.

-T, --trackcalls
Display the calling relationships exposed by running the program.

27.6.1.2. Modifiers

-f, --file=<file>
Name of a file to accumulate counts over several tracing runs. Should be used with the --count option.

-C, --coverdir=<dir>
Directory where the report files go. The coverage report for package.module is written to file dir/package/module.cover.

-m, --missing
When generating annotated listings, mark lines which were not executed with >>>>>>.

-s, --summary
When using --count or --report, write a brief summary to stdout for each file processed.

-R, --no-report
Do not generate annotated listings. This is useful if you intend to make several runs with --count, and then produce a single set of
annotated listings at the end.

-g, --timings
Prefix each line with the time since the program started. Only used while tracing.

27.6.1.3. Filters

These options may be repeated multiple times.

--ignore-module=<mod>
Ignore each of the given module names and its submodules (if it is a package). The argument can be a list of names separated by a comma.

--ignore-dir=<dir>
Ignore all modules and packages in the named directory and subdirectories. The argument can be a list of directories separated by \texttt{os.pathsep}.
27.6.2. Programmatic Interface

class Trace(count=1, trace=1, countfuncs=0, countcallers=0, ignoremods=(), ignoredirs=(), infile=None, outfile=None, timing=False)

Create an object to trace execution of a single statement or expression. All parameters are optional. count enables counting of line numbers. trace enables line execution tracing. countfuncs enables listing of the functions called during the run. countcallers enables call relationship tracking. ignoremods is a list of modules or packages to ignore. ignoredirs is a list of directories whose modules or packages should be ignored. infile is the name of the file from which to read stored count information. outfile is the name of the file in which to write updated count information. timing enables a timestamp relative to when tracing was started to be displayed.

run(cmd)

Execute the command and gather statistics from the execution with the current tracing parameters. cmd must be a string or code object, suitable for passing into exec().

runcxtx(cmd, globals=None, locals=None)

Execute the command and gather statistics from the execution with the current tracing parameters, in the defined global and local environments. If not defined, globals and locals default to empty dictionaries.

runfunc(func, *args, **kwds)

Call func with the given arguments under control of the Trace object with the current tracing parameters.
results()

Return a CoverageResults object that contains the cumulative results of all previous calls to run, runctx and runfunc for the given Trace instance. Does not reset the accumulated trace results.

```
class trace.CoverageResults
```

A container for coverage results, created by Trace.results(). Should not be created directly by the user.

```
update(other)
```

Merge in data from another CoverageResults object.

```
write_results(show_missing=True, summary=False, coverdir=None)
```

Write coverage results. Set show_missing to show lines that had no hits. Set summary to include in the output the coverage summary per module. coverdir specifies the directory into which the coverage result files will be output. If None, the results for each source file are placed in its directory.

A simple example demonstrating the use of the programmatic interface:

```
import sys
import trace

# create a Trace object, telling it what to ignore, # do tracing or line-counting or both.
tracer = trace.Trace(
    ignoredirs=[sys.prefix, sys.exec_prefix],
    trace=0,
```
count=1)

# run the new command using the given tracer
tracer.run('main()')

# make a report, placing output in the current directory
r = tracer.results()
r.write_results(show_missing=True, coverdir=".")
27.7. `tracemalloc` — Trace memory allocations

*New in version 3.4.*

The tracemalloc module is a debug tool to trace memory blocks allocated by Python. It provides the following information:

- Traceback where an object was allocated
- Statistics on allocated memory blocks per filename and per line number: total size, number and average size of allocated memory blocks
- Compute the differences between two snapshots to detect memory leaks

To trace most memory blocks allocated by Python, the module should be started as early as possible by setting the `PYTHONTRACEMALLOC` environment variable to 1, or by using `-X tracemalloc` command line option. The `tracemalloc.start()` function can be called at runtime to start tracing Python memory allocations.

By default, a trace of an allocated memory block only stores the most recent frame (1 frame). To store 25 frames at startup: set the `PYTHONTRACEMALLOC` environment variable to 25, or use the `-X tracemalloc=25` command line option.
27.7.1. Examples

27.7.1.1. Display the top 10

Display the 10 files allocating the most memory:

```python
import tracemalloc

tracemalloc.start()

# ... run your application ...

snapshot = tracemalloc.take_snapshot()
top_stats = snapshot.statistics('lineno')

print('Top 10')
for stat in top_stats[:10]:
    print(stat)
```

Example of output of the Python test suite:

```
[ Top 10 ]
< frozen importlib._bootstrap >: 716: size= 4855 KiB, count=
< frozen importlib._bootstrap >: 284: size= 521 KiB, count=
/usr/lib/python3.4/collections/__init__.py: 368: size=
/usr/lib/python3.4/unittest/case.py: 381: size= 185 KiB, count=
< frozen importlib._bootstrap >: 1446: size= 70.4 KiB, count=
< frozen importlib._bootstrap >: 1454: size= 52.0 KiB, count=
<string>: 5: size= 49.7 KiB, count= 148, average= 344 B
/usr/lib/python3.4/sysconfig.py: 411: size= 48.0 KiB,
```

We can see that Python loaded 4.8 MiB data (bytecode and
constants) from modules and that the collections module allocated 244 KiB to build namedtuple types.

See Snapshot.statistics() for more options.

27.7.1.2. Compute differences

Take two snapshots and display the differences:

```python
import tracemalloc
tracealloc.start()
# ... start your application ...

snapshot1 = tracealloc.take_snapshot()
# ... call the function leaking memory ...
snapshot2 = tracealloc.take_snapshot()

top_stats = snapshot2.compare_to(snapshot1, 'lineno')

print("[ Top 10 differences ]")
for stat in top_stats[:10]:
    print(stat)
```

Example of output before/after running some tests of the Python test suite:

```
[ Top 10 differences ]
< frozen importlib._bootstrap >: 716: size=8173 KiB (+4
/usr/lib/python3.4/linecache.py: 127: size=940 KiB (+
/usr/lib/python3.4/unittest/case.py: 571: size=298 Ki
< frozen importlib._bootstrap >: 284: size=1005 KiB (+1
/usr/lib/python3.4/mimetypes.py: 217: size=112 KiB (+
/usr/lib/python3.4/http/server.py: 848: size=96.0 KiB
/usr/lib/python3.4(inspect.py: 1465: size=83.5 KiB (+
```
We can see that Python has loaded 8.2 MiB of module data (bytecode and constants), and that this is 4.4 MiB more than had been loaded before the tests, when the previous snapshot was taken. Similarly, the `linecache` module has cached 940 KiB of Python source code to format tracebacks, all of it since the previous snapshot.

If the system has little free memory, snapshots can be written on disk using the `Snapshot.dump()` method to analyze the snapshot offline. Then use the `Snapshot.load()` method reload the snapshot.

### 27.7.1.3. Get the traceback of a memory block

Code to display the traceback of the biggest memory block:

```python
import tracemalloc

# Store 25 frames
tracemalloc.start(25)

# ... run your application ...

snapshot = tracemalloc.take_snapshot()
top_stats = snapshot.statistics('traceback')

# pick the biggest memory block
stat = top_stats[0]
print("%s memory blocks: %.1f KiB" % (stat.count, stat.size/1024))
for line in stat.traceback.format():
    print(line)
```
Example of output of the Python test suite (traceback limited to 25 frames):

903 memory blocks: 870.1 KiB
File "<frozen importlib._bootstrap>" , line 716
File "<frozen importlib._bootstrap>" , line 1036
File "<frozen importlib._bootstrap>" , line 934
File "<frozen importlib._bootstrap>" , line 1068
File "<frozen importlib._bootstrap>" , line 619
File "<frozen importlib._bootstrap>" , line 1581
File "<frozen importlib._bootstrap>" , line 1614
File "/usr/lib/python3.4/doctest.py" , line 101

    import pdb
File "<frozen importlib._bootstrap>" , line 284
File "<frozen importlib._bootstrap>" , line 938
File "<frozen importlib._bootstrap>" , line 1068
File "<frozen importlib._bootstrap>" , line 619
File "<frozen importlib._bootstrap>" , line 1581
File "<frozen importlib._bootstrap>" , line 1614
File "/usr/lib/python3.4/test/support/__init__.py"

    import doctest
File "/usr/lib/python3.4/test/test_pickletools.py"
support.run_doctest(pickletools)
File "/usr/lib/python3.4/test/regrtest.py" , line 1
test_runner()
File "/usr/lib/python3.4/test/regrtest.py" , line 9
display_failure=not verbose)
File "/usr/lib/python3.4/test/regrtest.py" , line 7
match_tests=ns.match_tests)
File "/usr/lib/python3.4/test/regrtest.py" , line 1
main()
File "/usr/lib/python3.4/test/__main__.py" , line 3
regrtest.main_in_temp_cwd()
File "/usr/lib/python3.4/runpy.py" , line 73
exec(code, run_globals)
File "/usr/lib/python3.4/runpy.py" , line 160
"__main__", fname, loader, pkg_name)
We can see that the most memory was allocated in the importlib
module to load data (bytecode and constants) from modules: 870
KiB. The traceback is where the importlib loaded data most
recently: on the import pdb line of the doctest module. The
traceback may change if a new module is loaded.

27.7.1.4. Pretty top
Code to display the 10 lines allocating the most memory with a pretty
output, ignoring <frozen
importlib._bootstrap> and
<unknown> files:
import linecache
import os
import tracemalloc
def display_top(snapshot, group_by='lineno', limit=10
snapshot = snapshot.filter_traces((
tracemalloc.Filter(False, "<frozen importlib._bootst
tracemalloc.Filter(False, "<unknown>"),
))
top_stats = snapshot.statistics(group_by)
print("Top %s lines" % limit)
for index, stat in enumerate(top_stats[:limit],
frame = stat.traceback[0]
# replace "/path/to/module/file.py" with "module/fil
filename = os.sep.join(frame.filename.split(
print("#%s: %s:%s: %.1f KiB"
% (index, filename, frame.lineno, stat
line = linecache.getline(frame.filename, frame
if line:
print('
%s' % line)


other = top_stats[limit:]
if other:
    size = sum(stat.size for stat in other)
    print("%s other: %.1f KiB" % (len(other), size))
total = sum(stat.size for stat in top_stats)
print("Total allocated size: %.1f KiB" % (total))

tracemalloc.start()

# ... run your application ...

snapshot = tracemalloc.take_snapshot()
display_top(snapshot)

Example of output of the Python test suite:

Top 10 lines
#1: Lib/base64.py:414: 419.8 KiB
    _b85chars2 = [(a + b) for a in _b85chars for b in _b85chars]
#2: Lib/base64.py:306: 419.8 KiB
    _a85chars2 = [(a + b) for a in _a85chars for b in _a85chars]
#3: collections/__init__.py:368: 293.6 KiB
    exec(class_definition, namespace)
#4: Lib/abc.py:133: 115.2 KiB
    cls = super().__new__(mcls, name, bases, namespace)
#5: unittest/case.py:574: 103.1 KiB
    testMethod()
#6: Lib/linecache.py:127: 95.4 KiB
    lines = fp.readlines()
#7: urllib/parse.py:476: 71.8 KiB
    for a in _hexdig for b in _hexdig}
#8: <string>:5: 62.0 KiB
#9: Lib/_weakrefset.py:37: 60.0 KiB
    self.data = set()
#10: Lib/base64.py:142: 59.8 KiB
\_b32tab2 = [a + b for a in \_b32tab for b in \_b32tab

6220 other: 3602.8 KiB
Total allocated size: 5303.1 KiB

See \texttt{Snapshot.statistics()} for more options.
27.7.2. API

27.7.2.1. Functions

tracemalloc.\texttt{clear\_traces}()

Clear traces of memory blocks allocated by Python.

See also \texttt{stop}().

tracemalloc.\texttt{get\_object\_traceback}(\texttt{obj})

Get the traceback where the Python object \texttt{obj} was allocated. Return a \texttt{Traceback} instance, or None if the \texttt{tracemalloc} module is not tracing memory allocations or did not trace the allocation of the object.

See also \texttt{gc.get\_referrers}() and \texttt{sys.getsizeof}() functions.

tracemalloc.\texttt{get\_traceback\_limit}()

Get the maximum number of frames stored in the traceback of a trace.

The \texttt{tracemalloc} module must be tracing memory allocations to get the limit, otherwise an exception is raised.

The limit is set by the \texttt{start}() function.

tracemalloc.\texttt{get\_traced\_memory}()

Get the current size and peak size of memory blocks traced by the \texttt{tracemalloc} module as a tuple: (current: int, peak: int).
tracemalloc.get_tracemalloc_memory()

Get the memory usage in bytes of the tracemalloc module used to store traces of memory blocks. Return an int.

tracemalloc.is_tracing()

True if the tracemalloc module is tracing Python memory allocations, False otherwise.

See also start() and stop() functions.

tracemalloc.start(nframe: int=1)

Start tracing Python memory allocations: install hooks on Python memory allocators. Collected tracebacks of traces will be limited to nframe frames. By default, a trace of a memory block only stores the most recent frame: the limit is 1. nframe must be greater or equal to 1.

Storing more than 1 frame is only useful to compute statistics grouped by 'traceback' or to compute cumulative statistics: see the Snapshot.compare_to() and Snapshot.statistics() methods.

Storing more frames increases the memory and CPU overhead of the tracemalloc module. Use the get_tracemalloc_memory() function to measure how much memory is used by the tracemalloc module.

The PYTHONTRACEMALLOC environment variable (PYTHONTRACEMALLOC=NFRAME) and the -X tracemalloc=NFRAME command line option can be used to start tracing at startup.
See also `stop()`, `is_tracing()` and `get_traceback_limit()` functions.

```python
tracemalloc.stop()
```

Stop tracing Python memory allocations: uninstall hooks on Python memory allocators. Also clears all previously collected traces of memory blocks allocated by Python.

Call `take_snapshot()` function to take a snapshot of traces before clearing them.

See also `start()`, `is_tracing()` and `clear_traces()` functions.

```python
tracemalloc.take_snapshot()
```

Take a snapshot of traces of memory blocks allocated by Python. Return a new `Snapshot` instance.

The snapshot does not include memory blocks allocated before the `tracemalloc` module started to trace memory allocations.

Tracebacks of traces are limited to `get_traceback_limit()` frames. Use the `nframe` parameter of the `start()` function to store more frames.

The `tracemalloc` module must be tracing memory allocations to take a snapshot, see the `start()` function.

See also the `get_object_traceback()` function.

### 27.7.2.2. Filter

```python
class tracemalloc.Filter(inclusive: bool, filename_pattern: str,
```
Filter on traces of memory blocks.

See the `fnmatch.fnmatch()` function for the syntax of `filename_pattern`. The '.pyc' file extension is replaced with '.py'.

Examples:

- Filter(True, subprocess.__file__) only includes traces of the `subprocess` module
- Filter(False, tracemalloc.__file__) excludes traces of the `tracemalloc` module
- Filter(False, "<unknown>") excludes empty tracebacks

*Changed in version 3.5:* The '.pyo' file extension is no longer replaced with '.py'.

**inclusive**

If `inclusive` is True (include), only trace memory blocks allocated in a file with a name matching `filename_pattern` at line number `lineno`.

If `inclusive` is False (exclude), ignore memory blocks allocated in a file with a name matching `filename_pattern` at line number `lineno`.

**lineno**

Line number (int) of the filter. If `lineno` is None, the filter matches any line number.

**filename_pattern**
Filename pattern of the filter (str).

all_frames
If `all_frames` is True, all frames of the traceback are checked. If `all_frames` is False, only the most recent frame is checked.

This attribute has no effect if the traceback limit is 1. See the `get_traceback_limit()` function and `Snapshot.traceback_limit` attribute.

27.7.2.3. Frame

`class` `tracemalloc.Frame`
Frame of a traceback.

The `Traceback` class is a sequence of `Frame` instances.

filename
Filename (str).

lineno
Line number (int).

27.7.2.4. Snapshot

`class` `tracemalloc.Snapshot`
Snapshot of traces of memory blocks allocated by Python.

The `take_snapshot()` function creates a snapshot instance.

`compare_to(old_snapshot: Snapshot, group_by: str, cumulative: bool=False)`
Compute the differences with an old snapshot. Get statistics as a sorted list of `StatisticDiff` instances grouped by `group_by`.

See the `Snapshot.statistics()` method for `group_by` and `cumulative` parameters.

The result is sorted from the biggest to the smallest by: absolute value of `StatisticDiff.size_diff`, `StatisticDiff.size`, absolute value of `StatisticDiff.count_diff`, `Statistic.count` and then by `StatisticDiff.traceback`.

**dump(filename)**
Write the snapshot into a file.

Use `load()` to reload the snapshot.

**filter_traces(filters)**
Create a new `Snapshot` instance with a filtered `traces` sequence, `filters` is a list of `Filter` instances. If `filters` is an empty list, return a new `Snapshot` instance with a copy of the traces.

All inclusive filters are applied at once, a trace is ignored if no inclusive filters match it. A trace is ignored if at least one exclusive filter matches it.

**classmethod load(filename)**
Load a snapshot from a file.

See also `dump()`.
**statistics** *(group_by: str, cumulative: bool=False)*

Get statistics as a sorted list of *Statistic* instances grouped by *group_by*:

<table>
<thead>
<tr>
<th>group_by</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>'filename'</td>
<td>filename</td>
</tr>
<tr>
<td>'lineno'</td>
<td>filename and line number</td>
</tr>
<tr>
<td>'traceback'</td>
<td>traceback</td>
</tr>
</tbody>
</table>

If *cumulative* is True, cumulate size and count of memory blocks of all frames of the traceback of a trace, not only the most recent frame. The cumulative mode can only be used with *group_by* equals to 'filename' and 'lineno'.

The result is sorted from the biggest to the smallest by: *Statistic.size*, *Statistic.count* and then by *Statistic.traceback*.

**traceback_limit**

Maximum number of frames stored in the traceback of *traces*: result of the *get_traceback_limit()* when the snapshot was taken.

**traces**

Traces of all memory blocks allocated by Python: sequence of *Trace* instances.

The sequence has an undefined order. Use the *Snapshot.statistics()* method to get a sorted list of statistics.
27.7.2.5. Statistic

```python
class tracemalloc.Statistic
    Statistic on memory allocations.

Snapshot.statistics() returns a list of Statistic instances.
```

See also the StatisticDiff class.

- **count**
  Number of memory blocks (int).

- **size**
  Total size of memory blocks in bytes (int).

- **traceback**
  Traceback where the memory block was allocated, Traceback instance.

27.7.2.6. StatisticDiff

```python
class tracemalloc.StatisticDiff
    Statistic difference on memory allocations between an old and a new Snapshot instance.

Snapshot.compare_to() returns a list of StatisticDiff instances. See also the Statistic class.
```

- **count**
  Number of memory blocks in the new snapshot (int): 0 if the memory blocks have been released in the new snapshot.
**count_diff**
Difference of number of memory blocks between the old and the new snapshots (int): 0 if the memory blocks have been allocated in the new snapshot.

**size**
Total size of memory blocks in bytes in the new snapshot (int): 0 if the memory blocks have been released in the new snapshot.

**size_diff**
Difference of total size of memory blocks in bytes between the old and the new snapshots (int): 0 if the memory blocks have been allocated in the new snapshot.

**traceback**
Traceback where the memory blocks were allocated, `Traceback` instance.

### 27.7.2.7. Trace

**class** `tracemalloc.Trace`
Trace of a memory block.

The `Snapshot.traces` attribute is a sequence of `Trace` instances.

**size**
Size of the memory block in bytes (int).

**traceback**
Traceback where the memory block was allocated, `Traceback` instance.
27.7.2.8. Traceback

```python
class tracemalloc.Traceback
    Sequence of Frame instances sorted from the most recent frame to the oldest frame.
```

A traceback contains at least 1 frame. If the tracemalloc module failed to get a frame, the filename "<unknown>" at line number 0 is used.

When a snapshot is taken, tracebacks of traces are limited to `get_traceback_limit()` frames. See the `take_snapshot()` function.

The `Trace.traceback` attribute is an instance of `Traceback` instance.

```python
format(limit=None)
    Format the traceback as a list of lines with newlines. Use the linecache module to retrieve lines from the source code. If `limit` is set, only format the `limit` most recent frames.
```

Similar to the `traceback.format_tb()` function, except that `format()` does not include newlines.

Example:

```python
print("Traceback (most recent call first):")
for line in traceback:
    print(line)
```
Traceback (most recent call first):
  File "test.py", line 9
    obj = Object()
  File "test.py", line 12
    tb = tracemalloc.get_object_traceback(f())
28. Software Packaging and Distribution

These libraries help you with publishing and installing Python software. While these modules are designed to work in conjunction with the Python Package Index, they can also be used with a local index server, or without any index server at all.

- **28.1. distutils** — Building and installing Python modules
- **28.2. ensurepip** — Bootstrapping the pip installer
  - 28.2.1. Command line interface
  - 28.2.2. Module API
- **28.3. venv** — Creation of virtual environments
  - 28.3.1. Creating virtual environments
  - 28.3.2. API
  - 28.3.3. An example of extending EnvBuilder
- **28.4. zipapp** — Manage executable python zip archives
  - 28.4.1. Basic Example
  - 28.4.2. Command-Line Interface
  - 28.4.3. Python API
  - 28.4.4. Examples
  - 28.4.5. The Python Zip Application Archive Format
28.1. `distutils` — Building and installing Python modules

The `distutils` package provides support for building and installing additional modules into a Python installation. The new modules may be either 100%-pure Python, or may be extension modules written in C, or may be collections of Python packages which include modules coded in both Python and C.

Most Python users will not want to use this module directly, but instead use the cross-version tools maintained by the Python Packaging Authority. In particular, `setuptools` is an enhanced alternative to `distutils` that provides:

- support for declaring project dependencies
- additional mechanisms for configuring which files to include in source releases (including plugins for integration with version control systems)
- the ability to declare project “entry points”, which can be used as the basis for application plugin systems
- the ability to automatically generate Windows command line executables at installation time rather than needing to prebuild them
- consistent behaviour across all supported Python versions

The recommended `pip` installer runs all `setup.py` scripts with `setuptools`, even if the script itself only imports `distutils`. Refer to the [Python Packaging User Guide](https://docs.python.org/3/tutorials/distutils/) for more information.

For the benefits of packaging tool authors and users seeking a deeper understanding of the details of the current packaging and distribution
system, the legacy distutils based user documentation and API reference remain available:

- Installing Python Modules (Legacy version)
- Distributing Python Modules (Legacy version)
28.2. **ensurepip** — Bootstrapping the pip installer

*New in version 3.4.*

The **ensurepip** package provides support for bootstrapping the **pip** installer into an existing Python installation or virtual environment. This bootstrapping approach reflects the fact that **pip** is an independent project with its own release cycle, and the latest available stable version is bundled with maintenance and feature releases of the CPython reference interpreter.

In most cases, end users of Python shouldn’t need to invoke this module directly (as **pip** should be bootstrapped by default), but it may be needed if installing **pip** was skipped when installing Python (or when creating a virtual environment) or after explicitly uninstalling **pip**.

**Note:** This module *does not* access the internet. All of the components needed to bootstrap **pip** are included as internal parts of the package.

**See also:**

- **Installing Python Modules**
  - The end user guide for installing Python packages
- **PEP 453**: Explicit bootstrapping of **pip** in Python installations
  - The original rationale and specification for this module.
28.2.1. Command line interface

The command line interface is invoked using the interpreter’s -m switch.

The simplest possible invocation is:

```
python -m ensurepip
```

This invocation will install pip if it is not already installed, but otherwise does nothing. To ensure the installed version of pip is at least as recent as the one bundled with ensurepip, pass the --upgrade option:

```
python -m ensurepip --upgrade
```

By default, pip is installed into the current virtual environment (if one is active) or into the system site packages (if there is no active virtual environment). The installation location can be controlled through two additional command line options:

- **--root <dir>**: Installs pip relative to the given root directory rather than the root of the currently active virtual environment (if any) or the default root for the current Python installation.
- **--user**: Installs pip into the user site packages directory rather than globally for the current Python installation (this option is not permitted inside an active virtual environment).

By default, the scripts pipX and pipX.Y will be installed (where X.Y stands for the version of Python used to invoke ensurepip). The scripts installed can be controlled through two additional command line options:
- `--altinstall`: if an alternate installation is requested, the `pipX` script will *not* be installed.

- `--default-pip`: if a “default pip” installation is requested, the `pip` script will be installed in addition to the two regular scripts.

Providing both of the script selection options will trigger an exception.
28.2.2. Module API

`ensurepip` exposes two functions for programmatic use:

`ensurepip.version()`

Returns a string specifying the bundled version of pip that will be installed when bootstrapping an environment.

`ensurepip.bootstrap(root=None, upgrade=False, user=False, altinstall=False, default_pip=False, verbosity=0)`

Bootstraps pip into the current or designated environment.

`root` specifies an alternative root directory to install relative to. If `root` is None, then installation uses the default install location for the current environment.

`upgrade` indicates whether or not to upgrade an existing installation of an earlier version of pip to the bundled version.

`user` indicates whether to use the user scheme rather than installing globally.

By default, the scripts `pipX` and `pipX.Y` will be installed (where `X.Y` stands for the current version of Python).

If `altinstall` is set, then `pipX` will not be installed.

If `default_pip` is set, then `pip` will be installed in addition to the two regular scripts.

Setting both `altinstall` and `default_pip` will trigger `ValueError`.

`verbosity` controls the level of output to `sys.stdout` from the
bootstrapping operation.

**Note:** The bootstrapping process has side effects on both `sys.path` and `os.environ`. Invoking the command line interface in a subprocess instead allows these side effects to be avoided.

**Note:** The bootstrapping process may install additional modules required by `pip`, but other software should not assume those dependencies will always be present by default (as the dependencies may be removed in a future version of `pip`).
28.3. **venv** — Creation of virtual environments

*New in version 3.3.*

**Source code:** Lib/venv

The *venv* module provides support for creating lightweight “virtual environments” with their own site directories, optionally isolated from system site directories. Each virtual environment has its own Python binary (allowing creation of environments with various Python versions) and can have its own independent set of installed Python packages in its site directories.

See **PEP 405** for more information about Python virtual environments.
28.3.1. Creating virtual environments

Creation of virtual environments is done by executing the pyvenv script:

```
pyvenv /path/to/new/virtual/environment
```

Running this command creates the target directory (creating any parent directories that don’t exist already) and places a pyvenv.cfg file in it with a home key pointing to the Python installation the command was run from. It also creates a bin (or Scripts on Windows) subdirectory containing a copy of the python binary (or binaries, in the case of Windows). It also creates an (initially empty) lib/pythonX.Y/site-packages subdirectory (on Windows, this is Lib\site-packages).

**See also:** Python Packaging User Guide: Creating and using virtual environments

On Windows, you may have to invoke the pyvenv script as follows, if you don’t have the relevant PATH and PATHEXT settings:

```
c:\Temp>c:\Python35\python c:\Python35\Tools\Scripts\pyvenv.py myenv
```

or equivalently:

```
c:\Temp>c:\Python35\python -m venv myenv
```

The command, if run with -h, will show the available options:

```
usage: venv [-h] [--system-site-packages] [--symlink
```
[--upgrade] [--without-pip] ENV_DIR

Creates virtual Python environments in one or more target directories.

Positional arguments:
  ENV_DIR A directory to create the environment in.

Optional arguments:
  -h, --help show this help message and exit
  --system-site-packages Give access to the global site-packages dir of the virtual environment.
  --symlinks Try to use symlinks rather than copies, when symlinks are the default for the platform.
  --copies Try to use copies rather than symlinks, even when symlinks are the default for the platform.
  --clear Delete the environment directory if it already exists. If not specified and the directory exists, an error is raised.
  --upgrade Upgrade the environment directory to use this version of Python, assuming Python has been upgraded in-place.
  --without-pip Skips installing or upgrading pip in the virtual environment (pip is bootstrapped by default).

Depending on how the venv functionality has been invoked, the usage message may vary slightly, e.g. referencing pyvenv rather than venv.

*Changed in version 3.4:* Installs pip by default, added the --without-pip and --copies options

*Changed in version 3.4:* In earlier versions, if the target directory already existed, an error was raised, unless the --clear or --upgrade option was provided. Now, if an existing directory is specified, its contents are removed and the directory is processed as if it had been newly created.
The created pyvenv.cfg file also includes the include-system-site-packages key, set to true if venv is run with the --system-site-packages option, false otherwise.

Unless the --without-pip option is given, ensurepip will be invoked to bootstrap pip into the virtual environment.

Multiple paths can be given to pyvenv, in which case an identical virtualenv will be created, according to the given options, at each provided path.

Once a venv has been created, it can be “activated” using a script in the venv's binary directory. The invocation of the script is platform-specific:

<table>
<thead>
<tr>
<th>Platform</th>
<th>Shell</th>
<th>Command to activate virtual environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posix</td>
<td>bash/zsh</td>
<td>$ source &lt;venv&gt;/bin/activate</td>
</tr>
<tr>
<td></td>
<td>fish</td>
<td>$. &lt;venv&gt;/bin/activate.fish</td>
</tr>
<tr>
<td></td>
<td>csh/tcsh</td>
<td>$ source &lt;venv&gt;/bin/activate.csh</td>
</tr>
<tr>
<td>Windows</td>
<td>cmd.exe</td>
<td>C:&gt; &lt;venv&gt;/Scripts/activate.bat</td>
</tr>
<tr>
<td></td>
<td>PowerShell</td>
<td>PS C:&gt; &lt;venv&gt;/Scripts/Activate.ps1</td>
</tr>
</tbody>
</table>

You don’t specifically need to activate an environment; activation just prepends the venv’s binary directory to your path, so that “python” invokes the venv’s Python interpreter and you can run installed scripts without having to use their full path. However, all scripts installed in a venv should be runnable without activating it, and run with the venv’s Python automatically.

You can deactivate a venv by typing “deactivate” in your shell. The
exact mechanism is platform-specific: for example, the Bash activation script defines a “deactivate” function, whereas on Windows there are separate scripts called deactivate.bat and Deactivate.ps1 which are installed when the venv is created.

New in version 3.4: fish and csh activation scripts.

**Note:** A virtual environment (also called a venv) is a Python environment such that the Python interpreter, libraries and scripts installed into it are isolated from those installed in other virtual environments, and (by default) any libraries installed in a “system” Python, i.e. one which is installed as part of your operating system.

A venv is a directory tree which contains Python executable files and other files which indicate that it is a venv.

Common installation tools such as Setuptools and pip work as expected with venvs - i.e. when a venv is active, they install Python packages into the venv without needing to be told to do so explicitly. Of course, you need to install them into the venv first: this could be done by running ez_setup.py with the venv activated, followed by running easy_install pip. Alternatively, you could download the source tarballs and run python setup.py install after unpacking, with the venv activated.

When a venv is active (i.e. the venv’s Python interpreter is running), the attributes `sys.prefix` and `sys.exec_prefix` point to the base directory of the venv, whereas `sys.base_prefix` and `sys.base_exec_prefix` point to the non-venv Python installation which was used to create the venv. If a venv is not active, then `sys.prefix` is the same as `sys.base_prefix` and `sys.exec_prefix` is the same as `sys.base_exec_prefix` (they
all point to a non-venv Python installation).

When a venv is active, any options that change the installation path will be ignored from all distutils configuration files to prevent projects being inadvertently installed outside of the virtual environment.

When working in a command shell, users can make a venv active by running an activate script in the venv’s executables directory (the precise filename is shell-dependent), which prepends the venv’s directory for executables to the PATH environment variable for the running shell. There should be no need in other circumstances to activate a venv – scripts installed into venvs have a shebang line which points to the venv’s Python interpreter. This means that the script will run with that interpreter regardless of the value of PATH.

On Windows, shebang line processing is supported if you have the Python Launcher for Windows installed (this was added to Python in 3.3 - see PEP 397 for more details). Thus, double-clicking an installed script in a Windows Explorer window should run the script with the correct interpreter without there needing to be any reference to its venv in PATH.
28.3.2. API

The high-level method described above makes use of a simple API which provides mechanisms for third-party virtual environment creators to customize environment creation according to their needs, the EnvBuilder class.

```python
class venv.EnvBuilder(system_site_packages=False, clear=False, symlinks=False, upgrade=False, with_pip=False)

The EnvBuilder class accepts the following keyword arguments on instantiation:

- system_site_packages – a Boolean value indicating that the system Python site-packages should be available to the environment (defaults to False).
- clear – a Boolean value which, if true, will delete the contents of any existing target directory, before creating the environment.
- symlinks – a Boolean value indicating whether to attempt to symlink the Python binary (and any necessary DLLs or other binaries, e.g. pythonw.exe), rather than copying. Defaults to True on Linux and Unix systems, but False on Windows.
- upgrade – a Boolean value which, if true, will upgrade an existing environment with the running Python - for use when that Python has been upgraded in-place (defaults to False).
- with_pip – a Boolean value which, if true, ensures pip is installed in the virtual environment. This uses ensurepip with the --default-pip option.

Changed in version 3.4: Added the with_pip parameter
```

Creators of third-party virtual environment tools will be free to use
the provided EnvBuilder class as a base class.

The returned env-builder is an object which has a method, create:

\texttt{create(env\_dir)}

This method takes as required argument the path (absolute or relative to the current directory) of the target directory which is to contain the virtual environment. The create method will either create the environment in the specified directory, or raise an appropriate exception.

The create method of the EnvBuilder class illustrates the hooks available for subclass customization:

\begin{verbatim}
def create(self, env_dir):
    """
    Create a virtualized Python environment in env_dir is the target directory to create a """
    env_dir = os.path.abspath(env_dir)
    context = self.ensure_directories(env_dir)
    self.create_configuration(context)
    self.setup_python(context)
    self.setup_scripts(context)
    self.post_setup(context)
\end{verbatim}

Each of the methods ensure\_directories(), create\_configuration(), setup\_python(), setup\_scripts() and post\_setup() can be overridden.

\texttt{ensure\_directories(env\_dir)}

Creates the environment directory and all necessary directories,
and returns a context object. This is just a holder for attributes (such as paths), for use by the other methods. The directories are allowed to exist already, as long as either clear or upgrade were specified to allow operating on an existing environment directory.

**create_configuration(context)**

Creates the pyvenv.cfg configuration file in the environment.

**setup_python(context)**

Creates a copy of the Python executable (and, under Windows, DLLs) in the environment. On a POSIX system, if a specific executable python3.x was used, symlinks to python and python3 will be created pointing to that executable, unless files with those names already exist.

**setup_scripts(context)**

Installs activation scripts appropriate to the platform into the virtual environment.

**post_setup(context)**

A placeholder method which can be overridden in third party implementations to pre-install packages in the virtual environment or perform other post-creation steps.

In addition, `EnvBuilder` provides this utility method that can be called from `setup_scripts()` or `post_setup()` in subclasses to assist in installing custom scripts into the virtual environment.

**install_scripts(context, path)**

`path` is the path to a directory that should contain subdirectories “common”, “posix”, “nt”, each containing scripts destined for the
bin directory in the environment. The contents of “common” and the directory corresponding to `os.name` are copied after some text replacement of placeholders:

- `__VENV_DIR__` is replaced with the absolute path of the environment directory.
- `__VENV_NAME__` is replaced with the environment name (final path segment of environment directory).
- `__VENV_PROMPT__` is replaced with the prompt (the environment name surrounded by parentheses and with a following space)
- `__VENV_BIN_NAME__` is replaced with the name of the bin directory (either `bin` or `Scripts`).
- `__VENV_PYTHON__` is replaced with the absolute path of the environment’s executable.

The directories are allowed to exist (for when an existing environment is being upgraded).

There is also a module-level convenience function:

```python
venv.create(env_dir, system_site_packages=False, clear=False, symlinks=False, with_pip=False)
```

Create an `EnvBuilder` with the given keyword arguments, and call its `create()` method with the `env_dir` argument.

*Changed in version 3.4:* Added the `with_pip` parameter
28.3.3. An example of extending EnvBuilder

The following script shows how to extend `EnvBuilder` by implementing a subclass which installs setuptools and pip into a created venv:

```python
import os
import os.path
from subprocess import Popen, PIPE
import sys
from threading import Thread
from urllib.parse import urlparse
from urllib.request import urlretrieve
import venv

class ExtendedEnvBuilder(venv.EnvBuilder):
    """
    This builder installs setuptools and pip so that easy_install other packages into the created env.

    :param nodist: If True, setuptools and pip are not installed into the created environment.
    :param nopip: If True, pip is not installed into the created environment.
    :param progress: If setuptools or pip are installed, the progress can be monitored by passing a progress callable. If specified, it is called with two arguments: a string indicating where the setup is occurring, and a context indicating where the setup is occurring. The context argument can have one of three values: 'main', indicating that it is being called from the main thread, or 'stdout' and 'stderr', which are obtained by reading lines from the output streams of a subprocess.
    """
```
which is used to install the app.

If a callable is not specified, information is output to sys.stderr.

```python
def __init__(self, *args, **kwargs):
    self.nodist = kwargs.pop('nodist', False)
    self.nopip = kwargs.pop('nopip', False)
    self.progress = kwargs.pop('progress', None)
    self.verbose = kwargs.pop('verbose', False)
    super().__init__(*args, **kwargs)

def post_setup(self, context):
    ""
    Set up any packages which need to be pre-installed into the environment being created.
    
    :param context: The information for the environment being processed.
    ""
    os.environ['VIRTUAL_ENV'] = context.env_dir
    if not self.nodist:
        self.install_setuptools(context)
    # Can't install pip without setuptools
    if not self.nopip and not self.nodist:
        self.install_pip(context)

def reader(self, stream, context):
    ""
    Read lines from a subprocess' output stream, calling a progress callable (if specified) or write progress information to sys.stderr.
    ""
    progress = self.progress
    while True:
        s = stream.readline()
        if not s:
```
break
if progress is not None:
    progress(s, context)
else:
    if not self.verbose:
        sys.stderr.write('..')
    else:
        sys.stderr.write(s.decode('utf-8'))
sys.stderr.flush()
stream.close()

def install_script(self, context, name, url):
    _, _, path, _, _, _ = urlparse(url)
    fn = os.path.split(path)[-1]
    binpath = context.bin_path
    distpath = os.path.join(binpath, fn)
    # Download script into the env's binaries folder
    urlretrieve(url, distpath)
    progress = self.progress
    if self.verbose:
        term = '\n'
    else:
        term = ''
    if progress is not None:
        progress('Installing %s ...%s' % (name,)
    else:
        sys.stderr.write('Installing %s ...%s' %
        sys.stderr.flush()
    # Install in the env
    args = [context.env_exe, fn]
    p = Popen(args, stdout=PIPE, stderr=PIPE, cwd=t1 = Thread(target=self.reader, args=(p.stdout,)t1.start()
    t2 = Thread(target=self.reader, args=(p.stderr,)t2.start()
p.wait()
t1.join()
if progress is not None:
    progress('done.', 'main')
else:
    sys.stderr.write('done.\n')
# Clean up - no longer needed
os.unlink(distpath)


def install_setuptools(self, context):
    
    Install setuptools in the environment.

    :param context: The information for the environment creation request being processed.
    
    url = 'https://bitbucket.org/pypa/setuptools/downloads/ez_setup.py'
    self.install_script(context, 'setuptools', url)
    # clear up the setuptools archive which gets downloaded
    pred = lambda o: o.startswith('setuptools-')
    files = filter(pred, os.listdir(context.bin_path))
    for f in files:
        f = os.path.join(context.bin_path, f)
        os.unlink(f)


def install_pip(self, context):
    
    Install pip in the environment.

    :param context: The information for the environment creation request being processed.
    
    url = 'https://raw.github.com/pypa/pip/master/contrib/get-pip.py'
    self.install_script(context, 'pip', url)


def main(args=None):
    compatible = True
    if sys.version_info < (3, 3):
compatible = False

elif not hasattr(sys, 'base_prefix'):
    compatible = False

if not compatible:
    raise ValueError('This script is only for use with Python 3.3 or later')

else:
    import argparse

    parser = argparse.ArgumentParser(prog=__name__,
                                     description='')

    parser.add_argument('dirs', metavar='ENV_DIR',
                        help='A directory to create the environment in.

    parser.add_argument('--no-setuptools', default=False, action='store_true',
                        help='Don't install setuptools or pip in the virtual environment.

    parser.add_argument('--no-pip', default=False, action='store_true',
                        help='Don't install pip in the virtual environment.

    parser.add_argument('--system-site-packages', action='store_true',
                        help='Give the virtual environment access to the system site-packages.

    if os.name == 'nt':
        use_symlinks = False
    else:
        use_symlinks = True

    parser.add_argument('--symlinks', default=use_symlinks, action='store_true',
                        help='Try to use symlinks rather than copies, when symlinks are not the default for the platform.')
parser.add_argument('--clear', default=False, 
dest='clear', help='Delete the contents of the 
environment directory if it already exists, before 
environment creation.')

parser.add_argument('--upgrade', default=False, 
dest='upgrade', help='Upgrade the environment directory to use this version of Python, assuming Python has been upgraded in-place.')

parser.add_argument('--verbose', default=False, 
dest='verbose', help='Display the output from the scripts which install setuptools and pip.')

options = parser.parse_args(args)

if options.upgrade and options.clear:
    raise ValueError('you cannot supply --upgrade and --clear together.')

builder = ExtendedEnvBuilder(system_site_packages
    clear=options
    symlinks=options
    upgrade=options
    nodist=options
    nopip=options
    verbose=options)

for d in options.dirs:
    builder.create(d)

if __name__ == '__main__':
    rc = 1
    try:
        main()
        rc = 0
    except Exception as e:
        print('Error: %s' % e, file=sys.stderr)
    sys.exit(rc)
This script is also available for download online.
28.4. **zipapp** — Manage executable python zip archives

*New in version 3.5.*  

**Source code:** Lib/zipapp.py

This module provides tools to manage the creation of zip files containing Python code, which can be executed directly by the Python interpreter. The module provides both a Command-Line Interface and a Python API.
28.4.1. Basic Example

The following example shows how the Command-Line Interface can be used to create an executable archive from a directory containing Python code. When run, the archive will execute the main function from the module myapp in the archive.

```
$ python -m zipapp myapp -m "myapp:main"
$ python myapp.pyz
<output from myapp>
```
28.4.2. Command-Line Interface

When called as a program from the command line, the following form is used:

```
$ python -m zipapp source [options]
```

If `source` is a directory, this will create an archive from the contents of `source`. If `source` is a file, it should be an archive, and it will be copied to the target archive (or the contents of its shebang line will be displayed if the –info option is specified).

The following options are understood:

- **-o <output>, --output=<output>**
  Write the output to a file named `output`. If this option is not specified, the output filename will be the same as the input `source`, with the extension `.pyz` added. If an explicit filename is given, it is used as is (so a `.pyz` extension should be included if required).

  An output filename must be specified if the `source` is an archive (and in that case, `output` must not be the same as `source`).

- **-p <interpreter>, --python=<interpreter>**
  Add a `#!` line to the archive specifying `interpreter` as the command to run. Also, on POSIX, make the archive executable. The default is to write no `#!` line, and not make the file executable.

- **-m <mainfn>, --main=<mainfn>**
  Write a `__main__.py` file to the archive that executes `mainfn`. The `mainfn` argument should have the form “pkg.mod:fn”, where “pkg.mod” is a package/module in the archive, and “fn” is a callable
in the given module. The __main__.py file will execute that callable.

--main cannot be specified when copying an archive.

--info
Display the interpreter embedded in the archive, for diagnostic purposes. In this case, any other options are ignored and SOURCE must be an archive, not a directory.

-h, --help
Print a short usage message and exit.
28.4.3. Python API

The module defines two convenience functions:

\texttt{zipapp.create_archive(source, target=\texttt{None}, interpreter=\texttt{None}, main=\texttt{None})}

Create an application archive from \texttt{source}. The source can be any of the following:

- The name of a directory, or a \texttt{pathlib\_Path} object referring to a directory, in which case a new application archive will be created from the content of that directory.
- The name of an existing application archive file, or a \texttt{pathlib\_Path} object referring to such a file, in which case the file is copied to the target (modifying it to reflect the value given for the \texttt{interpreter} argument). The file name should include the \texttt{.pyz} extension, if required.
- A file object open for reading in bytes mode. The content of the file should be an application archive, and the file object is assumed to be positioned at the start of the archive.

The \texttt{target} argument determines where the resulting archive will be written:

- If it is the name of a file, or a \texttt{pathlib\_Path} object, the archive will be written to that file.
- If it is an open file object, the archive will be written to that file object, which must be open for writing in bytes mode.
- If the target is omitted (or \texttt{None}), the source must be a directory and the target will be a file with the same name as the source, with a \texttt{.pyz} extension added.

The \texttt{interpreter} argument specifies the name of the Python interpreter with which the archive will be executed. It is written as a
“shebang” line at the start of the archive. On POSIX, this will be interpreted by the OS, and on Windows it will be handled by the Python launcher. Omitting the interpreter results in no shebang line being written. If an interpreter is specified, and the target is a filename, the executable bit of the target file will be set.

The main argument specifies the name of a callable which will be used as the main program for the archive. It can only be specified if the source is a directory, and the source does not already contain a __main__.py file. The main argument should take the form “pkg.module:callable” and the archive will be run by importing “pkg.module” and executing the given callable with no arguments. It is an error to omit main if the source is a directory and does not contain a __main__.py file, as otherwise the resulting archive would not be executable.

If a file object is specified for source or target, it is the caller's responsibility to close it after calling create_archive.

When copying an existing archive, file objects supplied only need read and readline, or write methods. When creating an archive from a directory, if the target is a file object it will be passed to the zipfile.ZipFile class, and must supply the methods needed by that class.

zipapp.get_interpreter(archive)

Return the interpreter specified in the #! line at the start of the archive. If there is no #! line, return None. The archive argument can be a filename or a file-like object open for reading in bytes mode. It is assumed to be at the start of the archive.
28.4.4. Examples

Pack up a directory into an archive, and run it.

```
$ python -m zipapp myapp
$ python myapp.pyz
<output from myapp>
```

The same can be done using the `create_archive()` function:

```
>>> import zipapp
>>> zipapp.create_archive('myapp.pyz', 'myapp')
```

To make the application directly executable on POSIX, specify an interpreter to use.

```
$ python -m zipapp myapp -p "/usr/bin/env python"
$ ./myapp.pyz
<output from myapp>
```

To replace the shebang line on an existing archive, create a modified archive using the `create_archive()` function:

```
>>> import zipapp
>>> zipapp.create_archive('old_archive.pyz', 'new_archive.pyz')
```

To update the file in place, do the replacement in memory using a `BytesIO` object, and then overwrite the source afterwards. Note that there is a risk when overwriting a file in place that an error will result in the loss of the original file. This code does not protect against such errors, but production code should do so. Also, this method will only work if the archive fits in memory:
>>> import zipapp
>>> import io
>>> temp = io.BytesIO()
>>> zipapp.create_archive('myapp.pyz', temp, '/usr/bin/python2')
>>> with open('myapp.pyz', 'wb') as f:
...     f.write(temp.getvalue())

Note that if you specify an interpreter and then distribute your application archive, you need to ensure that the interpreter used is portable. The Python launcher for Windows supports most common forms of POSIX `#!` line, but there are other issues to consider:

- If you use `"/usr/bin/env python"` (or other forms of the "python" command, such as `"/usr/bin/python"`), you need to consider that your users may have either Python 2 or Python 3 as their default, and write your code to work under both versions.
- If you use an explicit version, for example `"/usr/bin/env python3"` your application will not work for users who do not have that version. (This may be what you want if you have not made your code Python 2 compatible).
- There is no way to say "python X.Y or later", so be careful of using an exact version like `"/usr/bin/env python3.4"` as you will need to change your shebang line for users of Python 3.5, for example.
28.4.5. The Python Zip Application Archive Format

Python has been able to execute zip files which contain a __main__.py file since version 2.6. In order to be executed by Python, an application archive simply has to be a standard zip file containing a __main__.py file which will be run as the entry point for the application. As usual for any Python script, the parent of the script (in this case the zip file) will be placed on sys.path and thus further modules can be imported from the zip file.

The zip file format allows arbitrary data to be prepended to a zip file. The zip application format uses this ability to prepend a standard POSIX “shebang” line to the file (#!/path/to/interpreter).

Formally, the Python zip application format is therefore:

1. An optional shebang line, containing the characters b'#!' followed by an interpreter name, and then a newline (b'\n') character. The interpreter name can be anything acceptable to the OS “shebang” processing, or the Python launcher on Windows. The interpreter should be encoded in UTF-8 on Windows, and in sys.getfilesystemencoding() on POSIX.

2. Standard zipfile data, as generated by the zipfile module. The zipfile content must include a file called __main__.py (which must be in the “root” of the zipfile - i.e., it cannot be in a subdirectory). The zipfile data can be compressed or uncompressed.

If an application archive has a shebang line, it may have the executable bit set on POSIX systems, to allow it to be executed directly.
There is no requirement that the tools in this module are used to create application archives - the module is a convenience, but archives in the above format created by any means are acceptable to Python.
29. Python Runtime Services

The modules described in this chapter provide a wide range of services related to the Python interpreter and its interaction with its environment. Here's an overview:

- **29.1. sys** — System-specific parameters and functions
- **29.2. sysconfig** — Provide access to Python's configuration information
  - 29.2.1. Configuration variables
  - 29.2.2. Installation paths
  - 29.2.3. Other functions
  - 29.2.4. Using sysconfig as a script
- **29.3. builtins** — Built-in objects
- **29.4. __main__** — Top-level script environment
- **29.5. warnings** — Warning control
  - 29.5.1. Warning Categories
  - 29.5.2. The Warnings Filter
    - 29.5.2.1. Default Warning Filters
  - 29.5.3. Temporarily Suppressing Warnings
  - 29.5.4. Testing Warnings
  - 29.5.5. Updating Code For New Versions of Python
  - 29.5.6. Available Functions
  - 29.5.7. Available Context Managers
- **29.6. contextlib** — Utilities for with-statement contexts
  - 29.6.1. Utilities
  - 29.6.2. Examples and Recipes
    - 29.6.2.1. Supporting a variable number of context managers
    - 29.6.2.2. Simplifying support for single optional context managers
    - 29.6.2.3. Catching exceptions from __enter__ methods
• 29.6.2.4. Cleaning up in an __enter__ implementation
• 29.6.2.5. Replacing any use of try-finally and flag variables
• 29.6.2.6. Using a context manager as a function decorator
  • 29.6.3. Single use, reusable and reentrant context managers
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• 29.13. site — Site-specific configuration hook
  • 29.13.1. Readline configuration
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• 29.14. fpectl — Floating point exception control
  • 29.14.1. Example
  • 29.14.2. Limitations and other considerations
29.1. **sys** — System-specific parameters and functions

This module provides access to some variables used or maintained by the interpreter and to functions that interact strongly with the interpreter. It is always available.

**sys.abiflags**
On POSIX systems where Python was built with the standard configure script, this contains the ABI flags as specified by PEP 3149.

*New in version 3.2.*

**sys.argv**
The list of command line arguments passed to a Python script. argv[0] is the script name (it is operating system dependent whether this is a full pathname or not). If the command was executed using the -c command line option to the interpreter, argv[0] is set to the string '-c'. If no script name was passed to the Python interpreter, argv[0] is the empty string.

To loop over the standard input, or the list of files given on the command line, see the fileinput module.

**sys.base_exec_prefix**
Set during Python startup, before site.py is run, to the same value as exec_prefix. If not running in a virtual environment, the values will stay the same; if site.py finds that a virtual environment is in use, the values of prefix and exec_prefix
will be changed to point to the virtual environment, whereas
base_prefix and base_exec_prefix will remain pointing to
the base Python installation (the one which the virtual environment
was created from).

New in version 3.3.

sys.base_prefix
Set during Python startup, before site.py is run, to the same
value as prefix. If not running in a virtual environment, the values
will stay the same; if site.py finds that a virtual environment is in
use, the values of prefix and exec_prefix will be changed to
point to the virtual environment, whereas base_prefix and
base_exec_prefix will remain pointing to the base Python
installation (the one which the virtual environment was created
from).

New in version 3.3.

sys.byteorder
An indicator of the native byte order. This will have the value
'big' on big-endian (most-significant byte first) platforms, and
'little' on little-endian (least-significant byte first) platforms.

sys.builtin_module_names
A tuple of strings giving the names of all modules that are compiled
into this Python interpreter. (This information is not available in any
other way — modules.keys() only lists the imported modules.)

sys.call_tracing(func, args)
Call func(*args), while tracing is enabled. The tracing state is
saved, and restored afterwards. This is intended to be called from
a debugger from a checkpoint, to recursively debug some other code.

sys.\texttt{copyright}
A string containing the copyright pertaining to the Python interpreter.

sys.\texttt{\_clear\_type\_cache()}
Clear the internal type cache. The type cache is used to speed up attribute and method lookups. Use the function \textit{only} to drop unnecessary references during reference leak debugging.

This function should be used for internal and specialized purposes only.

sys.\texttt{\_current\_frames()}
Return a dictionary mapping each thread's identifier to the topmost stack frame currently active in that thread at the time the function is called. Note that functions in the \texttt{traceback} module can build the call stack given such a frame.

This is most useful for debugging deadlock: this function does not require the deadlocked threads' cooperation, and such threads' call stacks are frozen for as long as they remain deadlocked. The frame returned for a non-deadlocked thread may bear no relationship to that thread's current activity by the time calling code examines the frame.

This function should be used for internal and specialized purposes only.

sys.\texttt{\_debugmallocstats()}
Print low-level information to stderr about the state of CPython's
memory allocator.

If Python is configured –with-pydebug, it also performs some expensive internal consistency checks.

*New in version 3.3.*

**CPython implementation detail:** This function is specific to CPython. The exact output format is not defined here, and may change.

**sys.dllhandle**

Integer specifying the handle of the Python DLL. Availability: Windows.

**sys.displayhook(value)**

If `value` is not None, this function prints `repr(value)` to `sys.stdout`, and saves `value` in builtins._. If `repr(value)` is not encodable to `sys.stdout.encoding` with `sys.stdout.errors` error handler (which is probably 'strict'), encode it to `sys.stdout.encoding` with 'backslashreplace' error handler.

`sys.displayhook` is called on the result of evaluating an expression entered in an interactive Python session. The display of these values can be customized by assigning another one-argument function to `sys.displayhook`.

Pseudo-code:

```python
def displayhook(value):
    if value is None:
        return
    # Set '_' to None to avoid recursion
```
```python
builtins._ = None
text = repr(value)
try:
    sys.stdout.write(text)
except UnicodeEncodeError:
    bytes = text.encode(sys.stdout.encoding,
    if hasattr(sys.stdout, 'buffer'):
        sys.stdout.buffer.write(bytes)
    else:
        text = bytes.decode(sys.stdout.encodi
    sys.stdout.write(text)
sys.stdout.write("\n")
builtins._ = value
```

*Changed in version 3.2:* Use 'backslashreplace' error handler on `UnicodeEncodeError`.

**sys.dont_write_bytecode**

If this is true, Python won’t try to write .pyc files on the import of source modules. This value is initially set to True or False depending on the `-B` command line option and the `PYTHONDONTWRITEBYTECODE` environment variable, but you can set it yourself to control bytecode file generation.

**sys.excepthook(type, value, traceback)**

This function prints out a given traceback and exception to `sys.stderr`.

When an exception is raised and uncaught, the interpreter calls `sys.excepthook` with three arguments, the exception class, exception instance, and a traceback object. In an interactive session this happens just before control is returned to the prompt; in a Python program this happens just before the program exits.
The handling of such top-level exceptions can be customized by assigning another three-argument function to `sys.excepthook`.

```
sys.__displayhook__
sys.__excepthook__
```

These objects contain the original values of `displayhook` and `excepthook` at the start of the program. They are saved so that `displayhook` and `excepthook` can be restored in case they happen to get replaced with broken objects.

```
sys.exc_info()
```

This function returns a tuple of three values that give information about the exception that is currently being handled. The information returned is specific both to the current thread and to the current stack frame. If the current stack frame is not handling an exception, the information is taken from the calling stack frame, or its caller, and so on until a stack frame is found that is handling an exception. Here, “handling an exception” is defined as “executing an except clause.” For any stack frame, only information about the exception being currently handled is accessible.

If no exception is being handled anywhere on the stack, a tuple containing three `None` values is returned. Otherwise, the values returned are `(type, value, traceback)`. Their meaning is:

- `type` gets the type of the exception being handled (a subclass of `BaseException`);
- `value` gets the exception instance (an instance of the exception type);
- `traceback` gets a traceback object (see the Reference Manual) which encapsulates the call stack at the point where the exception originally occurred.

```
sys.exec_prefix
```

A string giving the site-specific directory prefix where the platform-
dependent Python files are installed; by default, this is also '/usr/local'. This can be set at build time with the --exec-prefix argument to the configure script. Specifically, all configuration files (e.g. the pyconfig.h header file) are installed in the directory exec_prefix/lib/pythonX.Y/config, and shared library modules are installed in exec_prefix/lib/pythonX.Y/lib-dynload, where X.Y is the version number of Python, for example 3.2.

**Note:** If a virtual environment is in effect, this value will be changed in site.py to point to the virtual environment. The value for the Python installation will still be available, via base_exec_prefix.

**sys.executable**

A string giving the absolute path of the executable binary for the Python interpreter, on systems where this makes sense. If Python is unable to retrieve the real path to its executable, sys.executable will be an empty string or None.

**sys.exit([arg])**

Exit from Python. This is implemented by raising the SystemExit exception, so cleanup actions specified by finally clauses of try statements are honored, and it is possible to intercept the exit attempt at an outer level.

The optional argument arg can be an integer giving the exit status (defaulting to zero), or another type of object. If it is an integer, zero is considered “successful termination” and any nonzero value is considered “abnormal termination” by shells and the like. Most systems require it to be in the range 0-127, and produce undefined
results otherwise. Some systems have a convention for assigning specific meanings to specific exit codes, but these are generally underdeveloped; Unix programs generally use 2 for command line syntax errors and 1 for all other kind of errors. If another type of object is passed, None is equivalent to passing zero, and any other object is printed to `stderr` and results in an exit code of 1. In particular, `sys.exit("some error message")` is a quick way to exit a program when an error occurs.

Since `exit()` ultimately “only” raises an exception, it will only exit the process when called from the main thread, and the exception is not intercepted.

**sys.**flags

The struct sequence `flags` exposes the status of command line flags. The attributes are read only.

<table>
<thead>
<tr>
<th>attribute</th>
<th>flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>debug</td>
<td>-d</td>
</tr>
<tr>
<td>inspect</td>
<td>-i</td>
</tr>
<tr>
<td>interactive</td>
<td>-i</td>
</tr>
<tr>
<td>optimize</td>
<td>-O or -OO</td>
</tr>
<tr>
<td>dont_write_bytecode</td>
<td>-B</td>
</tr>
<tr>
<td>no_user_site</td>
<td>-s</td>
</tr>
<tr>
<td>no_site</td>
<td>-S</td>
</tr>
<tr>
<td>ignore_environment</td>
<td>-E</td>
</tr>
<tr>
<td>verbose</td>
<td>-v</td>
</tr>
<tr>
<td>bytes_warning</td>
<td>-b</td>
</tr>
<tr>
<td>quiet</td>
<td>-q</td>
</tr>
<tr>
<td>attribute</td>
<td>float.h macro</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>epsilon</td>
<td>DBL_EPSILON</td>
</tr>
<tr>
<td>dig</td>
<td>DBL_DIG</td>
</tr>
<tr>
<td>mantDig</td>
<td>DBL_MANT_DIG</td>
</tr>
<tr>
<td>max</td>
<td>DBL_MAX</td>
</tr>
</tbody>
</table>

sys.float_info

A struct sequence holding information about the float type. It contains low level information about the precision and internal representation. The values correspond to the various floating-point constants defined in the standard header file float.h for the ‘C’ programming language; see section 5.2.4.2.2 of the 1999 ISO/IEC C standard [C99], ‘Characteristics of floating types’, for details.
<table>
<thead>
<tr>
<th>max_exp</th>
<th>DBL_MAX_EXP</th>
<th>that ( \text{radix}^{(e-1)} ) is a representable finite float</th>
</tr>
</thead>
<tbody>
<tr>
<td>max_10_exp</td>
<td>DBL_MAX_10_EXP</td>
<td>maximum integer ( e ) such that ( 10^{e} ) is in the range of representable finite floats</td>
</tr>
<tr>
<td>min</td>
<td>DBL_MIN</td>
<td>minimum positive normalized float</td>
</tr>
<tr>
<td>min_exp</td>
<td>DBL_MIN_EXP</td>
<td>minimum integer ( e ) such that ( \text{radix}^{(e-1)} ) is a normalized float</td>
</tr>
<tr>
<td>min_10_exp</td>
<td>DBL_MIN_10_EXP</td>
<td>minimum integer ( e ) such that ( 10^{e} ) is a normalized float</td>
</tr>
<tr>
<td>radix</td>
<td>FLT_RADIX</td>
<td>radix of exponent representation</td>
</tr>
<tr>
<td>rounds</td>
<td>FLT_ROUNDS</td>
<td>integer constant representing the rounding mode used for arithmetic operations. This reflects the value of the system FLT_ROUNDS macro at interpreter startup time. See section 5.2.4.2.2 of the C99 standard for an explanation of the possible values and their meanings.</td>
</tr>
</tbody>
</table>

The attribute `sys.float_info.dig` needs further explanation. If `s` is any string representing a decimal number with at most `sys.float_info.dig` significant digits, then converting `s` to a float and back again will recover a string representing the same decimal value:
But for strings with more than `sys.float_info.dig` significant digits, this isn’t always true:

```
>>> s = '9876543211234567'  # 16 significant digits
>>> format(float(s), '.16g')  # conversion changes value
'9876543211234568'
```

`sys.float_repr_style`

A string indicating how the `repr()` function behaves for floats. If the string has value 'short' then for a finite float `x`, `repr(x)` aims to produce a short string with the property that `float(repr(x)) == x`. This is the usual behaviour in Python 3.1 and later. Otherwise, `float_repr_style` has value 'legacy' and `repr(x)` behaves in the same way as it did in versions of Python prior to 3.1.

*New in version 3.1.*

`sys.getallocatedblocks()`

Return the number of memory blocks currently allocated by the interpreter, regardless of their size. This function is mainly useful for tracking and debugging memory leaks. Because of the interpreter’s internal caches, the result can vary from call to call; you may have to call `_clear_type_cache()` and `gc.collect()` to get more predictable results.
If a Python build or implementation cannot reasonably compute this information, `getallocatedblocks()` is allowed to return 0 instead.

*New in version 3.4.*

**sys.getcheckinterval()**
Return the interpreter's "check interval"; see `setcheckinterval()`.

*Deprecated since version 3.2:* Use `getswitchinterval()` instead.

**sys.getdefaultencoding()**
Return the name of the current default string encoding used by the Unicode implementation.

**sys.getdlopenflags()**
Return the current value of the flags that are used for `dlopen()` calls. Symbolic names for the flag values can be found in the `os` module (RTLD_xxx constants, e.g. `os.RTLD_LAZY`). Availability: Unix.

**sys.getfilesystemencoding()**
Return the name of the encoding used to convert Unicode filenames into system file names. The result value depends on the operating system:

- On Mac OS X, the encoding is 'utf-8'.
- On Unix, the encoding is the user's preference according to the result of `nl_langinfo(CODESET)`. On Windows NT+, file names are Unicode natively, so no conversion is performed. `getfilesystemencoding()` still
returns 'mbcs', as this is the encoding that applications should use when they explicitly want to convert Unicode strings to byte strings that are equivalent when used as file names.

- On Windows 9x, the encoding is 'mbcs'.

  *Changed in version 3.2: getfilesystemencoding() result cannot be None anymore.*

**sys.getrefcount(object)**

Return the reference count of the object. The count returned is generally one higher than you might expect, because it includes the (temporary) reference as an argument to getrefcount().

**sys.getrecursionlimit()**

Return the current value of the recursion limit, the maximum depth of the Python interpreter stack. This limit prevents infinite recursion from causing an overflow of the C stack and crashing Python. It can be set by setrecursionlimit().

**sys.getsizeof(object[, default])**

Return the size of an object in bytes. The object can be any type of object. All built-in objects will return correct results, but this does not have to hold true for third-party extensions as it is implementation specific.

Only the memory consumption directly attributed to the object is accounted for, not the memory consumption of objects it refers to.

If given, default will be returned if the object does not provide means to retrieve the size. Otherwise a TypeError will be raised.

getsizeof() calls the object's __sizeof__ method and adds
an additional garbage collector overhead if the object is managed by the garbage collector.

See recursive sizeof recipe for an example of using getsizeof() recursively to find the size of containers and all their contents.

**sys.getswitchinterval()**

Return the interpreter’s “thread switch interval”; see setswitchinterval().

*New in version 3.2.*

**sys._getframe([depth])**

Return a frame object from the call stack. If optional integer depth is given, return the frame object that many calls below the top of the stack. If that is deeper than the call stack, ValueError is raised. The default for depth is zero, returning the frame at the top of the call stack.

**CPython implementation detail:** This function should be used for internal and specialized purposes only. It is not guaranteed to exist in all implementations of Python.

**sys.getprofile()**

Get the profiler function as set by setprofile().

**sys.gettrace()**

Get the trace function as set by settrace().

**CPython implementation detail:** The gettrace() function is intended only for implementing debuggers, profilers, coverage tools and the like. Its behavior is part of the implementation platform, rather than part of the language definition, and thus may not be
available in all Python implementations.

**sys.getwindowsversion()**

Return a named tuple describing the Windows version currently running. The named elements are *major*, *minor*, *build*, *platform*, *service_pack*, *service_pack_minor*, *service_pack_major*, *suite_mask*, and *product_type*. *service_pack* contains a string while all other values are integers. The components can also be accessed by name, so `sys.getwindowsversion()[0]` is equivalent to `sys.getwindowsversion().major`. For compatibility with prior versions, only the first 5 elements are retrievable by indexing.

*platform* may be one of the following values:

<table>
<thead>
<tr>
<th>Constant</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (VER_PLATFORM_WIN32s)</td>
<td>Win32s on Windows 3.1</td>
</tr>
<tr>
<td>1 (VER_PLATFORM_WIN32_WINDOWS)</td>
<td>Windows 95/98/ME</td>
</tr>
<tr>
<td>2 (VER_PLATFORM_WIN32_NT)</td>
<td>Windows NT/2000/XP/x64</td>
</tr>
<tr>
<td>3 (VER_PLATFORM_WIN32_CE)</td>
<td>Windows CE</td>
</tr>
</tbody>
</table>

*product_type* may be one of the following values:

<table>
<thead>
<tr>
<th>Constant</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (VER_NT_WORKSTATION)</td>
<td>The system is a workstation.</td>
</tr>
<tr>
<td>2 (VER_NT_DOMAIN_CONTROLLER)</td>
<td>The system is a domain controller.</td>
</tr>
<tr>
<td></td>
<td>The system is a server, but</td>
</tr>
</tbody>
</table>
This function wraps the Win32 GetVersionEx() function; see the Microsoft documentation on OSVERSIONINFOEX() for more information about these fields.

Availability: Windows.

*Changed in version 3.2:* Changed to a named tuple and added *service_pack_minor*, *service_pack_major*, *suite_mask*, and *product_type*.

**sys.get_coroutine_wrapper()**

Returns None, or a wrapper set by `set_coroutine_wrapper()`.

*New in version 3.5:* See PEP 492 for more details.

**Note:** This function has been added on a provisional basis (see PEP 411 for details.) Use it only for debugging purposes.

**sys.hash_info**

A `struct sequence` giving parameters of the numeric hash implementation. For more details about hashing of numeric types, see Hashing of numeric types.

<table>
<thead>
<tr>
<th>attribute</th>
<th>explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>width</td>
<td>width in bits used for hash values</td>
</tr>
<tr>
<td>modulus</td>
<td>prime modulus P used for numeric hash scheme</td>
</tr>
<tr>
<td>inf</td>
<td>hash value returned for a positive infinity</td>
</tr>
<tr>
<td>nan</td>
<td>hash value returned for a nan</td>
</tr>
<tr>
<td>imag</td>
<td>multiplier used for the imaginary part of a complex number</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>algorithm</td>
<td>name of the algorithm for hashing of str, bytes, and memoryview</td>
</tr>
<tr>
<td>hash_bits</td>
<td>internal output size of the hash algorithm</td>
</tr>
<tr>
<td>seed_bits</td>
<td>size of the seed key of the hash algorithm</td>
</tr>
</tbody>
</table>

*New in version 3.2.*

*Changed in version 3.4: Added* `algorithm`, `hash_bits` *and* `seed_bits`

### `sys.hexversion`

The version number encoded as a single integer. This is guaranteed to increase with each version, including proper support for non-production releases. For example, to test that the Python interpreter is at least version 1.5.2, use:

```python
if sys.hexversion >= 0x010502F0:
    # use some advanced feature
...
else:
    # use an alternative implementation or warn the user
...
```

This is called `hexversion` since it only really looks meaningful when viewed as the result of passing it to the built-in `hex()` function. The `struct` sequence `sys.version_info` may be used for a more human-friendly encoding of the same information.

More details of `hexversion` can be found at API and ABI Versioning.

### `sys.implementation`

```python
if sys.implementation:
    # do something
else:
    # do something else
```
An object containing information about the implementation of the currently running Python interpreter. The following attributes are required to exist in all Python implementations.

*name* is the implementation's identifier, e.g. 'cpython'. The actual string is defined by the Python implementation, but it is guaranteed to be lower case.

*version* is a named tuple, in the same format as `sys.version_info`. It represents the version of the Python implementation. This has a distinct meaning from the specific version of the Python language to which the currently running interpreter conforms, which `sys.version_info` represents. For example, for PyPy 1.8 `sys.implementation.version` might be `sys.version_info(1, 8, 0, 'final', 0)`, whereas `sys.version_info` would be `sys.version_info(2, 7, 2, 'final', 0)`. For CPython they are the same value, since it is the reference implementation.

*hexversion* is the implementation version in hexadecimal format, like `sys.hexversion`.

*cache_tag* is the tag used by the import machinery in the filenames of cached modules. By convention, it would be a composite of the implementation's name and version, like 'cpython-33'. However, a Python implementation may use some other value if appropriate. If `cache_tag` is set to None, it indicates that module caching should be disabled.

`sys.implementation` may contain additional attributes specific to the Python implementation. These non-standard attributes must start with an underscore, and are not described here. Regardless
of its contents, `sys.implementation` will not change during a run of the interpreter, nor between implementation versions. (It may change between Python language versions, however.) See [PEP 421](https://www.python.org/dev/peps/pep-0421/) for more information.

*New in version 3.3.*

**sys.int_info**

A *struct sequence* that holds information about Python’s internal representation of integers. The attributes are read only.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>bits_per_digit</td>
<td>number of bits held in each digit. Python integers are stored internally in base $2^{\text{int_info.bits_per_digit}}$</td>
</tr>
<tr>
<td>sizeof_digit</td>
<td>size in bytes of the C type used to represent a digit</td>
</tr>
</tbody>
</table>

*New in version 3.1.*

**sys.__interactivehook__**

When this attribute exists, its value is automatically called (with no arguments) when the interpreter is launched in interactive mode. This is done after the `PYTHONSTARTUP` file is read, so that you can set this hook there. The `site` module sets this.

*New in version 3.4.*

**sys.intern(string)**

Enter *string* in the table of “interned” strings and return the interned string – which is *string* itself or a copy. Interning strings is useful to gain a little performance on dictionary lookup – if the keys in a dictionary are interned, and the lookup key is interned, the key
comparisons (after hashing) can be done by a pointer compare instead of a string compare. Normally, the names used in Python programs are automatically interned, and the dictionaries used to hold module, class or instance attributes have interned keys.

Interned strings are not immortal; you must keep a reference to the return value of `intern()` around to benefit from it.

```python
sys.is_finalizing()
```
Return `True` if the Python interpreter is shutting down, `False` otherwise.

*New in version 3.5.*

```python
sys.last_type
sys.last_value
sys.last_traceback
```
These three variables are not always defined; they are set when an exception is not handled and the interpreter prints an error message and a stack traceback. Their intended use is to allow an interactive user to import a debugger module and engage in post-mortem debugging without having to re-execute the command that caused the error. (Typical use is `import pdb; pdb.pm()` to enter the post-mortem debugger; see `pdb` module for more information.)

The meaning of the variables is the same as that of the return values from `exc_info()` above.

```python
sys.maxsize
```
An integer giving the maximum value a variable of type `Py_ssize_t` can take. It's usually $2^{31} - 1$ on a 32-bit platform and $2^{63} - 1$ on a 64-bit platform.
sys.**maxunicode**

An integer giving the value of the largest Unicode code point, i.e. 1114111 (0x10FFFF in hexadecimal).

*Changed in version 3.3:* Before **PEP 393**, `sys.maxunicode` used to be either 0xFFFF or 0x10FFFF, depending on the configuration option that specified whether Unicode characters were stored as UCS-2 or UCS-4.

**sys.meta_path**

A list of finder objects that have their `find_module()` methods called to see if one of the objects can find the module to be imported. The `find_module()` method is called at least with the absolute name of the module being imported. If the module to be imported is contained in a package then the parent package's `__path__` attribute is passed in as a second argument. The method returns None if the module cannot be found, else returns a loader.

`sys.meta_path` is searched before any implicit default finders or `sys.path`.

See **PEP 302** for the original specification.

**sys.modules**

This is a dictionary that maps module names to modules which have already been loaded. This can be manipulated to force reloading of modules and other tricks. However, replacing the dictionary will not necessarily work as expected and deleting essential items from the dictionary may cause Python to fail.

**sys.path**
A list of strings that specifies the search path for modules. Initialized from the environment variable `PYTHONPATH`, plus an installation-dependent default.

As initialized upon program startup, the first item of this list, `path[0]`, is the directory containing the script that was used to invoke the Python interpreter. If the script directory is not available (e.g. if the interpreter is invoked interactively or if the script is read from standard input), `path[0]` is the empty string, which directs Python to search modules in the current directory first. Notice that the script directory is inserted before the entries inserted as a result of `PYTHONPATH`.

A program is free to modify this list for its own purposes. Only strings and bytes should be added to `sys.path`; all other data types are ignored during import.

**See also:** Module `site` This describes how to use .pth files to extend `sys.path`.

**sys.path_hooks**
A list of callables that take a path argument to try to create a finder for the path. If a finder can be created, it is to be returned by the callable, else raise `ImportError`.

Originally specified in **PEP 302**.

**sys.path_importer_cache**
A dictionary acting as a cache for finder objects. The keys are paths that have been passed to `sys.path_hooks` and the values are the finders that are found. If a path is a valid file system path but no finder is found on `sys.path_hooks` then None is stored.
Originally specified in **PEP 302**.

*Changed in version 3.3:* None is stored instead of `imp.NullImporter` when no finder is found.

**sys.platform**

This string contains a platform identifier that can be used to append platform-specific components to `sys.path`, for instance.

For Unix systems, except on Linux, this is the lowercased OS name as returned by `uname -s` with the first part of the version as returned by `uname -r` appended, e.g. 'sunos5' or 'freebsd8', *at the time when Python was built*. Unless you want to test for a specific system version, it is therefore recommended to use the following idiom:

```python
if sys.platform.startswith('freebsd'):
    # FreeBSD-specific code here...
elif sys.platform.startswith('linux'):
    # Linux-specific code here...
```

For other systems, the values are:

<table>
<thead>
<tr>
<th>System</th>
<th>platform value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linux</td>
<td>'linux'</td>
</tr>
<tr>
<td>Windows</td>
<td>'win32'</td>
</tr>
<tr>
<td>Windows/Cygwin</td>
<td>'cygwin'</td>
</tr>
<tr>
<td>Mac OS X</td>
<td>'darwin'</td>
</tr>
</tbody>
</table>

*Changed in version 3.3:* On Linux, `sys.platform` doesn't contain the major version anymore. It is always 'linux', instead of 'linux2' or 'linux3'. Since older Python versions include the
version number, it is recommended to always use the `startswith` idiom presented above.

**See also:** `os.name` has a coarser granularity. `os.uname()` gives system-dependent version information. The `platform` module provides detailed checks for the system's identity.

### `sys.prefix`
A string giving the site-specific directory prefix where the platform independent Python files are installed; by default, this is the string `/usr/local`. This can be set at build time with the `--prefix` argument to the `configure` script. The main collection of Python library modules is installed in the directory `prefix/lib/pythonX.Y` while the platform independent header files (all except `pyconfig.h`) are stored in `prefix/include/pythonX.Y`, where `X.Y` is the version number of Python, for example 3.2.

**Note:** If a virtual environment is in effect, this value will be changed in `site.py` to point to the virtual environment. The value for the Python installation will still be available, via `base_prefix`.

### `sys.ps1`  
### `sys.ps2`
Strings specifying the primary and secondary prompt of the interpreter. These are only defined if the interpreter is in interactive mode. Their initial values in this case are `''` and `''`. If a non-string object is assigned to either variable, its `str()` is re-evaluated each time the interpreter prepares to read a new
interactive command; this can be used to implement a dynamic prompt.

**sys.setcheckinterval(interval)**

Set the interpreter’s “check interval”. This integer value determines how often the interpreter checks for periodic things such as thread switches and signal handlers. The default is 100, meaning the check is performed every 100 Python virtual instructions. Setting it to a larger value may increase performance for programs using threads. Setting it to a value <= 0 checks every virtual instruction, maximizing responsiveness as well as overhead.

*Deprecated since version 3.2:* This function doesn’t have an effect anymore, as the internal logic for thread switching and asynchronous tasks has been rewritten. Use `setswitchinterval()` instead.

**sys.setdlopenflags(n)**

Set the flags used by the interpreter for dlopen() calls, such as when the interpreter loads extension modules. Among other things, this will enable a lazy resolving of symbols when importing a module, if called as `sys.setdlopenflags(0)`. To share symbols across extension modules, call as `sys.setdlopenflags(os.RTLD_GLOBAL)`. Symbolic names for the flag values can be found in the `os` module (RTLD_xxx constants, e.g. `os.RTLD_LAZY`).

Availability: Unix.

**sys.setprofile(profilefunc)**

Set the system’s profile function, which allows you to implement a Python source code profiler in Python. See chapter *The Python
Profilers for more information on the Python profiler. The system’s profile function is called similarly to the system’s trace function (see `settrace()`), but it isn’t called for each executed line of code (only on call and return, but the return event is reported even when an exception has been set). The function is thread-specific, but there is no way for the profiler to know about context switches between threads, so it does not make sense to use this in the presence of multiple threads. Also, its return value is not used, so it can simply return None.

```
sys.setrecursionlimit(limit)
```

Set the maximum depth of the Python interpreter stack to `limit`. This limit prevents infinite recursion from causing an overflow of the C stack and crashing Python.

The highest possible limit is platform-dependent. A user may need to set the limit higher when they have a program that requires deep recursion and a platform that supports a higher limit. This should be done with care, because a too-high limit can lead to a crash.

If the new limit is too low at the current recursion depth, a `RecursionError` exception is raised.

*Changed in version 3.5.1:* A `RecursionError` exception is now raised if the new limit is too low at the current recursion depth.

```
sys.setswitchinterval(interval)
```

Set the interpreter’s thread switch interval (in seconds). This floating-point value determines the ideal duration of the “timeslices” allocated to concurrently running Python threads. Please note that the actual value can be higher, especially if long-running internal functions or methods are used. Also, which thread becomes scheduled at the end of the interval is the operating system’s
decision. The interpreter doesn’t have its own scheduler.

_New in version 3.2._

```
sys.settrace(tracefunc)
```

Set the system's trace function, which allows you to implement a Python source code debugger in Python. The function is thread-specific; for a debugger to support multiple threads, it must be registered using `settrace()` for each thread being debugged.

Trace functions should have three arguments: `frame`, `event`, and `arg`. `frame` is the current stack frame. `event` is a string: 'call', 'line', 'return', 'exception', 'c_call', 'c_return', or 'c_exception'. `arg` depends on the event type.

The trace function is invoked (with `event` set to 'call') whenever a new local scope is entered; it should return a reference to a local trace function to be used that scope, or None if the scope shouldn't be traced.

The local trace function should return a reference to itself (or to another function for further tracing in that scope), or None to turn off tracing in that scope.

The events have the following meaning:

'field'

A function is called (or some other code block entered). The global trace function is called; `arg` is None; the return value specifies the local trace function.

'field'

The interpreter is about to execute a new line of code or re-execute the condition of a loop. The local trace function is
called; `arg` is None; the return value specifies the new local trace function. See Objects/lnotab_notes.txt for a detailed explanation of how this works.

'return'
A function (or other code block) is about to return. The local trace function is called; `arg` is the value that will be returned, or None if the event is caused by an exception being raised. The trace function’s return value is ignored.

'exception'
An exception has occurred. The local trace function is called; `arg` is a tuple `(exception, value, traceback);` the return value specifies the new local trace function.

'c_call'
A C function is about to be called. This may be an extension function or a built-in. `arg` is the C function object.

'c_return'
A C function has returned. `arg` is the C function object.

'c_exception'
A C function has raised an exception. `arg` is the C function object.

Note that as an exception is propagated down the chain of callers, an 'exception' event is generated at each level.

For more information on code and frame objects, refer to The standard type hierarchy.

**CPython implementation detail:** The `settrace()` function is intended only for implementing debuggers, profilers, coverage tools and the like. Its behavior is part of the implementation platform, rather than part of the language definition, and thus may not be
available in all Python implementations.

```python
sys.set_tsc_dump(on_flag)
```
Activate dumping of VM measurements using the Pentium timestamp counter, if `on_flag` is true. Deactivate these dumps if `on_flag` is off. The function is available only if Python was compiled with `--with-tsc`. To understand the output of this dump, read `Python/ceval.c` in the Python sources.

**CPython implementation detail:** This function is intimately bound to CPython implementation details and thus not likely to be implemented elsewhere.

```python
sys.set_coroutine_wrapper(wrapper)
```
Allows intercepting creation of `coroutine` objects (only ones that are created by an `async def` function; generators decorated with `types.coroutine()` or `asyncio.coroutine()` will not be intercepted).

The `wrapper` argument must be either:

- a callable that accepts one argument (a coroutine object);
- None, to reset the wrapper.

If called twice, the new wrapper replaces the previous one. The function is thread-specific.

The `wrapper` callable cannot define new coroutines directly or indirectly:

```python
def wrapper(coro):
    async def wrap(coro):
        return await coro
    return wrap(coro)
```
sys.set_coroutine_wrapper(wrapper)

async def foo():
    pass

# The following line will fail with a RuntimeError,
# ``wrapper`` creates a ``wrap(coro)`` coroutine:
foo()

See also get_coroutine_wrapper().

*New in version 3.5:* See PEP 492 for more details.

**Note:** This function has been added on a provisional basis (see PEP 411 for details.) Use it only for debugging purposes.

```python
sys.stdin
sys.stdout
sys.stderr
```

File objects used by the interpreter for standard input, output and errors:

- `stdin` is used for all interactive input (including calls to `input()`);
- `stdout` is used for the output of `print()` and expression statements and for the prompts of `input()`;
- The interpreter's own prompts and its error messages go to `stderr`.

These streams are regular text files like those returned by the `open()` function. Their parameters are chosen as follows:

- The character encoding is platform-dependent. Under Windows, if the stream is interactive (that is, if its `isatty()`
method returns True), the console codepage is used, otherwise the ANSI code page. Under other platforms, the locale encoding is used (see `locale.getpreferredencoding()`).

Under all platforms though, you can override this value by setting the `PYTHONIOENCODING` environment variable before starting Python.

- When interactive, standard streams are line-buffered. Otherwise, they are block-buffered like regular text files. You can override this value with the `-u` command-line option.

**Note:** To write or read binary data from/to the standard streams, use the underlying binary `buffer` object. For example, to write bytes to `stdout`, use `sys.stdout.buffer.write(b'abc')`. However, if you are writing a library (and do not control in which context its code will be executed), be aware that the standard streams may be replaced with file-like objects like `io.StringIO` which do not support the buffer attribute.

```python
sys.__stdin__
sys.__stdout__
sys.__stderr__
```

These objects contain the original values of stdin, stderr and stdout at the start of the program. They are used during finalization, and could be useful to print to the actual standard stream no matter if the `sys.std*` object has been redirected.

It can also be used to restore the actual files to known working file objects in case they have been overwritten with a broken object. However, the preferred way to do this is to explicitly save the
previous stream before replacing it, and restore the saved object.

Note: Under some conditions stdin, stdout and stderr as well as the original values __stdin__, __stdout__ and __stderr__ can be None. It is usually the case for Windows GUI apps that aren’t connected to a console and Python apps started with `pythonw`.

**sys.thread_info**

A struct sequence holding information about the thread implementation.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Explanation</th>
</tr>
</thead>
</table>
| name      | Name of the thread implementation:  
  - 'nt': Windows threads  
  - 'pthread': POSIX threads  
  - 'solaris': Solaris threads |
| lock      | Name of the lock implementation:  
  - 'semaphore': a lock uses a semaphore  
  - 'mutex+cond': a lock uses a mutex and a condition variable  
  - None if this information is unknown |
| version   | Name and version of the thread library. It is a string, or None if these informations are unknown. |

*New in version 3.3.*
sys.tracebacklimit
When this variable is set to an integer value, it determines the maximum number of levels of traceback information printed when an unhandled exception occurs. The default is 1000. When set to 0 or less, all traceback information is suppressed and only the exception type and value are printed.

sys.version
A string containing the version number of the Python interpreter plus additional information on the build number and compiler used. This string is displayed when the interactive interpreter is started. Do not extract version information out of it, rather, use version_info and the functions provided by the platform module.

sys.api_version
The C API version for this interpreter. Programmers may find this useful when debugging version conflicts between Python and extension modules.

sys.version_info
A tuple containing the five components of the version number: major, minor, micro, releaselevel, and serial. All values except releaselevel are integers; the release level is 'alpha', 'beta', 'candidate', or 'final'. The version_info value corresponding to the Python version 2.0 is (2, 0, 0, 'final', 0). The components can also be accessed by name, so sys.version_info[0] is equivalent to sys.version_info.major and so on.

Changed in version 3.1: Added named component attributes.
sys.**warnoptions**
This is an implementation detail of the warnings framework; do not modify this value. Refer to the `warnings` module for more information on the warnings framework.

sys.**winver**
The version number used to form registry keys on Windows platforms. This is stored as string resource 1000 in the Python DLL. The value is normally the first three characters of `version`. It is provided in the `sys` module for informational purposes; modifying this value has no effect on the registry keys used by Python. Availability: Windows.

sys.**_xoptions**
A dictionary of the various implementation-specific flags passed through the `-X` command-line option. Option names are either mapped to their values, if given explicitly, or to `True`. Example:

```bash
$ ./python -Xa=b -Xc
Python 3.2a3+ (py3k, Oct 16 2010, 20:14:50)
[GCC 4.4.3] on linux2
Type "help", "copyright", "credits" or "license"
>>> import sys
>>> sys._xoptions
{'a': 'b', 'c': True}
```

**CPython implementation detail**: This is a CPython-specific way of accessing options passed through `-X`. Other implementations may export them through other means, or not at all. 
*New in version 3.2.*
29.2. `sysconfig` — Provide access to Python’s configuration information

*New in version 3.2.*

**Source code:** `Lib/sysconfig.py`  

The `sysconfig` module provides access to Python's configuration information like the list of installation paths and the configuration variables relevant for the current platform.
29.2.1. Configuration variables

A Python distribution contains a Makefile and a pyconfig.h header file that are necessary to build both the Python binary itself and third-party C extensions compiled using distutils.

`sysconfig` puts all variables found in these files in a dictionary that can be accessed using `get_config_vars()` or `get_config_var()`.

Notice that on Windows, it's a much smaller set.

`sysconfig.get_config_vars(*args)`

With no arguments, return a dictionary of all configuration variables relevant for the current platform.

With arguments, return a list of values that result from looking up each argument in the configuration variable dictionary.

For each argument, if the value is not found, return None.

`sysconfig.get_config_var(name)`

Return the value of a single variable `name`. Equivalent to `get_config_vars().get(name)`.

If `name` is not found, return None.

Example of usage:

```python
>>> import sysconfig
>>> sysconfig.get_config_var('Py_ENABLE_SHARED')
0
>>> sysconfig.get_config_var('LIBDIR')
```
'/usr/local/lib'

```python
>>> sysconfig.get_config_vars('AR', 'CXX')
['ar', 'g++']
```
29.2.2. Installation paths

Python uses an installation scheme that differs depending on the platform and on the installation options. These schemes are stored in `sysconfig` under unique identifiers based on the value returned by `os.name`.

Every new component that is installed using `distutils` or a Distutils-based system will follow the same scheme to copy its file in the right places.

Python currently supports seven schemes:

- `posix_prefix`: scheme for Posix platforms like Linux or Mac OS X. This is the default scheme used when Python or a component is installed.
- `posix_home`: scheme for Posix platforms used when a `home` option is used upon installation. This scheme is used when a component is installed through Distutils with a specific home prefix.
- `posix_user`: scheme for Posix platforms used when a component is installed through Distutils and the `user` option is used. This scheme defines paths located under the user home directory.
- `nt`: scheme for NT platforms like Windows.
- `nt_user`: scheme for NT platforms, when the `user` option is used.

Each scheme is itself composed of a series of paths and each path has a unique identifier. Python currently uses eight paths:

- `stdlib`: directory containing the standard Python library files that are not platform-specific.
- `platstdlib`: directory containing the standard Python library files that are platform-specific.
- **platlib**: directory for site-specific, platform-specific files.
- **purelib**: directory for site-specific, non-platform-specific files.
- **include**: directory for non-platform-specific header files.
- **platinclude**: directory for platform-specific header files.
- **scripts**: directory for script files.
- **data**: directory for data files.

**sysconfig** provides some functions to determine these paths.

**sysconfig.get_scheme_names()**

Return a tuple containing all schemes currently supported in **sysconfig**.

**sysconfig.get_path_names()**

Return a tuple containing all path names currently supported in **sysconfig**.

**sysconfig.get_path(name[, scheme[, vars[, expand]]])**

Return an installation path corresponding to the path *name*, from the install scheme named *scheme*.

*name* has to be a value from the list returned by **get_path_names()**.

**sysconfig** stores installation paths corresponding to each path name, for each platform, with variables to be expanded. For instance the *stdlib* path for the *nt* scheme is: `{base}/Lib`.

**get_path()** will use the variables returned by **get_config_vars()** to expand the path. All variables have default values for each platform so one may call this function and get the default value.
If `scheme` is provided, it must be a value from the list returned by `get_scheme_names()`. Otherwise, the default scheme for the current platform is used.

If `vars` is provided, it must be a dictionary of variables that will update the dictionary returned by `get_config_vars()`.

If `expand` is set to False, the path will not be expanded using the variables.

If `name` is not found, return None.

```python
sysconfig.get_paths([scheme, vars, expand])
```

Returns a dictionary containing all installation paths corresponding to an installation scheme. See `get_path()` for more information.

If `scheme` is not provided, will use the default scheme for the current platform.

If `vars` is provided, it must be a dictionary of variables that will update the dictionary used to expand the paths.

If `expand` is set to False, the paths will not be expanded.

If `scheme` is not an existing scheme, `get_paths()` will raise a `KeyError`. 

```python
```
29.2.3. Other functions

sysconfig.get_python_version()
Return the MAJOR.MINOR Python version number as a string. Similar to sys.version[:3].

sysconfig.get_platform()
Return a string that identifies the current platform.

This is used mainly to distinguish platform-specific build directories and platform-specific built distributions. Typically includes the OS name and version and the architecture (as supplied by os.uname()), although the exact information included depends on the OS; e.g. for IRIX the architecture isn’t particularly important (IRIX only runs on SGI hardware), but for Linux the kernel version isn’t particularly important.

Examples of returned values:

- linux-i586
- linux-alpha (?)
- solaris-2.6-sun4u
- irix-5.3
- irix64-6.2

Windows will return one of:

- win-amd64 (64bit Windows on AMD64 (aka x86_64, Intel64, EM64T, etc)
- win-ia64 (64bit Windows on Itanium)
- win32 (all others - specifically, sys.platform is returned)

Mac OS X can return:
• macosx-10.6-ppc
• macosx-10.4-ppc64
• macosx-10.3-i386
• macosx-10.4-fat

For other non-POSIX platforms, currently just returns `sys.platform`.

`sysconfig.is_python_build()`  
Return True if the current Python installation was built from source.

`sysconfig.parse_config_h(fp[, vars])`  
Parse a config.h-style file.

`fp` is a file-like object pointing to the config.h-like file.

A dictionary containing name/value pairs is returned. If an optional dictionary is passed in as the second argument, it is used instead of a new dictionary, and updated with the values read in the file.

`sysconfig.get_config_h_filename()`  
Return the path of pyconfig.h.

`sysconfig.get_makefile_filename()`  
Return the path of Makefile.
29.2.4. Using `sysconfig` as a script

You can use `sysconfig` as a script with Python’s `-m` option:

```
$ python -m sysconfig
Platform: "macosx-10.4-i386"
Python version: "3.2"
Current installation scheme: "posix_prefix"

Paths:
  data = "/usr/local"
  include = "/Users/tarek/Dev/svn.python.org/py3k/Include"
  platincludedir = "."
  platlib = "/usr/local/lib/python3.2/site-packages"
  platstdlibdir = "/usr/local/lib/python3.2"  
  purelib = "/usr/local/lib/python3.2/site-packages"
  scripts = "/usr/local/bin"
  stdlib = "/usr/local/lib/python3.2"

Variables:
  AC_APPLE_UNIVERSAL_BUILD = "0"
  AIX_GENUINE_CPLUSPLUS = "0"
  AR = "ar"
  ARFLAGS = "rc"
  ASDLGEN = "/Parser/astl_c.py"
  ...
```

This call will print in the standard output the information returned by `get_platform()`, `get_python_version()`, `get_path()` and `get_config_vars()`.
29.3. **builtins** — Built-in objects

This module provides direct access to all ‘built-in’ identifiers of Python; for example, `builtins.open` is the full name for the built-in function `open()`. See Built-in Functions and Built-in Constants for documentation.

This module is not normally accessed explicitly by most applications, but can be useful in modules that provide objects with the same name as a built-in value, but in which the built-in of that name is also needed. For example, in a module that wants to implement an `open()` function that wraps the built-in `open()`, this module can be used directly:

```python
import builtins

def open(path):
    f = builtins.open(path, 'r')
    return UpperCaser(f)

class UpperCaser:
    '''Wrapper around a file that converts output to upper-case.'''

    def __init__(self, f):
        self._f = f

    def read(self, count=-1):
        return self._f.read(count).upper()

    # ...
```

As an implementation detail, most modules have the name
__builtins__ made available as part of their globals. The value of __builtins__ is normally either this module or the value of this module's __dict__ attribute. Since this is an implementation detail, it may not be used by alternate implementations of Python.
29.4. __main__ — Top-level script environment

'__main__' is the name of the scope in which top-level code executes. A module's __name__ is set equal to '__main__' when read from standard input, a script, or from an interactive prompt.

A module can discover whether or not it is running in the main scope by checking its own __name__, which allows a common idiom for conditionally executing code in a module when it is run as a script or with python -m but not when it is imported:

```python
if __name__ == '__main__':
    # execute only if run as a script
    main()
```

For a package, the same effect can be achieved by including a __main__.py module, the contents of which will be executed when the module is run with -m.
29.5. **warnings** — Warning control

**Source code:** Lib/warnings.py

Warning messages are typically issued in situations where it is useful to alert the user of some condition in a program, where that condition (normally) doesn't warrant raising an exception and terminating the program. For example, one might want to issue a warning when a program uses an obsolete module.

Python programmers issue warnings by calling the `warn()` function defined in this module. (C programmers use `PyErr_WarnEx()`; see *Exception Handling* for details).

Warning messages are normally written to `sys.stderr`, but their disposition can be changed flexibly, from ignoring all warnings to turning them into exceptions. The disposition of warnings can vary based on the warning category (see below), the text of the warning message, and the source location where it is issued. Repetitions of a particular warning for the same source location are typically suppressed.

There are two stages in warning control: first, each time a warning is issued, a determination is made whether a message should be issued or not; next, if a message is to be issued, it is formatted and printed using a user-settable hook.

The determination whether to issue a warning message is controlled by the warning filter, which is a sequence of matching rules and
actions. Rules can be added to the filter by calling `filterwarnings()` and reset to its default state by calling `resetwarnings()`.

The printing of warning messages is done by calling `showwarning()`, which may be overridden; the default implementation of this function formats the message by calling `formatwarning()`, which is also available for use by custom implementations.

**See also:** `logging.captureWarnings()` allows you to handle all warnings with the standard logging infrastructure.
29.5.1. Warning Categories

There are a number of built-in exceptions that represent warning categories. This categorization is useful to be able to filter out groups of warnings. The following warnings category classes are currently defined:

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warning</td>
<td>This is the base class of all warning category classes. It is a subclass of Exception.</td>
</tr>
<tr>
<td>UserWarning</td>
<td>The default category for warn().</td>
</tr>
<tr>
<td>DeprecationWarning</td>
<td>Base category for warnings about deprecated features (ignored by default).</td>
</tr>
<tr>
<td>SyntaxWarning</td>
<td>Base category for warnings about dubious syntactic features.</td>
</tr>
<tr>
<td>RuntimeWarning</td>
<td>Base category for warnings about dubious runtime features.</td>
</tr>
<tr>
<td>FutureWarning</td>
<td>Base category for warnings about constructs that will change semantically in the future.</td>
</tr>
<tr>
<td>PendingDeprecationWarning</td>
<td>Base category for warnings about features that will be deprecated in the future (ignored by default).</td>
</tr>
<tr>
<td>ImportWarning</td>
<td>Base category for warnings triggered during the process of importing a module (ignored by</td>
</tr>
</tbody>
</table>
While these are technically built-in exceptions, they are documented here, because conceptually they belong to the warnings mechanism.

User code can define additional warning categories by subclassing one of the standard warning categories. A warning category must always be a subclass of the `Warning` class.
29.5.2. The Warnings Filter

The warnings filter controls whether warnings are ignored, displayed, or turned into errors (raising an exception).

Conceptually, the warnings filter maintains an ordered list of filter specifications; any specific warning is matched against each filter specification in the list in turn until a match is found; the match determines the disposition of the match. Each entry is a tuple of the form \((action, message, category, module, lineno)\), where:

- **action** is one of the following strings:

<table>
<thead>
<tr>
<th>Value</th>
<th>Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;error&quot;</td>
<td>turn matching warnings into exceptions</td>
</tr>
<tr>
<td>&quot;ignore&quot;</td>
<td>never print matching warnings</td>
</tr>
<tr>
<td>&quot;always&quot;</td>
<td>always print matching warnings</td>
</tr>
<tr>
<td>&quot;default&quot;</td>
<td>print the first occurrence of matching warnings for each location where the warning is issued</td>
</tr>
<tr>
<td>&quot;module&quot;</td>
<td>print the first occurrence of matching warnings for each module where the warning is issued</td>
</tr>
<tr>
<td>&quot;once&quot;</td>
<td>print only the first occurrence of matching warnings, regardless of location</td>
</tr>
</tbody>
</table>

- **message** is a string containing a regular expression that the warning message must match (the match is compiled to always be case-insensitive).

- **category** is a class (a subclass of `Warning`) of which the warning category must be a subclass in order to match.
• *module* is a string containing a regular expression that the module name must match (the match is compiled to be case-sensitive).

• *lineno* is an integer that the line number where the warning occurred must match, or 0 to match all line numbers.

Since the **Warning** class is derived from the built-in **Exception** class, to turn a warning into an error we simply raise `category(message)`.

The warnings filter is initialized by `-W` options passed to the Python interpreter command line. The interpreter saves the arguments for all `-W` options without interpretation in `sys.warnoptions`; the `warnings` module parses these when it is first imported (invalid options are ignored, after printing a message to `sys.stderr`).

### 29.5.2.1. Default Warning Filters

By default, Python installs several warning filters, which can be overridden by the command-line options passed to `-W` and calls to `filterwarnings()`.

- **DeprecationWarning** and **PendingDeprecationWarning**, and **ImportWarning** are ignored.
- **BytesWarning** is ignored unless the `-b` option is given once or twice; in this case this warning is either printed (`-b`) or turned into an exception (`-bb`).
- **ResourceWarning** is ignored unless Python was built in debug mode.

*Changed in version 3.2: **DeprecationWarning** is now ignored by default in addition to **PendingDeprecationWarning**.*
29.5.3. Temporarily Suppressing Warnings

If you are using code that you know will raise a warning, such as a deprecated function, but do not want to see the warning, then it is possible to suppress the warning using the `catch_warnings` context manager:

```python
import warnings
def fxn():
    warnings.warn("deprecated", DeprecationWarning)

with warnings.catch_warnings():
    warnings.simplefilter("ignore")
    fxn()
```

While within the context manager all warnings will simply be ignored. This allows you to use known-deprecated code without having to see the warning while not suppressing the warning for other code that might not be aware of its use of deprecated code. Note: this can only be guaranteed in a single-threaded application. If two or more threads use the `catch_warnings` context manager at the same time, the behavior is undefined.
29.5.4. Testing Warnings

To test warnings raised by code, use the `catch_warnings` context manager. With it you can temporarily mutate the warnings filter to facilitate your testing. For instance, do the following to capture all raised warnings to check:

```python
import warnings

def fxn():
    warnings.warn("deprecated", DeprecationWarning)

with warnings.catch_warnings(record=True) as w:
    # Cause all warnings to always be triggered.
    warnings.simplefilter("always")
    # Trigger a warning.
    fxn()
    # Verify some things
    assert len(w) == 1
    assert issubclass(w[-1].category, DeprecationWarning)
    assert "deprecated" in str(w[-1].message)
```

One can also cause all warnings to be exceptions by using `error` instead of `always`. One thing to be aware of is that if a warning has already been raised because of a once/default rule, then no matter what filters are set the warning will not be seen again unless the warnings registry related to the warning has been cleared.

Once the context manager exits, the warnings filter is restored to its state when the context was entered. This prevents tests from changing the warnings filter in unexpected ways between tests and leading to indeterminate test results. The `showwarning()` function in the
module is also restored to its original value. Note: this can only be guaranteed in a single-threaded application. If two or more threads use the `catch_warnings` context manager at the same time, the behavior is undefined.

When testing multiple operations that raise the same kind of warning, it is important to test them in a manner that confirms each operation is raising a new warning (e.g. set warnings to be raised as exceptions and check the operations raise exceptions, check that the length of the warning list continues to increase after each operation, or else delete the previous entries from the warnings list before each new operation).
29.5.5. Updating Code For New Versions of Python

Warnings that are only of interest to the developer are ignored by default. As such you should make sure to test your code with typically ignored warnings made visible. You can do this from the command-line by passing `-wd` to the interpreter (this is shorthand for `-W default`). This enables default handling for all warnings, including those that are ignored by default. To change what action is taken for encountered warnings you simply change what argument is passed to `-W`, e.g. `-W error`. See the `-W` flag for more details on what is possible.

To programmatically do the same as `-wd`, use:

```
warnings.simplefilter('default')
```

Make sure to execute this code as soon as possible. This prevents the registering of what warnings have been raised from unexpectedly influencing how future warnings are treated.

Having certain warnings ignored by default is done to prevent a user from seeing warnings that are only of interest to the developer. As you do not necessarily have control over what interpreter a user uses to run their code, it is possible that a new version of Python will be released between your release cycles. The new interpreter release could trigger new warnings in your code that were not there in an older interpreter, e.g. `DeprecationWarning` for a module that you are using. While you as a developer want to be notified that your code is using a deprecated module, to a user this information is essentially noise and provides no benefit to them.
The `unittest` module has been also updated to use the 'default' filter while running tests.
### 29.5.6. Available Functions

**warnings.warn**(message, category=None, stacklevel=1)

Issue a warning, or maybe ignore it or raise an exception. The `category` argument, if given, must be a warning category class (see above); it defaults to `UserWarning`. Alternatively `message` can be a `Warning` instance, in which case `category` will be ignored and `message.__class__` will be used. In this case the message text will be `str(message)`. This function raises an exception if the particular warning issued is changed into an error by the warnings filter see above. The `stacklevel` argument can be used by wrapper functions written in Python, like this:

```python
def deprecation(message):
    warnings.warn(message, DeprecationWarning, stacklevel=2)
```

This makes the warning refer to `deprecation()`'s caller, rather than to the source of `deprecation()` itself (since the latter would defeat the purpose of the warning message).

**warnings.warn_explicit**(message, category, filename, lineno, module=None, registry=None, module_globals=None)

This is a low-level interface to the functionality of `warn()`, passing in explicitly the message, category, filename and line number, and optionally the module name and the registry (which should be the `__warningregistry__` dictionary of the module). The module name defaults to the filename with `.py` stripped; if no registry is passed, the warning is never suppressed. `message` must be a string and `category` a subclass of `Warning` or `message` may be a `Warning` instance, in which case `category` will be ignored.
module_globals, if supplied, should be the global namespace in use by the code for which the warning is issued. (This argument is used to support displaying source for modules found in zipfiles or other non-filesystem import sources).

```
warnings.showwarning(message, category, filename, lineno, 
file=None, line=None)
```

Write a warning to a file. The default implementation calls formatwarning(message, category, filename, lineno, line) and writes the resulting string to file, which defaults to sys.stderr. You may replace this function with any callable by assigning to warnings.showwarning. line is a line of source code to be included in the warning message; if line is not supplied, showwarning() will try to read the line specified by filename and lineno.

```
warnings.formatwarning(message, category, filename, lineno, 
line=None)
```

Format a warning the standard way. This returns a string which may contain embedded newlines and ends in a newline. line is a line of source code to be included in the warning message; if line is not supplied, formatwarning() will try to read the line specified by filename and lineno.

```
warnings.filterwarnings(action, message="", 
category=Warning, module="", lineno=0, append=False)
```

Insert an entry into the list of warnings filter specifications. The entry is inserted at the front by default; if append is true, it is inserted at the end. This checks the types of the arguments, compiles the message and module regular expressions, and inserts them as a tuple in the list of warnings filters. Entries closer to the front of the list override entries later in the list, if both match a
particular warning. Omitted arguments default to a value that matches everything.

```
warnings.simplefilter(action=category=Warning, lineno=0, append=False)
```

Insert a simple entry into the list of warnings filter specifications. The meaning of the function parameters is as for `filterwarnings()`, but regular expressions are not needed as the filter inserted always matches any message in any module as long as the category and line number match.

```
warnings.resetwarnings()
```

Reset the warnings filter. This discards the effect of all previous calls to `filterwarnings()`, including that of the `-W` command line options and calls to `simplefilter()`.
29.5.7. Available Context Managers

```python
class warnings.catch_warnings(*, record=False, module=None)
```

A context manager that copies and, upon exit, restores the warnings filter and the `showwarning()` function. If the `record` argument is `False` (the default) the context manager returns `None` on entry. If `record` is `True`, a list is returned that is progressively populated with objects as seen by a custom `showwarning()` function (which also suppresses output to `sys.stdout`). Each object in the list has attributes with the same names as the arguments to `showwarning()`.

The `module` argument takes a module that will be used instead of the module returned when you import `warnings` whose filter will be protected. This argument exists primarily for testing the `warnings` module itself.

**Note:** The `catch_warnings` manager works by replacing and then later restoring the module's `showwarning()` function and internal list of filter specifications. This means the context manager is modifying global state and therefore is not thread-safe.
29.6. `contextlib` — Utilities for `with`-statement contexts

Source code: `Lib/contextlib.py`

This module provides utilities for common tasks involving the `with` statement. For more information see also Context Manager Types and With Statement Context Managers.
29.6.1. Utilities

Functions and classes provided:

@contextlib.contextmanager

This function is a decorator that can be used to define a factory function for with statement context managers, without needing to create a class or separate __enter__() and __exit__() methods.

A simple example (this is not recommended as a real way of generating HTML!):

```python
from contextlib import contextmanager

class contextmanager:
    def __enter__(self):
        return self

    def __exit__(self, exc_type, exc_val, exc_tb):
        if exc_val:
            print(exc_val)

def tag(name):
    print("<%s>") % name
    yield
    print("</%s>") % name

>>> with tag("h1"):
    ...   print("foo")
    ...
<h1>
foo
</h1>
```

The function being decorated must return a generator-iterator when called. This iterator must yield exactly one value, which will be bound to the targets in the with statement's as clause, if any.

At the point where the generator yields, the block nested in the
The `with` statement is executed. The generator is then resumed after the block is exited. If an unhandled exception occurs in the block, it is reraised inside the generator at the point where the yield occurred. Thus, you can use a `try...except...finally` statement to trap the error (if any), or ensure that some cleanup takes place. If an exception is trapped merely in order to log it or to perform some action (rather than to suppress it entirely), the generator must reraise that exception. Otherwise the generator context manager will indicate to the `with` statement that the exception has been handled, and execution will resume with the statement immediately following the `with` statement.

`contextmanager()` uses `ContextDecorator` so the context managers it creates can be used as decorators as well as in `with` statements. When used as a decorator, a new generator instance is implicitly created on each function call (this allows the otherwise “one-shot” context managers created by `contextmanager()` to meet the requirement that context managers support multiple invocations in order to be used as decorators).

*Changed in version 3.2:* Use of `ContextDecorator`.

`contextlib.closing(thing)`

Return a context manager that closes `thing` upon completion of the block. This is basically equivalent to:

```python
from contextlib import contextmanager

@contextmanager
def closing(thing):
    try:
        yield thing
    finally:
```
And lets you write code like this:

```python
from contextlib import closing
from urllib.request import urlopen

with closing(urlopen('http://www.python.org')) as page:
    for line in page:
        print(line)
```

without needing to explicitly close `page`. Even if an error occurs, `page.close()` will be called when the `with` block is exited.

```python
contextlib.suppress(*exceptions)
```

Return a context manager that suppresses any of the specified exceptions if they occur in the body of a `with` statement and then resumes execution with the first statement following the end of the `with` statement.

As with any other mechanism that completely suppresses exceptions, this context manager should be used only to cover very specific errors where silently continuing with program execution is known to be the right thing to do.

For example:

```python
from contextlib import suppress

with suppress(FileNotFoundError):
    os.remove('somefile.tmp')

with suppress(FileNotFoundError):
    os.remove('someotherfile.tmp')
```
This code is equivalent to:

```python
try:
    os.remove('somefile.tmp')
except FileNotFoundError:
    pass

try:
    os.remove('someotherfile.tmp')
except FileNotFoundError:
    pass
```

This context manager is **reentrant**.

*New in version 3.4.*

```python
contextlib.redirect_stdout(new_target)
```

Context manager for temporarily redirecting `sys.stdout` to another file or file-like object.

This tool adds flexibility to existing functions or classes whose output is hardwired to stdout.

For example, the output of `help()` normally is sent to `sys.stdout`. You can capture that output in a string by redirecting the output to an `io.StringIO` object:

```python
f = io.StringIO()
with redirect_stdout(f):
    help(pow)
s = f.getvalue()
```

To send the output of `help()` to a file on disk, redirect the output to a regular file:
```python
with open('help.txt', 'w') as f:
    with redirect_stdout(f):
        help(pow)
```

To send the output of `help()` to `sys.stderr`:

```python
with redirect_stdout(sys.stderr):
    help(pow)
```

Note that the global side effect on `sys.stdout` means that this context manager is not suitable for use in library code and most threaded applications. It also has no effect on the output of subprocesses. However, it is still a useful approach for many utility scripts.

This context manager is reentrant.

*New in version 3.4.*

```
contextlib.redirect_stderr(new_target)
```

Similar to `redirect_stdout()` but redirecting `sys.stderr` to another file or file-like object.

This context manager is reentrant.

*New in version 3.5.*

```
class contextlib.ContextDecorator
```

A base class that enables a context manager to also be used as a decorator.

Context managers inheriting from `ContextDecorator` have to implement `__enter__` and `__exit__` as normal. `__exit__` retains its optional exception handling even when used as a
ContextDecorator is used by `contextmanager()`, so you get this functionality automatically.

Example of ContextDecorator:

```python
from contextlib import ContextDecorator

class mycontext(ContextDecorator):
    def __enter__(self):
        print('Starting')
        return self

    def __exit__(self, *exc):
        print('Finishing')
        return False

>>> @mycontext()
... def function():
...     print('The bit in the middle')
... >>> function()
Starting
The bit in the middle
Finishing

>>> with mycontext():
...     print('The bit in the middle')
... Starting
The bit in the middle
Finishing
```

This change is just syntactic sugar for any construct of the following form:
```python
def f():
    with cm():
        # Do stuff
```

ContextDecorator lets you instead write:

```python
@cm()
def f():
    # Do stuff
```

It makes it clear that the cm applies to the whole function, rather than just a piece of it (and saving an indentation level is nice, too).

Existing context managers that already have a base class can be extended by using ContextDecorator as a mixin class:

```python
from contextlib import ContextDecorator

class mycontext(ContextBaseClass, ContextDecorator):
    def __enter__(self):
        return self

    def __exit__(self, *exc):
        return False
```

**Note:** As the decorated function must be able to be called multiple times, the underlying context manager must support use in multiple `with` statements. If this is not the case, then the original construct with the explicit `with` statement inside the function should be used.

*New in version 3.2.*

```python
class contextlib.ExitStack
```
A context manager that is designed to make it easy to programmatically combine other context managers and cleanup functions, especially those that are optional or otherwise driven by input data.

For example, a set of files may easily be handled in a single with statement as follows:

```python
with ExitStack() as stack:
    files = [stack.enter_context(open(fname)) for
    # All opened files will automatically be closed
    # the with statement, even if attempts to open
    # in the list raise an exception
```

Each instance maintains a stack of registered callbacks that are called in reverse order when the instance is closed (either explicitly or implicitly at the end of a `with` statement). Note that callbacks are not invoked implicitly when the context stack instance is garbage collected.

This stack model is used so that context managers that acquire their resources in their `__init__` method (such as file objects) can be handled correctly.

Since registered callbacks are invoked in the reverse order of registration, this ends up behaving as if multiple nested `with` statements had been used with the registered set of callbacks. This even extends to exception handling - if an inner callback suppresses or replaces an exception, then outer callbacks will be passed arguments based on that updated state.

This is a relatively low level API that takes care of the details of correctly unwinding the stack of exit callbacks. It provides a
suitable foundation for higher level context managers that manipulate the exit stack in application specific ways.

*New in version 3.3.*

**enter_context(cm)**

Enters a new context manager and adds its `__exit__()` method to the callback stack. The return value is the result of the context manager's own `__enter__()` method.

These context managers may suppress exceptions just as they normally would if used directly as part of a `with` statement.

**push(exit)**

Adds a context manager's `__exit__()` method to the callback stack.

As `__enter__` is *not* invoked, this method can be used to cover part of an `__enter__()` implementation with a context manager's own `__exit__()` method.

If passed an object that is not a context manager, this method assumes it is a callback with the same signature as a context manager's `__exit__()` method and adds it directly to the callback stack.

By returning true values, these callbacks can suppress exceptions the same way context manager `__exit__()` methods can.

The passed in object is returned from the function, allowing this method to be used as a function decorator.
**callback**(*callback*, *args*, **kwds*)

Accepts an arbitrary callback function and arguments and adds it to the callback stack.

Unlike the other methods, callbacks added this way cannot suppress exceptions (as they are never passed the exception details).

The passed in callback is returned from the function, allowing this method to be used as a function decorator.

**pop_all()**

Transfers the callback stack to a fresh `ExitStack` instance and returns it. No callbacks are invoked by this operation - instead, they will now be invoked when the new stack is closed (either explicitly or implicitly at the end of a `with` statement).

For example, a group of files can be opened as an “all or nothing” operation as follows:

```python
with ExitStack() as stack:
    files = [stack.enter_context(open(fname)) for fname]
    # Hold onto the close method, but don't call it yet.
    close_files = stack.pop_all().close
    # If opening any file fails, all previously closed automatically. If all files are open,
    # they will remain open even after the with block.
    # close_files() can then be invoked explicitly.
```

**close()**

Immediately unwinds the callback stack, invoking callbacks in the reverse order of registration. For any context managers and exit callbacks registered, the arguments passed in will indicate
that no exception occurred.
29.6.2. Examples and Recipes

This section describes some examples and recipes for making effective use of the tools provided by contextlib.

29.6.2.1. Supporting a variable number of context managers

The primary use case for ExitStack is the one given in the class documentation: supporting a variable number of context managers and other cleanup operations in a single with statement. The variability may come from the number of context managers needed being driven by user input (such as opening a user specified collection of files), or from some of the context managers being optional:

```python
with ExitStack() as stack:
    for resource in resources:
        stack.enter_context(resource)
    if need_special_resource():
        special = acquire_special_resource()
        stack.callback(release_special_resource, special)
# Perform operations that use the acquired resource
```

As shown, ExitStack also makes it quite easy to use with statements to manage arbitrary resources that don’t natively support the context management protocol.

29.6.2.2. Simplifying support for single optional context managers
In the specific case of a single optional context manager, `ExitStack` instances can be used as a “do nothing” context manager, allowing a context manager to easily be omitted without affecting the overall structure of the source code:

```python
def debug_trace(details):
    if __debug__:
        return TraceContext(details)
        # Don't do anything special with the context in
    return ExitStack()

with debug_trace():
    # Suite is traced in debug mode, but runs normal
```

29.6.2.3. Catching exceptions from `__enter__` methods

It is occasionally desirable to catch exceptions from an `__enter__` method implementation, `without` inadvertently catching exceptions from the `with` statement body or the context manager’s `__exit__` method. By using `ExitStack` the steps in the context management protocol can be separated slightly in order to allow this:

```python
stack = ExitStack()
try:
    x = stack.enter_context(cm)
except Exception:
    # handle __enter__ exception
else:
    with stack:
        # Handle normal case
```

Actually needing to do this is likely to indicate that the underlying API
should be providing a direct resource management interface for use with `try/except/finally` statements, but not all APIs are well designed in that regard. When a context manager is the only resource management API provided, then `ExitStack` can make it easier to handle various situations that can't be handled directly in a `with` statement.

29.6.2.4. Cleaning up in an `__enter__` implementation

As noted in the documentation of `ExitStack.push()`, this method can be useful in cleaning up an already allocated resource if later steps in the `__enter__()` implementation fail.

Here's an example of doing this for a context manager that accepts resource acquisition and release functions, along with an optional validation function, and maps them to the context management protocol:

```python
from contextlib import contextmanager, ExitStack

class ResourceManager:
    def __init__(self, acquire_resource, release_resource):
        self.acquire_resource = acquire_resource
        self.release_resource = release_resource
        if check_resource_ok is None:
            def check_resource_ok(resource):
                return True
            self.check_resource_ok = check_resource_ok

@contextmanager
def _cleanup_on_error(self):
```
with ExitStack() as stack:
    stack.push(self)
    yield
    # The validation check passed and didn't raise an exception
    # Accordingly, we want to keep the resource and pass it back to our caller
    stack.pop_all()

def __enter__(self):
    resource = self.acquire_resource()
    with self._cleanup_on_error():
        if not self.check_resource_ok(resource):
            msg = "Failed validation for {!r}"
            raise RuntimeError(msg.format(resource))
    return resource

def __exit__(self, *exc_details):
    # We don't need to duplicate any of our resource release logic
    self.release_resource()

29.6.2.5. Replacing any use of try-finally and flag variables

A pattern you will sometimes see is a try-finally statement with a flag variable to indicate whether or not the body of the finally clause should be executed. In its simplest form (that can't already be handled just by using an except clause instead), it looks something like this:

cleanup_needed = True
try:
    result = perform_operation()
    if result:
        cleanup_needed = False
finally:
    if cleanup_needed:
        cleanup_resources()

As with any try statement based code, this can cause problems for development and review, because the setup code and the cleanup code can end up being separated by arbitrarily long sections of code.

ExitStack makes it possible to instead register a callback for execution at the end of a with statement, and then later decide to skip executing that callback:

```python
from contextlib import ExitStack
with ExitStack() as stack:
    stack.callback(cleanup_resources)
    result = perform_operation()
    if result:
        stack.pop_all()
```

This allows the intended cleanup up behaviour to be made explicit up front, rather than requiring a separate flag variable.

If a particular application uses this pattern a lot, it can be simplified even further by means of a small helper class:

```python
from contextlib import ExitStack
class Callback(ExitStack):
    def __init__(self, callback, *args, **kwds):
        super(Callback, self).__init__()
        self.callback(callback, *args, **kwds)

    def cancel(self):
        self.pop_all()
```
with Callback(cleanup_resources) as cb:
    result = perform_operation()
    if result:
        cb.cancel()

If the resource cleanup isn't already neatly bundled into a standalone function, then it is still possible to use the decorator form of `ExitStack.callback()` to declare the resource cleanup in advance:

```python
from contextlib import ExitStack

with ExitStack() as stack:
    @stack.callback
def cleanup_resources():
        ...
        result = perform_operation()
        if result:
            stack.pop_all()
```

Due to the way the decorator protocol works, a callback function declared this way cannot take any parameters. Instead, any resources to be released must be accessed as closure variables.

**29.6.2.6. Using a context manager as a function decorator**

`ContextDecorator` makes it possible to use a context manager in both an ordinary `with` statement and also as a function decorator.

For example, it is sometimes useful to wrap functions or groups of statements with a logger that can track the time of entry and time of exit. Rather than writing both a function decorator and a context
manager for the task, inheriting from `ContextDecorator` provides both capabilities in a single definition:

```python
from contextlib import ContextDecorator
import logging

logging.basicConfig(level=logging.INFO)

class track_entry_and_exit(ContextDecorator):
    def __init__(self, name):
        self.name = name

    def __enter__(self):
        logging.info('Entering: {}'.format(self.name))

    def __exit__(self, exc_type, exc, exc_tb):
        logging.info('Exiting: {}'.format(self.name))

Instances of this class can be used as both a context manager:

```python
with track_entry_and_exit('widget loader'):
    print('Some time consuming activity goes here')
    load_widget()
```  

And also as a function decorator:

```python
@track_entry_and_exit('widget loader')
def activity():
    print('Some time consuming activity goes here')
    load_widget()
```

Note that there is one additional limitation when using context managers as function decorators: there's no way to access the return value of `__enter__()`. If that value is needed, then it is still
necessary to use an explicit `with` statement.

See also:

**PEP 0343 - The “with” statement**
The specification, background, and examples for the Python `with` statement.
29.6.3. Single use, reusable and reentrant context managers

Most context managers are written in a way that means they can only be used effectively in a `with` statement once. These single use context managers must be created afresh each time they’re used - attempting to use them a second time will trigger an exception or otherwise not work correctly.

This common limitation means that it is generally advisable to create context managers directly in the header of the `with` statement where they are used (as shown in all of the usage examples above).

Files are an example of effectively single use context managers, since the first `with` statement will close the file, preventing any further IO operations using that file object.

Context managers created using `contextmanager()` are also single use context managers, and will complain about the underlying generator failing to yield if an attempt is made to use them a second time:

```python
>>> from contextlib import contextmanager
>>> @contextmanager
... def singleuse():
...     print("Before")
...     yield
...     print("After")
...
>>> cm = singleuse()
>>> with cm:
...     pass
```
29.6.3.1. Reentrant context managers

More sophisticated context managers may be “reentrant”. These context managers can not only be used in multiple `with` statements, but may also be used `inside` a `with` statement that is already using the same context manager.

`threading.RLock` is an example of a reentrant context manager, as are `suppress()` and `redirect_stdout()`. Here's a very simple example of reentrant use:

```python
>>> from contextlib import redirect_stdout
>>> from io import StringIO
>>> stream = StringIO()
>>> write_to_stream = redirect_stdout(stream)
>>> with write_to_stream:
...    print("This is written to the stream rather than stdout")
...    with write_to_stream:
...        print("This is also written to the stream rather than stdout")
>>> print("This is written directly to stdout")
This is written directly to stdout
>>> print(stream.getvalue())
This is written to the stream rather than stdout
This is also written to the stream
```
Real world examples of reentrancy are more likely to involve multiple functions calling each other and hence be far more complicated than this example.

Note also that being reentrant is not the same thing as being thread safe. `redirect_stdout()`, for example, is definitely not thread safe, as it makes a global modification to the system state by binding `sys.stdout` to a different stream.

### 29.6.3.2. Reusable context managers

Distinct from both single use and reentrant context managers are “reusable” context managers (or, to be completely explicit, “reusable, but not reentrant” context managers, since reentrant context managers are also reusable). These context managers support being used multiple times, but will fail (or otherwise not work correctly) if the specific context manager instance has already been used in a containing with statement.

`threading.Lock` is an example of a reusable, but not reentrant, context manager (for a reentrant lock, it is necessary to use `threading.RLock` instead).

Another example of a reusable, but not reentrant, context manager is `ExitStack`, as it invokes all currently registered callbacks when leaving any with statement, regardless of where those callbacks were added:

```python
>>> from contextlib import ExitStack
>>> stack = ExitStack()
>>> with stack:
...    stack.callback(print, "Callback: from first context")
...    print("Leaving first context")
```
Leaving first context
Callback: from first context

```python
>>> with stack:
...    stack.callback(print, "Callback: from second context")
...    print("Leaving second context")

Leaving second context
Callback: from second context

>>> with stack:
...    stack.callback(print, "Callback: from outer context")
...    with stack:
...        stack.callback(print, "Callback: from inner context")
...        print("Leaving inner context")
...        print("Leaving outer context")

Leaving inner context
Callback: from inner context
Callback: from outer context
Leaving outer context
```

As the output from the example shows, reusing a single stack object across multiple with statements works correctly, but attempting to nest them will cause the stack to be cleared at the end of the innermost with statement, which is unlikely to be desirable behaviour.

Using separate `ExitStack` instances instead of reusing a single instance avoids that problem:

```python
>>> from contextlib import ExitStack
>>> with ExitStack() as outer_stack:
...    outer_stack.callback(print, "Callback: from first context")
...    with ExitStack() as inner_stack:
...        inner_stack.callback(print, "Callback: from second context")
...        print("Leaving inner context")
```
... print("Leaving outer context")
...
Leaving inner context
Callback: from inner context
Leaving outer context
Callback: from outer context
29.7. abc — Abstract Base Classes

Source code: Lib/abc.py

This module provides the infrastructure for defining abstract base classes (ABCs) in Python, as outlined in PEP 3119; see the PEP for why this was added to Python. (See also PEP 3141 and the numbers module regarding a type hierarchy for numbers based on ABCs.)

The collections module has some concrete classes that derive from ABCs; these can, of course, be further derived. In addition the collections.abc submodule has some ABCs that can be used to test whether a class or instance provides a particular interface, for example, is it hashable or a mapping.

This module provides the following classes:

class abc.ABCMeta

Metaclass for defining Abstract Base Classes (ABCs).

Use this metaclass to create an ABC. An ABC can be subclassed directly, and then acts as a mix-in class. You can also register unrelated concrete classes (even built-in classes) and unrelated ABCs as “virtual subclasses” – these and their descendants will be considered subclasses of the registering ABC by the built-in issubclass() function, but the registering ABC won’t show up in their MRO (Method Resolution Order) nor will method implementations defined by the registering ABC be callable (not even via super()). [1]
Classes created with a metaclass of `ABCMeta` have the following method:

**register(subclass)**

Register `subclass` as a “virtual subclass” of this ABC. For example:

```python
from abc import ABCMeta

class MyABC(metaclass=ABCMeta):
    pass

MyABC.register(tuple)

assert issubclass(tuple, MyABC)
assert isinstance((), MyABC)
```

*Changed in version 3.3:* Returns the registered subclass, to allow usage as a class decorator.

*Changed in version 3.4:* To detect calls to `register()`, you can use the `get_cache_token()` function.

You can also override this method in an abstract base class:

**__subclasshook__(subclass)**

(Must be defined as a class method.)

Check whether `subclass` is considered a subclass of this ABC. This means that you can customize the behavior of `issubclass` further without the need to call `register()` on every class you want to consider a subclass of the ABC. (This class method is called from the `__subclasscheck__()` method of the ABC.)
This method should return True, False or NotImplemented. If it returns True, the subclass is considered a subclass of this ABC. If it returns False, the subclass is not considered a subclass of this ABC, even if it would normally be one. If it returns NotImplemented, the subclass check is continued with the usual mechanism.

For a demonstration of these concepts, look at this example ABC definition:

```python
class Foo:
    def __getitem__(self, index):
        ...
    def __len__(self):
        ...
    def get_iterator(self):
        return iter(self)

class MyIterable(metaclass=ABCMeta):
    @abstractmethod
    def __iter__(self):  # This method is defined here
        while False:
            yield None

    def get_iterator(self):
        return self.__iter__()

@classmethod
def __subclasshook__(cls, C):
    if cls is MyIterable:
        if any("__iter__" in B.__dict__ for B
            return True
    return NotImplemented
```
The ABC MyIterable defines the standard iterable method, \_\_iter\_\_(), as an abstract method. The implementation given here can still be called from subclasses. The get\_iterator() method is also part of the MyIterable abstract base class, but it does not have to be overridden in non-abstract derived classes.

The \_\_subclasshook\_\_() class method defined here says that any class that has an \_\_iter\_\_() method in its \_\_dict\_\_ (or in that of one of its base classes, accessed via the \_\_mro\_\_ list) is considered a MyIterable too.

Finally, the last line makes Foo a virtual subclass of MyIterable, even though it does not define an \_\_iter\_\_() method (it uses the old-style iterable protocol, defined in terms of \_\_len\_\_() and \_\_getitem\_\_()). Note that this will not make get\_iterator available as a method of Foo, so it is provided separately.

class abc.**ABC**

A helper class that has **ABCMeta** as its metaclass. With this class, an abstract base class can be created by simply deriving from **ABC**, avoiding sometimes confusing metaclass usage.

Note that the type of **ABC** is still **ABCMeta**, therefore inheriting from **ABC** requires the usual precautions regarding metaclass usage, as multiple inheritance may lead to metaclass conflicts.

*New in version 3.4.*

The **abc** module also provides the following decorators:
@abc.abstractmethod
A decorator indicating abstract methods.

Using this decorator requires that the class's metaclass is ABCMeta or is derived from it. A class that has a metaclass derived from ABCMeta cannot be instantiated unless all of its abstract methods and properties are overridden. The abstract methods can be called using any of the normal ‘super’ call mechanisms. abstractmethod() may be used to declare abstract methods for properties and descriptors.

Dynamically adding abstract methods to a class, or attempting to modify the abstraction status of a method or class once it is created, are not supported. The abstractmethod() only affects subclasses derived using regular inheritance; “virtual subclasses” registered with the ABC's register() method are not affected.

When abstractmethod() is applied in combination with other method descriptors, it should be applied as the innermost decorator, as shown in the following usage examples:

class C(metaclass=ABCMeta):
    @abstractmethod
    def my_abstract_method(self, ...):
        ...

    @classmethod
    @abstractmethod
    def my_abstract_classmethod(cls, ...):
        ...

    @staticmethod
    @abstractmethod
    def my_abstract_staticmethod(...):
        ...
@property
@abstractmethod
def my_abstract_property(self):
...

@my_abstract_property.setter
@abstractmethod
def my_abstract_property(self, val):
...

@abstractmethod
def _get_x(self):
...

@abstractmethod
def _set_x(self, val):
...

x = property(_get_x, _set_x)

In order to correctly interoperate with the abstract base class machinery, the descriptor must identify itself as abstract using __isabstractmethod__. In general, this attribute should be True if any of the methods used to compose the descriptor are abstract. For example, Python’s built-in property does the equivalent of:

class Descriptor:
...

@property
def __isabstractmethod__(self):
    return any(getattr(f, '__isabstractmethod__')
                f in (self._fget, self._fset,

Note: Unlike Java abstract methods, these abstract methods may have an implementation. This implementation can be called via the super() mechanism from the class that overrides it. This
could be useful as an end-point for a super-call in a framework that uses cooperative multiple-inheritance.

@abc.abstractclassmethod
A subclass of the built-in `classmethod()`, indicating an abstract classmethod. Otherwise it is similar to `abstractmethod()`.

This special case is deprecated, as the `classmethod()` decorator is now correctly identified as abstract when applied to an abstract method:

```python
class C(metaclass=ABCMeta):
    @classmethod
    @abstractmethod
    def my_abstract_classmethod(cls, ...):
        ...
```

*New in version 3.2.*

*Deprecated since version 3.3:* It is now possible to use `classmethod` with `abstractmethod()`, making this decorator redundant.

@abc.abstractstaticmethod
A subclass of the built-in `staticmethod()`, indicating an abstract staticmethod. Otherwise it is similar to `abstractmethod()`.

This special case is deprecated, as the `staticmethod()` decorator is now correctly identified as abstract when applied to an abstract method:

```python
class C(metaclass=ABCMeta):
    @staticmethod
    @abstractmethod
```

New in version 3.2.

*Deprecated since version 3.3:* It is now possible to use `staticmethod` with `abstractmethod()`, making this decorator redundant.

```python
@abc.abstractproperty(fget=None, fset=None, fdel=None, doc=None)
```

A subclass of the built-in `property()`, indicating an abstract property.

Using this function requires that the class’s metaclass is `ABCMeta` or is derived from it. A class that has a metaclass derived from `ABCMeta` cannot be instantiated unless all of its abstract methods and properties are overridden. The abstract properties can be called using any of the normal ‘super’ call mechanisms.

This special case is deprecated, as the `property()` decorator is now correctly identified as abstract when applied to an abstract method:

```python
class C(metaclass=ABCMeta):
    @property
    @abstractmethod
    def my_abstract_property(self):
        ...
```

The above example defines a read-only property; you can also define a read-write abstract property by appropriately marking one or more of the underlying methods as abstract:
```python
class C(metaclass=ABCMeta):
    @property
    def x(self):
        ...

    @x.setter
    @abstractmethod
    def x(self, val):
        ...
```

If only some components are abstract, only those components need to be updated to create a concrete property in a subclass:

```python
class D(C):
    @C.x.setter
    def x(self, val):
        ...
```

*Deprecated since version 3.3:* It is now possible to use `property`, `property.getter()`, `property.setter()` and `property.deleter()` with `abstractmethod()`, making this decorator redundant.

The `abc` module also provides the following functions:

- `abc.get_cache_token()`
  Returns the current abstract base class cache token.

  The token is an opaque object (that supports equality testing) identifying the current version of the abstract base class cache for virtual subclasses. The token changes with every call to `ABCMeta.register()` on any ABC.

  *New in version 3.4.*
C++ programmers should note that Python's virtual base class concept is not the same as C++'s.
29.8. **atexit** — Exit handlers

The `atexit` module defines functions to register and unregister cleanup functions. Functions thus registered are automatically executed upon normal interpreter termination. `atexit` runs these functions in the reverse order in which they were registered; if you register A, B, and C, at interpreter termination time they will be run in the order C, B, A.

**Note:** The functions registered via this module are not called when the program is killed by a signal not handled by Python, when a Python fatal internal error is detected, or when `os._exit()` is called.

```python
atexit.register(func, *args, **kargs)
```

Register `func` as a function to be executed at termination. Any optional arguments that are to be passed to `func` must be passed as arguments to `register()`. It is possible to register the same function and arguments more than once.

At normal program termination (for instance, if `sys.exit()` is called or the main module's execution completes), all functions registered are called in last in, first out order. The assumption is that lower level modules will normally be imported before higher level modules and thus must be cleaned up later.

If an exception is raised during execution of the exit handlers, a traceback is printed (unless `SystemExit` is raised) and the exception information is saved. After all exit handlers have had a chance to run the last exception to be raised is re-raised.

This function returns `func`, which makes it possible to use it as a
decorator.

**atexit_unregister(func)**

Remove *func* from the list of functions to be run at interpreter shutdown. After calling `unregister()`, *func* is guaranteed not to be called when the interpreter shuts down, even if it was registered more than once. `unregister()` silently does nothing if *func* was not previously registered.

**See also:**

**Module readline**

Useful example of `atexit` to read and write `readline` history files.
29.8.1. **atexit** Example

The following simple example demonstrates how a module can initialize a counter from a file when it is imported and save the counter’s updated value automatically when the program terminates without relying on the application making an explicit call into this module at termination.

```python
try:
    with open("counterfile") as infile:
        _count = int(infile.read())
except FileNotFoundError:
    _count = 0

def incrcounter(n):
    global _count
    _count = _count + n

def savecounter():
    with open("counterfile", "w") as outfile:
        outfile.write("%d" % _count)

import atexit
atexit.register(savecounter)
```

Positional and keyword arguments may also be passed to `register()` to be passed along to the registered function when it is called:

```python
def goodbye(name, adjective):
    print('Goodbye, %s, it was %s to meet you.' % (name, adjective))

import atexit
atexit.register(goodbye, 'Donny', 'nice')
```
Usage as a decorator:

```python
import atexit
def goodbye():
    print("You are now leaving the Python sector.")
```

This only works with functions that can be called without arguments.
29.9. `traceback` — Print or retrieve a stack traceback

This module provides a standard interface to extract, format and print stack traces of Python programs. It exactly mimics the behavior of the Python interpreter when it prints a stack trace. This is useful when you want to print stack traces under program control, such as in a “wrapper” around the interpreter.

The module uses traceback objects — this is the object type that is stored in the `sys.last_traceback` variable and returned as the third item from `sys.exc_info()`.

The module defines the following functions:

`traceback.print_tb(traceback, limit=None, file=None)`

Print up to `limit` stack trace entries from `traceback` (starting from the caller’s frame) if `limit` is positive. Otherwise, print the last `abs(limit)` entries. If `limit` is omitted or None, all entries are printed. If `file` is omitted or None, the output goes to `sys.stderr`; otherwise it should be an open file or file-like object to receive the output.

*Changed in version 3.5:* Added negative limit support.

`traceback.print_exception(type, value, traceback, limit=None, file=None, chain=True)`

Print exception information and stack trace entries from `traceback` to `file`. This differs from `print_tb()` in the following ways:

- if `traceback` is not None, it prints a header Traceback (most
recent call last):

- it prints the exception type and value after the stack trace
- if type is SyntaxError and value has the appropriate format, it prints the line where the syntax error occurred with a caret indicating the approximate position of the error.

The optional limit argument has the same meaning as for print_tb(). If chain is true (the default), then chained exceptions (the __cause__ or __context__ attributes of the exception) will be printed as well, like the interpreter itself does when printing an unhandled exception.

```
traceback.print_exc(limit=None, file=None, chain=True)
```

This is a shorthand for print_exception(*sys.exc_info(), limit, file, chain).

```
traceback.print_last(limit=None, file=None, chain=True)
```

This is a shorthand for print_exception(sys.last_type, sys.last_value, sys.last_traceback, limit, file, chain). In general it will work only after an exception has reached an interactive prompt (see sys.last_type).

```
traceback.print_stack(f=None, limit=None, file=None)
```

Print up to limit stack trace entries (starting from the invocation point) if limit is positive. Otherwise, print the last abs(limit) entries. If limit is omitted or None, all entries are printed. The optional f argument can be used to specify an alternate stack frame to start. The optional file argument has the same meaning as for print_tb().

*Changed in version 3.5: Added negative limit support.*

```
traceback.extract_tb(traceback, limit=None)
```
Return a list of “pre-processed” stack trace entries extracted from the traceback object traceback. It is useful for alternate formatting of stack traces. The optional limit argument has the same meaning as for print_tb(). A “pre-processed” stack trace entry is a 4-tuple (filename, line number, function name, text) representing the information that is usually printed for a stack trace. The text is a string with leading and trailing whitespace stripped; if the source is not available it is None.

```
traceback.extract_stack(f=None, limit=None)
```

Extract the raw traceback from the current stack frame. The return value has the same format as for extract_tb(). The optional f and limit arguments have the same meaning as for print_stack().

```
traceback.format_list(list)
```

Given a list of tuples as returned by extract_tb() or extract_stack(), return a list of strings ready for printing. Each string in the resulting list corresponds to the item with the same index in the argument list. Each string ends in a newline; the strings may contain internal newlines as well, for those items whose source text line is not None.

```
traceback.format_exception_only(type, value)
```

Format the exception part of a traceback. The arguments are the exception type and value such as given by sys.last_type and sys.last_value. The return value is a list of strings, each ending in a newline. Normally, the list contains a single string; however, for SyntaxError exceptions, it contains several lines that (when printed) display detailed information about where the syntax error occurred. The message indicating which exception
occurred is the always last string in the list.

```
traceback.format_exception(type, value, tb, limit=None, chain=True)
```

Format a stack trace and the exception information. The arguments have the same meaning as the corresponding arguments to `print_exception()`. The return value is a list of strings, each ending in a newline and some containing internal newlines. When these lines are concatenated and printed, exactly the same text is printed as does `print_exception()`.

```
traceback.format_exc(limit=None, chain=True)
```

This is like `print_exc(limit)` but returns a string instead of printing to a file.

```
traceback.format_tb(tb, limit=None)
```

A shorthand for `format_list(extract_tb(tb, limit))`.

```
traceback.format_stack(f=None, limit=None)
```

A shorthand for `format_list(extract_stack(f, limit))`.

```
traceback.clear_frames(tb)
```

Clears the local variables of all the stack frames in a traceback `tb` by calling the `clear()` method of each frame object.

*New in version 3.4.*

```
traceback.walk_stack(f)
```

Walk a stack following `f.f_back` from the given frame, yielding the frame and line number for each frame. If `f` is `None`, the current stack is used. This helper is used with `StackSummary.extract()`.
New in version 3.5.

traceback.walk_tb(tb)

Walk a traceback following tb_next yielding the frame and line number for each frame. This helper is used with StackSummary.extract().

New in version 3.5.

The module also defines the following classes:
29.9.1. `TracebackException` Objects

*New in version 3.5.*

`TracebackException` objects are created from actual exceptions to capture data for later printing in a lightweight fashion.

```python
class traceback.TracebackException(exc_type, exc_value, exc_traceback, *, limit=None, lookup_lines=True, capture_locals=False)
```

Capture an exception for later rendering. `limit`, `lookup_lines` and `capture_locals` are as for the `StackSummary` class.

Note that when locals are captured, they are also shown in the traceback.

```python
__cause__
A `TracebackException` of the original `__cause__`.

__context__
A `TracebackException` of the original `__context__`.

__suppress_context__
The `__suppress_context__` value from the original exception.

stack
A `StackSummary` representing the traceback.

exc_type
The class of the original traceback.

filename
For syntax errors - the file name where the error occurred.

**lineno**
For syntax errors - the line number where the error occurred.

**text**
For syntax errors - the text where the error occurred.

**offset**
For syntax errors - the offset into the text where the error occurred.

**msg**
For syntax errors - the compiler error message.

```python
classmethod from_exception(exc, *, limit=None, lookup_lines=True, capture_locals=False)
```
Capture an exception for later rendering. `limit, lookup_lines` and `capture_locals` are as for the `StackSummary` class.

Note that when locals are captured, they are also shown in the traceback.

```python
format(*, chain=True)
```
Format the exception.

If `chain` is not True, `__cause__` and `__context__` will not be formatted.

The return value is a generator of strings, each ending in a newline and some containing internal newlines. `print_exception()` is a wrapper around this method which just prints the lines to a file.
The message indicating which exception occurred is always the last string in the output.

**format_exception_only()**

Format the exception part of the traceback.

The return value is a generator of strings, each ending in a newline.

Normally, the generator emits a single string; however, for SyntaxError exceptions, it emits several lines that (when printed) display detailed information about where the syntax error occurred.

The message indicating which exception occurred is always the last string in the output.
29.9.2. **StackSummary** Objects

*New in version 3.5.*

**StackSummary** objects represent a call stack ready for formatting.

```python
class traceback.StackSummary
    @classmethod
    def extract(cls, frame_gen, *, limit=None, lookup_lines=True, capture_locals=False)

    Construct a StackSummary object from a frame generator (such as is returned by walk_stack() or walk_tb()).

    If `limit` is supplied, only this many frames are taken from `frame_gen`. If `lookup_lines` is False, the returned FrameSummary objects will not have read their lines in yet, making the cost of creating the StackSummary cheaper (which may be valuable if it may not actually get formatted). If `capture_locals` is True the local variables in each FrameSummary are captured as object representations.

    @classmethod
    def from_list(cls, a_list)

    Construct a StackSummary object from a supplied old-style list of tuples. Each tuple should be a 4-tuple with filename, lineno, name, line as the elements.
```
29.9.3. FrameSummary Objects

*New in version 3.5.*

FrameSummary objects represent a single frame in a traceback.

```python
class traceback.FrameSummary(filename, lineno, name, lookup_line=True, locals=None, line=None)
```

Represent a single frame in the traceback or stack that is being formatted or printed. It may optionally have a stringified version of the frames locals included in it. If `lookup_line` is `False`, the source code is not looked up until the FrameSummary has the line attribute accessed (which also happens when casting it to a tuple). `line` may be directly provided, and will prevent line lookups happening at all. `locals` is an optional local variable dictionary, and if supplied the variable representations are stored in the summary for later display.
29.9.4. Traceback Examples

This simple example implements a basic read-eval-print loop, similar to (but less useful than) the standard Python interactive interpreter loop. For a more complete implementation of the interpreter loop, refer to the code module.

```python
import sys, traceback

def run_user_code(envdir):
    source = input(">>> ")
    try:
        exec(source, envdir)
    except Exception:
        print("Exception in user code:")
        print("-"*60)
        traceback.print_exc(file=sys.stdout)
        print("-"*60)

envdir = {}
while True:
    run_user_code(envdir)
```

The following example demonstrates the different ways to print and format the exception and traceback:

```python
import sys, traceback

def lumberjack():
    bright_side_of_death()

def bright_side_of_death():
    return tuple()[0]
```
try:
    lumberjack()
except IndexError:
    exc_type, exc_value, exc_traceback = sys.exc_info()
    print("*** print_tb:")
    traceback.print_tb(exc_traceback, limit=1, file=sys.stderr)
    print("*** print_exception:")
    traceback.print_exception(exc_type, exc_value, exc_traceback, limit=2, file=sys.stdout)
    print("*** print_exc:")
    traceback.print_exc()
    print("*** format_exc, first and last line:")
    formatted_lines = traceback.format_exc().splitlines()
    print(formatted_lines[0])
    print(formatted_lines[-1])
    print("*** format_exception:")
    print(repr(traceback.format_exception(exc_type, exc_value, exc_traceback)))
    print("*** extract_tb:")
    print(repr(traceback.extract_tb(exc_traceback)))
    print("*** format_tb:")
    print(repr(traceback.format_tb(exc_traceback)))
    print("*** tb_lineno:", exc_traceback.tb_lineno)

The output for the example would look similar to this:

*** print_tb:
    File "<doctest...>", line 10, in <module>
        lumberjack()
*** print_exception:
Traceback (most recent call last):
    File "<doctest...>", line 10, in <module>
        lumberjack()
    File "<doctest...>", line 4, in lumberjack
        bright_side_of_death()
IndexError: tuple index out of range
The following example shows the different ways to print and format the stack:

```python
>>> import traceback
>>> def another_function():
...     lumberstack()
...
>>> def lumberstack():
...     traceback.print_stack()
...     print(repr(traceback.extract_stack()))
```
...     print(repr(traceback.format_stack()))
...

>>> another_function()
    File "<doctest>", line 10, in <module>
        another_function()
    File "<doctest>", line 3, in another_function
        lumberstack()
    File "<doctest>", line 6, in lumberstack
        traceback.print_stack()
[("<doctest>", 10, "<module>", 'another_function()')
 ("<doctest>", 3, 'another_function', 'lumberstack()')
 ("<doctest>", 7, 'lumberstack', 'print(repr(traceback.extract_stack()))')
 [  File "<doctest>", line 10, in <module>
    another_function()
    File "<doctest>", line 3, in another_function
    lumberstack()
    File "<doctest>", line 6, in lumberstack
        traceback.print_stack()
]

This last example demonstrates the final few formatting functions:

>>> import traceback

>>> traceback.format_list([("spam.py", 3, "<module>"),
                          ("eggs.py", 42, "eggs"),
                          ("<doctest>", 10, "<module>"),
                          ("<doctest>", 3, 'another_function', 'lumberstack()')
                        ])
['File "spam.py", line 3, in <module>
 spam.eggs()
', 'File "eggs.py", line 42, in eggs
 return "bacon"
', 'File "<doctest>", line 10, in <module>
 another_function()
', 'File "<doctest>", line 3, in another_function
 lumberstack()
', 'File "<doctest>", line 6, in lumberstack
 traceback.print_stack()
']

>>> an_error = IndexError('tuple index out of range')

>>> traceback.format_exception_only(type(an_error), an_error)
['IndexError: tuple index out of range\n']
29.10. __future__ — Future statement definitions

Source code: Lib/__future__.py

__future__ is a real module, and serves three purposes:

- To avoid confusing existing tools that analyze import statements and expect to find the modules they’re importing.
- To ensure that future statements run under releases prior to 2.1 at least yield runtime exceptions (the import of __future__ will fail, because there was no module of that name prior to 2.1).
- To document when incompatible changes were introduced, and when they will be — or were — made mandatory. This is a form of executable documentation, and can be inspected programmatically via importing __future__ and examining its contents.

Each statement in __future__.py is of the form:

```
FeatureName = _Feature(OptionalRelease, MandatoryRelease, CompilerFlag)
```

where, normally, OptionalRelease is less than MandatoryRelease, and both are 5-tuples of the same form as sys.version_info:

```
(PY_MAJOR_VERSION, # the 2 in 2.1.0a3; an int
 PY_MINOR_VERSION, # the 1; an int
 PY_MICRO_VERSION, # the 0; an int
 PY_RELEASE_LEVEL, # "alpha", "beta", "candidate" or
 PY_RELEASE_SERIAL # the 3; an int
```
OptionalRelease records the first release in which the feature was accepted.

In the case of a MandatoryRelease that has not yet occurred, MandatoryRelease predicts the release in which the feature will become part of the language.

Else MandatoryRelease records when the feature became part of the language; in releases at or after that, modules no longer need a future statement to use the feature in question, but may continue to use such imports.

MandatoryRelease may also be None, meaning that a planned feature got dropped.

Instances of class _Feature have two corresponding methods, getOptionalRelease() and getMandatoryRelease().

CompilerFlag is the (bitfield) flag that should be passed in the fourth argument to the built-in function compile() to enable the feature in dynamically compiled code. This flag is stored in the compiler_flag attribute on _Feature instances.

No feature description will ever be deleted from __future__. Since its introduction in Python 2.1 the following features have found their way into the language using this mechanism:

<table>
<thead>
<tr>
<th>feature</th>
<th>optional in</th>
<th>mandatory in</th>
<th>effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>nested_scopes</td>
<td>2.1.0b1</td>
<td>2.2</td>
<td>PEP 227: Statically Nested Scopes</td>
</tr>
<tr>
<td>Feature</td>
<td>Version</td>
<td>Python Version</td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>----------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>generators</td>
<td>2.2.0a1</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>division</td>
<td>2.2.0a2</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>absolute_import</td>
<td>2.5.0a1</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>with_statement</td>
<td>2.5.0a1</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>print_function</td>
<td>2.6.0a2</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>unicode_literals</td>
<td>2.6.0a2</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>generator_stop</td>
<td>3.5.0b1</td>
<td>3.7</td>
<td></td>
</tr>
</tbody>
</table>

**See also:**

**Future statements**
How the compiler treats future imports.
This module provides an interface to the optional garbage collector. It provides the ability to disable the collector, tune the collection frequency, and set debugging options. It also provides access to unreachable objects that the collector found but cannot free. Since the collector supplements the reference counting already used in Python, you can disable the collector if you are sure your program does not create reference cycles. Automatic collection can be disabled by calling `gc.disable()`. To debug a leaking program call `gc.set_debug(gc.DEBUG_LEAK)`. Notice that this includes `gc.DEBUG_SAVEALL`, causing garbage-collected objects to be saved in `gc.garbage` for inspection.

The `gc` module provides the following functions:

- `gc.enable()`  
  Enable automatic garbage collection.

- `gc.disable()`  
  Disable automatic garbage collection.

- `gc.isenabled()`  
  Returns true if automatic collection is enabled.

- `gc.collect(generations=2)`  
  With no arguments, run a full collection. The optional argument `generation` may be an integer specifying which generation to collect (from 0 to 2). A `ValueError` is raised if the generation number is
invalid. The number of unreachable objects found is returned.

The free lists maintained for a number of built-in types are cleared whenever a full collection or collection of the highest generation (2) is run. Not all items in some free lists may be freed due to the particular implementation, in particular float.

\texttt{gc.set\_debug(flags)}

Set the garbage collection debugging flags. Debugging information will be written to \texttt{sys.stderr}. See below for a list of debugging flags which can be combined using bit operations to control debugging.

\texttt{gc.get\_debug()}

Return the debugging flags currently set.

\texttt{gc.get\_objects()}

Returns a list of all objects tracked by the collector, excluding the list returned.

\texttt{gc.get\_stats()}

Return a list of three per-generation dictionaries containing collection statistics since interpreter start. The number of keys may change in the future, but currently each dictionary will contain the following items:

- \texttt{collections} is the number of times this generation was collected;
- \texttt{collected} is the total number of objects collected inside this generation;
- \texttt{uncollectable} is the total number of objects which were found to be uncollectable (and were therefore moved to the \texttt{garbage} list) inside this generation.
New in version 3.4.

```python
gc.set_threshold(threshold0, threshold1, threshold2)
```
Set the garbage collection thresholds (the collection frequency). Setting threshold0 to zero disables collection.

The GC classifies objects into three generations depending on how many collection sweeps they have survived. New objects are placed in the youngest generation (generation 0). If an object survives a collection it is moved into the next older generation. Since generation 2 is the oldest generation, objects in that generation remain there after a collection. In order to decide when to run, the collector keeps track of the number object allocations and deallocations since the last collection. When the number of allocations minus the number of deallocations exceeds threshold0, collection starts. Initially only generation 0 is examined. If generation 0 has been examined more than threshold1 times since generation 1 has been examined, then generation 1 is examined as well. Similarly, threshold2 controls the number of collections of generation 1 before collecting generation 2.

```python
gc.get_count()
```
Return the current collection counts as a tuple of (count0, count1, count2).

```python
gc.get_threshold()
```
Return the current collection thresholds as a tuple of (threshold0, threshold1, threshold2).

```python
gc.get_referrers(*objs)
```
Return the list of objects that directly refer to any of objs. This function will only locate those containers which support garbage
collection; extension types which do refer to other objects but do not support garbage collection will not be found.

Note that objects which have already been dereferenced, but which live in cycles and have not yet been collected by the garbage collector can be listed among the resulting referrers. To get only currently live objects, call `collect()` before calling `get_referrers()`.

Care must be taken when using objects returned by `get_referrers()` because some of them could still be under construction and hence in a temporarily invalid state. Avoid using `get_referrers()` for any purpose other than debugging.

```python
gc.get_referents(*objs)
```

Return a list of objects directly referred to by any of the arguments. The referents returned are those objects visited by the arguments’ C-level `tp_traverse` methods (if any), and may not be all objects actually directly reachable. `tp_traverse` methods are supported only by objects that support garbage collection, and are only required to visit objects that may be involved in a cycle. So, for example, if an integer is directly reachable from an argument, that integer object may or may not appear in the result list.

```python
gc.is_tracked(obj)
```

Returns True if the object is currently tracked by the garbage collector, False otherwise. As a general rule, instances of atomic types aren’t tracked and instances of non-atomic types (containers, user-defined objects...) are. However, some type-specific optimizations can be present in order to suppress the garbage collector footprint of simple instances (e.g. dicts containing only atomic keys and values):
New in version 3.1.

The following variables are provided for read-only access (you can mutate the values but should not rebind them):

```
>>> gc.is_tracked(0)
False
>>> gc.is_tracked("a")
False
>>> gc.is_tracked([])
True
>>> gc.is_tracked({})
False
>>> gc.is_tracked({"a": 1})
False
>>> gc.is_tracked({"a": []})
True
```

```
gc.garbage
```

A list of objects which the collector found to be unreachable but could not be freed (uncollectable objects). Starting with Python 3.4, this list should be empty most of the time, except when using instances of C extension types with a non-NULL `tp_del` slot.

If `DEBUG_SAVEALL` is set, then all unreachable objects will be added to this list rather than freed.

Changed in version 3.2: If this list is non-empty at interpreter shutdown, a `ResourceWarning` is emitted, which is silent by default. If `DEBUG_UNCOLLECTABLE` is set, in addition all uncollectable objects are printed.

Changed in version 3.4: Following PEP 442, objects with a `__del__()` method don’t end up in `gc.garbage` anymore.
**gc.callbacks**

A list of callbacks that will be invoked by the garbage collector before and after collection. The callbacks will be called with two arguments, *phase* and *info*.

*phase* can be one of two values:

- “start”: The garbage collection is about to start.
- “stop”: The garbage collection has finished.

*info* is a dict providing more information for the callback. The following keys are currently defined:

- “generation”: The oldest generation being collected.
- “collected”: When *phase* is “stop”, the number of objects successfully collected.
- “uncollectable”: When *phase* is “stop”, the number of objects that could not be collected and were put in garbage.

Applications can add their own callbacks to this list. The primary use cases are:

- Gathering statistics about garbage collection, such as how often various generations are collected, and how long the collection takes.
- Allowing applications to identify and clear their own uncollectable types when they appear in garbage.

*New in version 3.3.*

The following constants are provided for use with *set_debug()*:
gc. **DEBUG_STATS**

Print statistics during collection. This information can be useful when tuning the collection frequency.

gc. **DEBUG_COLLECTABLE**

Print information on collectable objects found.

gc. **DEBUG_UNCOLLECTABLE**

Print information of uncollectable objects found (objects which are not reachable but cannot be freed by the collector). These objects will be added to the garbage list.

*Changed in version 3.2:* Also print the contents of the garbage list at interpreter shutdown, if it isn't empty.

gc. **DEBUG_SAVEALL**

When set, all unreachable objects found will be appended to garbage rather than being freed. This can be useful for debugging a leaking program.

gc. **DEBUG_LEAK**

The debugging flags necessary for the collector to print information about a leaking program (equal to DEBUG_COLLECTABLE | DEBUG_UNCOLLECTABLE | DEBUG_SAVEALL).
29.12. **inspect** — Inspect live objects

**Source code:** Lib/inspect.py

The `inspect` module provides several useful functions to help get information about live objects such as modules, classes, methods, functions, tracebacks, frame objects, and code objects. For example, it can help you examine the contents of a class, retrieve the source code of a method, extract and format the argument list for a function, or get all the information you need to display a detailed traceback.

There are four main kinds of services provided by this module: type checking, getting source code, inspecting classes and functions, and examining the interpreter stack.
29.12.1. Types and members

The `getmembers()` function retrieves the members of an object such as a class or module. The functions whose names begin with “is” are mainly provided as convenient choices for the second argument to `getmembers()`. They also help you determine when you can expect to find the following special attributes:

<table>
<thead>
<tr>
<th>Type</th>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>module</td>
<td><strong>doc</strong></td>
<td>documentation string</td>
</tr>
<tr>
<td></td>
<td><strong>file</strong></td>
<td>filename (missing for built-in modules)</td>
</tr>
<tr>
<td>class</td>
<td><strong>doc</strong></td>
<td>documentation string</td>
</tr>
<tr>
<td></td>
<td><strong>name</strong></td>
<td>name with which this class was defined</td>
</tr>
<tr>
<td></td>
<td><strong>qualname</strong></td>
<td>qualified name</td>
</tr>
<tr>
<td></td>
<td><strong>module</strong></td>
<td>name of module in which this class was defined</td>
</tr>
<tr>
<td>method</td>
<td><strong>doc</strong></td>
<td>documentation string</td>
</tr>
<tr>
<td></td>
<td><strong>name</strong></td>
<td>name with which this method was defined</td>
</tr>
<tr>
<td></td>
<td><strong>qualname</strong></td>
<td>qualified name</td>
</tr>
<tr>
<td></td>
<td><strong>func</strong></td>
<td>function object containing implementation of method</td>
</tr>
<tr>
<td></td>
<td><strong>self</strong></td>
<td>instance to which this method is bound, or None</td>
</tr>
<tr>
<td>function</td>
<td><strong>doc</strong></td>
<td>documentation string</td>
</tr>
</tbody>
</table>

name with which this function
<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>name</strong></td>
<td>was defined</td>
</tr>
<tr>
<td><strong>qualname</strong></td>
<td>qualified name</td>
</tr>
<tr>
<td><strong>code</strong></td>
<td>code object containing compiled function bytecode</td>
</tr>
<tr>
<td><strong>defaults</strong></td>
<td>tuple of any default values for positional or keyword parameters</td>
</tr>
<tr>
<td><strong>kwdefaults</strong></td>
<td>mapping of any default values for keyword-only parameters</td>
</tr>
<tr>
<td><strong>globals</strong></td>
<td>global namespace in which this function was defined</td>
</tr>
<tr>
<td><strong>annotations</strong></td>
<td>mapping of parameters names to annotations; &quot;return&quot; key is reserved for return annotations.</td>
</tr>
<tr>
<td>traceback</td>
<td>tb_frame frame object at this level</td>
</tr>
<tr>
<td></td>
<td>tb_lasti index of last attempted instruction in bytecode</td>
</tr>
<tr>
<td></td>
<td>tb_lineno current line number in Python source code</td>
</tr>
<tr>
<td></td>
<td>tb_next next inner traceback object (called by this level)</td>
</tr>
<tr>
<td>frame</td>
<td>f_back next outer frame object (this frame's caller)</td>
</tr>
<tr>
<td></td>
<td>f_builtins builtins namespace seen by this frame</td>
</tr>
<tr>
<td></td>
<td>f_code code object being executed in this frame</td>
</tr>
<tr>
<td></td>
<td>f_globals global namespace seen by this frame</td>
</tr>
<tr>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>f_lasti</td>
<td>index of last attempted instruction in bytecode</td>
</tr>
<tr>
<td>f_lineno</td>
<td>current line number in Python source code</td>
</tr>
<tr>
<td>f_locals</td>
<td>local namespace seen by this frame</td>
</tr>
<tr>
<td>f_restricted</td>
<td>0 or 1 if frame is in restricted execution mode</td>
</tr>
<tr>
<td>f_trace</td>
<td>tracing function for this frame, or None</td>
</tr>
<tr>
<td>code</td>
<td></td>
</tr>
<tr>
<td>co_argcount</td>
<td>number of arguments (not including * or ** args)</td>
</tr>
<tr>
<td>co_code</td>
<td>string of raw compiled bytecode</td>
</tr>
<tr>
<td>co_consts</td>
<td>tuple of constants used in the bytecode</td>
</tr>
<tr>
<td>co_filename</td>
<td>name of file in which this code object was created</td>
</tr>
<tr>
<td>co_firstlineno</td>
<td>number of first line in Python source code</td>
</tr>
<tr>
<td>co_flags</td>
<td>bitmap: 1=optimized</td>
</tr>
<tr>
<td>co_lnotab</td>
<td>encoded mapping of line numbers to bytecode indices</td>
</tr>
<tr>
<td>co_name</td>
<td>name with which this code object was defined</td>
</tr>
<tr>
<td>co_names</td>
<td>tuple of names of local variables</td>
</tr>
<tr>
<td>co_nlocals</td>
<td>number of local variables</td>
</tr>
<tr>
<td>co_stacksize</td>
<td>virtual machine stack space</td>
</tr>
<tr>
<td>Object</td>
<td>Attribute</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------</td>
</tr>
<tr>
<td>generator</td>
<td><code>__name__</code></td>
</tr>
<tr>
<td></td>
<td><code>__qualname__</code></td>
</tr>
<tr>
<td></td>
<td><code>gi_frame</code></td>
</tr>
<tr>
<td></td>
<td><code>gi_running</code></td>
</tr>
<tr>
<td></td>
<td><code>gi_code</code></td>
</tr>
<tr>
<td></td>
<td><code>gi_yieldfrom</code></td>
</tr>
<tr>
<td>coroutine</td>
<td><code>__name__</code></td>
</tr>
<tr>
<td></td>
<td><code>__qualname__</code></td>
</tr>
<tr>
<td></td>
<td><code>crAwait</code></td>
</tr>
<tr>
<td></td>
<td><code>cr_frame</code></td>
</tr>
<tr>
<td></td>
<td><code>cr_running</code></td>
</tr>
<tr>
<td></td>
<td><code>cr_code</code></td>
</tr>
<tr>
<td>builtin</td>
<td><code>__doc__</code></td>
</tr>
<tr>
<td></td>
<td><code>__name__</code></td>
</tr>
<tr>
<td></td>
<td><code>__qualname__</code></td>
</tr>
<tr>
<td></td>
<td><code>__self__</code></td>
</tr>
</tbody>
</table>

*Changed in version 3.5:* Add `__qualname__` and `gi_yieldfrom` attributes to generators.

The `__name__` attribute of generators is now set from the function
name, instead of the code name, and it can now be modified.

**inspect.getmembers**(object[, predicate])

Return all the members of an object in a list of (name, value) pairs sorted by name. If the optional *predicate* argument is supplied, only members for which the predicate returns a true value are included.

**Note:** *getmembers()* will only return class attributes defined in the metaclass when the argument is a class and those attributes have been listed in the metaclass’ custom __dir__().

**inspect.getmoduleinfo**(path)

Returns a named tuple ModuleInfo(name, suffix, mode, module_type) of values that describe how Python will interpret the file identified by *path* if it is a module, or None if it would not be identified as a module. In that tuple, *name* is the name of the module without the name of any enclosing package, *suffix* is the trailing part of the file name (which may not be a dot-delimited extension), *mode* is the open() mode that would be used ('r' or 'rb'), and *module_type* is an integer giving the type of the module. *module_type* will have a value which can be compared to the constants defined in the imp module; see the documentation for that module for more information on module types.

*Deprecated since version 3.3:* You may check the file path’s suffix against the supported suffixes listed in *importlib.machinery* to infer the same information.

**inspect.getmodulename**(path)

Return the name of the module named by the file *path*, without including the names of enclosing packages. The file extension is
checked against all of the entries in \texttt{importlib.machinery.all_suffixes()}. If it matches, the final path component is returned with the extension removed. Otherwise, \texttt{None} is returned.

Note that this function \textit{only} returns a meaningful name for actual Python modules - paths that potentially refer to Python packages will still return \texttt{None}.

\textit{Changed in version 3.3:} This function is now based directly on \texttt{importlib} rather than the deprecated \texttt{getmoduleinfo()}. 

\begin{description}
\item[\texttt{inspect.ismodule(object)}] Return true if the object is a module.
\item[\texttt{inspect.isclass(object)}] Return true if the object is a class, whether built-in or created in Python code.
\item[\texttt{inspect.ismethod(object)}] Return true if the object is a bound method written in Python.
\item[\texttt{inspect.isfunction(object)}] Return true if the object is a Python function, which includes functions created by a \texttt{lambda} expression.
\item[\texttt{inspect.isgeneratorfunction(object)}] Return true if the object is a Python generator function.
\item[\texttt{inspect.isgenerator(object)}] Return true if the object is a generator.
\item[\texttt{inspect.iscoroutinefunction(object)}]
Return true if the object is a coroutine function (a function defined with an `async def` syntax).

*New in version 3.5.*

`inspect.iscoroutine(object)`

Return true if the object is a coroutine created by an `async def` function.

*New in version 3.5.*

`inspect.isawaitable(object)`

Return true if the object can be used in `await` expression. Can also be used to distinguish generator-based coroutines from regular generators:

```python
def gen():
    yield
@types.coroutine
def gen_coro():
    yield

assert not isawaitable(gen())
assert isawaitable(gen_coro())
```

*New in version 3.5.*

`inspect.istraceback(object)`

Return true if the object is a traceback.

`inspect.isframe(object)`

Return true if the object is a frame.
inspect. **iscode**(object)
Return true if the object is a code.

inspect. **isbuiltin**(object)
Return true if the object is a built-in function or a bound built-in method.

inspect. **isroutine**(object)
Return true if the object is a user-defined or built-in function or method.

inspect. **isabstract**(object)
Return true if the object is an abstract base class.

inspect. **ismethoddescriptor**(object)
Return true if the object is a method descriptor, but not if
ismethod(), isclass(), isfunction() or isbuiltin() are true.

This, for example, is true of int.__add__. An object passing this
test has a __get__ attribute but not a __set__ attribute, but
beyond that the set of attributes varies. __name__ is usually
sensible, and __doc__ often is.

Methods implemented via descriptors that also pass one of the
other tests return false from the ismethoddescriptor() test,
simply because the other tests promise more – you can, e.g., count
on having the __func__ attribute (etc) when an object passes
ismethod().

inspect. **isdatadescriptor**(object)
Return true if the object is a data descriptor.
Data descriptors have both a `__get__` and a `__set__` attribute. Examples are properties (defined in Python), getsets, and members. The latter two are defined in C and there are more specific tests available for those types, which is robust across Python implementations. Typically, data descriptors will also have `__name__` and `__doc__` attributes (properties, getsets, and members have both of these attributes), but this is not guaranteed.

```
inspect.isgetsetdescriptor(object)
```

Return true if the object is a getset descriptor.

**CPython implementation detail:** getsets are attributes defined in extension modules via `PyGetSetDef` structures. For Python implementations without such types, this method will always return `False`.

```
inspect.ismemberdescriptor(object)
```

Return true if the object is a member descriptor.

**CPython implementation detail:** Member descriptors are attributes defined in extension modules via `PyMemberDef` structures. For Python implementations without such types, this method will always return `False`. 
29.12.2. Retrieving source code

inspect.getdoc(object)
Get the documentation string for an object, cleaned up with cleandoc(). If the documentation string for an object is not provided and the object is a class, a method, a property or a descriptor, retrieve the documentation string from the inheritance hierarchy.

*Changed in version 3.5:* Documentation strings are now inherited if not overridden.

inspect.getcomments(object)
Return in a single string any lines of comments immediately preceding the object's source code (for a class, function, or method), or at the top of the Python source file (if the object is a module).

inspect.getfile(object)
Return the name of the (text or binary) file in which an object was defined. This will fail with a TypeError if the object is a built-in module, class, or function.

inspect.getmodule(object)
Try to guess which module an object was defined in.

inspect.getsourcefile(object)
Return the name of the Python source file in which an object was defined. This will fail with a TypeError if the object is a built-in module, class, or function.

inspect.getsourcelines(object)
Return a list of source lines and starting line number for an object. The argument may be a module, class, method, function, traceback, frame, or code object. The source code is returned as a list of the lines corresponding to the object and the line number indicates where in the original source file the first line of code was found. An OSError is raised if the source code cannot be retrieved.

*Changed in version 3.3:* OSError is raised instead of IOError, now an alias of the former.

**inspect.getsource** *(object)*

Return the text of the source code for an object. The argument may be a module, class, method, function, traceback, frame, or code object. The source code is returned as a single string. An OSError is raised if the source code cannot be retrieved.

*Changed in version 3.3:* OSError is raised instead of IOError, now an alias of the former.

**inspect.cleandoc** *(doc)*

Clean up indentation from docstrings that are indented to line up with blocks of code. Any whitespace that can be uniformly removed from the second line onwards is removed. Also, all tabs are expanded to spaces.
29.12.3. Introspecting callables with the Signature object

*New in version 3.3.*

The Signature object represents the call signature of a callable object and its return annotation. To retrieve a Signature object, use the `signature()` function.

```
inspect.signature(callable, *, follow_wrapped=True)
```

Return a Signature object for the given callable:

```python
>>> from inspect import signature
>>> def foo(a, *, b:int, **kwargs):
...     pass

>>> sig = signature(foo)

>>> str(sig)
'(a, *, b:int, **kwargs)'

>>> str(sig.parameters['b'])
'b:int'

>>> sig.parameters['b'].annotation
<class 'int'>
```

Accepts a wide range of python callables, from plain functions and classes to `functools.partial()` objects.

Raises `ValueError` if no signature can be provided, and `TypeError` if that type of object is not supported.
New in version 3.5: follow_wrapped parameter. Pass False to get a signature of callable specifically (callable.__wrapped__ will not be used to unwrap decorated callables.)

Note: Some callables may not be introspectable in certain implementations of Python. For example, in CPython, some built-in functions defined in C provide no metadata about their arguments.

class inspect.Signature(parameters=None, *,
return_annotation=Signature.empty)

A Signature object represents the call signature of a function and its return annotation. For each parameter accepted by the function it stores a Parameter object in its parameters collection.

The optional parameters argument is a sequence of Parameter objects, which is validated to check that there are no parameters with duplicate names, and that the parameters are in the right order, i.e. positional-only first, then positional-or-keyword, and that parameters with defaults follow parameters without defaults.

The optional return_annotation argument, can be an arbitrary Python object, is the “return” annotation of the callable.

Signature objects are immutable. Use Signature.replace() to make a modified copy.

Changed in version 3.5: Signature objects are picklable and hashable.

empty
A special class-level marker to specify absence of a return annotation.

parameters
An ordered mapping of parameters’ names to the corresponding Parameter objects.

return_annotation
The “return” annotation for the callable. If the callable has no “return” annotation, this attribute is set to Signature.empty.

bind(*args, **kwargs)
Create a mapping from positional and keyword arguments to parameters. Returns BoundArguments if *args and **kwargs match the signature, or raises a TypeError.

bind_partial(*args, **kwargs)
Works the same way as Signature.bind(), but allows the omission of some required arguments (mimics functools.partial() behavior.) Returns BoundArguments, or raises a TypeError if the passed arguments do not match the signature.

replace(*[, parameters][, return_annotation])
Create a new Signature instance based on the instance replace was invoked on. It is possible to pass different parameters and/or return_annotation to override the corresponding properties of the base signature. To remove return_annotation from the copied Signature, pass in Signature.empty.

>>> def test(a, b):
...     pass
```python
global sig = signature(test)
global new_sig = sig.replace(return_annotation="new")
global str(new_sig)
"(a, b) -> 'new return anno'"
```
The name of the parameter as a string. The name must be a valid Python identifier.

**default**

The default value for the parameter. If the parameter has no default value, this attribute is set to `Parameter.empty`.

**annotation**

The annotation for the parameter. If the parameter has no annotation, this attribute is set to `Parameter.empty`.

**kind**

Describes how argument values are bound to the parameter. Possible values (accessible via `Parameter`, like `Parameter.KEYWORD_ONLY`):

<table>
<thead>
<tr>
<th>Name</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>POSITIONAL_ONLY</code></td>
<td>Value must be supplied as a positional argument.</td>
</tr>
<tr>
<td></td>
<td>Python has no explicit syntax for defining positional-only parameters,</td>
</tr>
<tr>
<td></td>
<td>but many built-in and extension module functions (especially those</td>
</tr>
<tr>
<td></td>
<td>that accept only one or two parameters) accept them.</td>
</tr>
<tr>
<td><code>POSITIONAL_OR_KEYWORD</code></td>
<td>Value may be supplied as either a keyword or positional argument (this</td>
</tr>
<tr>
<td></td>
<td>is the standard binding</td>
</tr>
<tr>
<td><strong>VAR_POSITIONAL</strong></td>
<td>A tuple of positional arguments that aren’t bound to any other parameter. This corresponds to a *args parameter in a Python function definition.</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>KEYWORD_ONLY</strong></td>
<td>Value must be supplied as a keyword argument. Keyword only parameters are those which appear after a * or *args entry in a Python function definition.</td>
</tr>
<tr>
<td><strong>VAR_KEYWORD</strong></td>
<td>A dict of keyword arguments that aren’t bound to any other parameter. This corresponds to a **kwargs parameter in a Python function definition.</td>
</tr>
</tbody>
</table>

Example: print all keyword-only arguments without default values:

```python
>>> def foo(a, b, *, c, d=10):
...     pass

>>> sig = signature(foo)
>>> for param in sig.parameters.values():
...     if (param.kind == param.KEYWORD_ONLY and param.default is parameter)
...         print('Parameter:', param)
Parameter: c
```
replace(*[, name][, kind][, default][, annotation])

Create a new Parameter instance based on the instance replaced was invoked on. To override a Parameter attribute, pass the corresponding argument. To remove a default value or/and an annotation from a Parameter, pass Parameter.empty.

```python
>>> from inspect import Parameter
>>> param = Parameter('foo', Parameter.KEYWORD_ONLY)
>>> str(param)
'foo=42'

>>> str(param.replace())  # Will create a shallow copy of 'param'
'foo=42'

>>> str(param.replace(default=Parameter.empty, kind='POSITIONAL_ONLY'))
'foo:'spam'
```

*Changed in version 3.4:* In Python 3.3 Parameter objects were allowed to have name set to None if their kind was set to POSITIONAL_ONLY. This is no longer permitted.

class inspect.BoundArguments

Result of a Signature.bind() or Signature.bind_partial() call. Holds the mapping of arguments to the function's parameters.

**arguments**

An ordered, mutable mapping (collections.OrderedDict) of parameters' names to arguments' values. Contains only explicitly bound arguments. Changes in arguments will reflect
in \texttt{args} and \texttt{kwargs}.

Should be used in conjunction with \texttt{Signature.parameters} for any argument processing purposes.

\begin{tcolorbox}[colback=white]
\textbf{Note:} Arguments for which \texttt{Signature.bind()} or \texttt{Signature.bind_partial()} relied on a default value are skipped. However, if needed, use \texttt{BoundArguments.apply_defaults()} to add them.
\end{tcolorbox}

\textbf{args}

A tuple of positional arguments values. Dynamically computed from the \texttt{arguments} attribute.

\textbf{kwargs}

A dict of keyword arguments values. Dynamically computed from the \texttt{arguments} attribute.

\textbf{signature}

A reference to the parent \texttt{Signature} object.

\textbf{apply_defaults()}

Set default values for missing arguments.

For variable-positional arguments (*args) the default is an empty tuple.

For variable-keyword arguments (**kwargs) the default is an empty dict.

\begin{Verbatim}
>>> \texttt{def foo(a, b='ham', *args): pass}
>>> ba = inspect.signature(foo).bind('spam')
>>> ba.apply_defaults()
\end{Verbatim}
New in version 3.5.

The `args` and `kwargs` properties can be used to invoke functions:

```python
def test(a, *, b):
    ...

sig = signature(test)
ba = sig.bind(10, b=20)
test(*ba.args, **ba.kwargs)
```

See also:

**PEP 362 - Function Signature Object.**

The detailed specification, implementation details and examples.
29.12.4. Classes and functions

inspect.getclasstree(classes, unique=False)

Arrange the given list of classes into a hierarchy of nested lists. Where a nested list appears, it contains classes derived from the class whose entry immediately precedes the list. Each entry is a 2-tuple containing a class and a tuple of its base classes. If the unique argument is true, exactly one entry appears in the returned structure for each class in the given list. Otherwise, classes using multiple inheritance and their descendants will appear multiple times.

inspect.getargspec(func)

Get the names and default values of a Python function's arguments. A named tuple ArgSpec(args, varargs, keywords, defaults) is returned. args is a list of the argument names. varargs and keywords are the names of the * and ** arguments or None. defaults is a tuple of default argument values or None if there are no default arguments; if this tuple has n elements, they correspond to the last n elements listed in args.

Deprecated since version 3.0: Use signature() and Signature Object, which provide a better introspecting API for callables. This function will be removed in Python 3.6.

inspect.getfullargspec(func)

Get the names and default values of a Python function's arguments. A named tuple is returned:

FullArgSpec(args, varargs, varkw, defaults, kwonlyargs, kwonlydefaults, annotations)
args is a list of the argument names. varargs and varkw are the names of the * and ** arguments or None. defaults is an n-tuple of the default values of the last n arguments, or None if there are no default arguments. kwonlyargs is a list of keyword-only argument names. kwonlydefaults is a dictionary mapping names from kwonlyargs to defaults. annotations is a dictionary mapping argument names to annotations.

The first four items in the tuple correspond to getargspec().

*Changed in version 3.4:* This function is now based on signature(), but still ignores __wrapped__ attributes and includes the already bound first parameter in the signature output for bound methods.

*Deprecated since version 3.5:* Use signature() and Signature Object, which provide a better introspecting API for callables.

inspect.getargvalues(frame)

Get information about arguments passed into a particular frame. A named tuple ArgInfo(args, varargs, keywords, locals) is returned. args is a list of the argument names. varargs and keywords are the names of the * and ** arguments or None. locals is the locals dictionary of the given frame.

*Deprecated since version 3.5:* Use signature() and Signature Object, which provide a better introspecting API for callables.

inspect.formatargspec(args[, varargs, varkw, defaults, kwonlyargs, kwonlydefaults, annotations[, formatarg, formatvarargs, formatvarkw, formatvalue, formatreturns, formatannotations]])

Format a pretty argument spec from the values returned by
getargspec() or getfullargspec().

The first seven arguments are (args, varargs, varkw, defaults, kwonlyargs, kwonlydefaults, annotations).

The other six arguments are functions that are called to turn argument names, * argument name, ** argument name, default values, return annotation and individual annotations into strings, respectively.

For example:

```python
>>> from inspect import formatargspec, getfullargspec
>>> def f(a: int, b: float):
...     pass
...
>>> formatargspec(*getfullargspec(f))
'(a: int, b: float)'
```

*Deprecated since version 3.5:* Use signature() and Signature Object, which provide a better introspecting API for callables.

inspect.formatargvalues(args[, varargs, varkw, locals, formatarg, formatvarargs, formatvarkw, formatvalue])

Format a pretty argument spec from the four values returned by getargvalues(). The format* arguments are the corresponding optional formatting functions that are called to turn names and values into strings.

*Deprecated since version 3.5:* Use signature() and Signature Object, which provide a better introspecting API for callables.

inspect.getmro(cls)
Return a tuple of class cls's base classes, including cls, in method resolution order. No class appears more than once in this tuple. Note that the method resolution order depends on cls's type. Unless a very peculiar user-defined metatype is in use, cls will be the first element of the tuple.

`inspect.getcallargs(func, *args, **kwds)`

Bind the `args` and `kwds` to the argument names of the Python function or method `func`, as if it was called with them. For bound methods, bind also the first argument (typically named `self`) to the associated instance. A dict is returned, mapping the argument names (including the names of the `*` and `**` arguments, if any) to their values from `args` and `kwds`. In case of invoking `func` incorrectly, i.e. whenever `func(*args, **kwds)` would raise an exception because of incompatible signature, an exception of the same type and the same or similar message is raised. For example:

```python
>>> from inspect import getcallargs
>>> def f(a, b=1, *pos, **named):
...     pass
>>> getcallargs(f, 1, 2, 3) == {'a': 1, 'named': {}}, True
>>> getcallargs(f, a=2, x=4) == {'a': 2, 'named': True}
>>> getcallargs(f)
Traceback (most recent call last):
  ...
TypeError: f() missing 1 required positional argument
```

*New in version 3.2.*

*Deprecated since version 3.5:* Use `Signature.bind()` and
Signature.bind_partial() instead.

inspect.getclosurevars(func)
Get the mapping of external name references in a Python function or method func to their current values. A named tuple ClosureVars(nonlocals, globals, builtins, unbound) is returned. nonlocals maps referenced names to lexical closure variables, globals to the function's module globals and builtins to the builtins visible from the function body. unbound is the set of names referenced in the function that could not be resolved at all given the current module globals and builtins.

TypeError is raised if func is not a Python function or method.

New in version 3.3.

inspect.unwrap(func, *, stop=None)
Get the object wrapped by func. It follows the chain of __wrapped__ attributes returning the last object in the chain.

stop is an optional callback accepting an object in the wrapper chain as its sole argument that allows the unwrapping to be terminated early if the callback returns a true value. If the callback never returns a true value, the last object in the chain is returned as usual. For example, signature() uses this to stop unwrapping if any object in the chain has a __signature__ attribute defined.

ValueError is raised if a cycle is encountered.

New in version 3.4.
29.12.5. The interpreter stack

When the following functions return “frame records,” each record is a named tuple `FrameInfo(frame, filename, lineno, function, code_context, index)`. The tuple contains the frame object, the filename, the line number of the current line, the function name, a list of lines of context from the source code, and the index of the current line within that list.

*Changed in version 3.5:* Return a named tuple instead of a tuple.

**Note:** Keeping references to frame objects, as found in the first element of the frame records these functions return, can cause your program to create reference cycles. Once a reference cycle has been created, the lifespan of all objects which can be accessed from the objects which form the cycle can become much longer even if Python’s optional cycle detector is enabled. If such cycles must be created, it is important to ensure they are explicitly broken to avoid the delayed destruction of objects and increased memory consumption which occurs.

Though the cycle detector will catch these, destruction of the frames (and local variables) can be made deterministic by removing the cycle in a `finally` clause. This is also important if the cycle detector was disabled when Python was compiled or using `gc.disable()`. For example:

```python
def handle_stackframe_without_leak():
    frame = inspect.currentframe()
    try:
        # do something with the frame
    finally:
```
If you want to keep the frame around (for example to print a traceback later), you can also break reference cycles by using the `frame.clear()` method.

The optional `context` argument supported by most of these functions specifies the number of lines of context to return, which are centered around the current line.

```python
inspect.getframeinfo(frame, context=1)
```

Get information about a frame or traceback object. A named tuple `Traceback(filename, lineno, function, code_context, index)` is returned.

```python
inspect.getouterframes(frame, context=1)
```

Get a list of frame records for a frame and all outer frames. These frames represent the calls that lead to the creation of `frame`. The first entry in the returned list represents `frame`; the last entry represents the outermost call on `frame`'s stack.

*Changed in version 3.5:* A list of named tuples `FrameInfo(frame, filename, lineno, function, code_context, index)` is returned.

```python
inspect.getinnerframes(traceback, context=1)
```

Get a list of frame records for a traceback's frame and all inner frames. These frames represent calls made as a consequence of `frame`. The first entry in the list represents `traceback`; the last entry represents where the exception was raised.

*Changed in version 3.5:* A list of named tuples
FrameInfo(frame, filename, lineno, function, code_context, index) is returned.

inspect.currentframe()

Return the frame object for the caller's stack frame.

**CPython implementation detail:** This function relies on Python stack frame support in the interpreter, which isn't guaranteed to exist in all implementations of Python. If running in an implementation without Python stack frame support this function returns None.

inspect.stack(context=1)

Return a list of frame records for the caller's stack. The first entry in the returned list represents the caller; the last entry represents the outermost call on the stack.

*Changed in version 3.5:* A list of named tuples FrameInfo(frame, filename, lineno, function, code_context, index) is returned.

inspect.trace(context=1)

Return a list of frame records for the stack between the current frame and the frame in which an exception currently being handled was raised in. The first entry in the list represents the caller; the last entry represents where the exception was raised.

*Changed in version 3.5:* A list of named tuples FrameInfo(frame, filename, lineno, function, code_context, index) is returned.
29.12.6. Fetching attributes statically

Both `getattr()` and `hasattr()` can trigger code execution when fetching or checking for the existence of attributes. Descriptors, like properties, will be invoked and `__getattr__()` and `__getattribute__()` may be called.

For cases where you want passive introspection, like documentation tools, this can be inconvenient. `getattr_static()` has the same signature as `getattr()` but avoids executing code when it fetches attributes.

```
inspect.getattr_static(obj, attr, default=None)
```

Retrieve attributes without triggering dynamic lookup via the descriptor protocol, `__getattr__()` or `__getattribute__()`.

Note: this function may not be able to retrieve all attributes that `getattr` can fetch (like dynamically created attributes) and may find attributes that `getattr` can’t (like descriptors that raise AttributeError). It can also return descriptors objects instead of instance members.

If the instance `__dict__` is shadowed by another member (for example a property) then this function will be unable to find instance members.

New in version 3.2.

`getattr_static()` does not resolve descriptors, for example slot descriptors or getset descriptors on objects implemented in C. The descriptor object is returned instead of the underlying attribute.
You can handle these with code like the following. Note that for arbitrary getset descriptors invoking these may trigger code execution:

```python
# example code for resolving the builtin descriptor
class _foo:
    __slots__ = ['foo']

slot_descriptor = type(_foo.foo)
getset_descriptor = type(type(open(__file__)).name)
wrapper_descriptor = type(str.__dict__['__add__'])
descriptor_types = (slot_descriptor, getset_descriptor)

result = getattr_static(some_object, 'foo')
if type(result) in descriptor_types:
    try:
        result = result.__get__()
    except AttributeError:
        # descriptors can raise AttributeError to
        # indicate there is no underlying value
        # in which case the descriptor itself will
        # have to do
        pass
```
29.12.7. Current State of Generators and Coroutines

When implementing coroutine schedulers and for other advanced uses of generators, it is useful to determine whether a generator is currently executing, is waiting to start or resume or execution, or has already terminated. `getgeneratorstate()` allows the current state of a generator to be determined easily.

```python
inspect.getgeneratorstate(generator)
```
Get current state of a generator-iterator.

Possible states are:
- GEN_CREATED: Waiting to start execution.
- GEN_RUNNING: Currently being executed by the interpreter.
- GEN_SUSPENDED: Currently suspended at a yield expression.
- GEN_CLOSED: Execution has completed.

*New in version 3.2.*

```python
inspect.getcoroutinestate(coroutine)
```
Get current state of a coroutine object. The function is intended to be used with coroutine objects created by `async def` functions, but will accept any coroutine-like object that has `cr_running` and `cr_frame` attributes.

Possible states are:
- CORO_CREATED: Waiting to start execution.
- CORO_RUNNING: Currently being executed by the interpreter.
- CORO_SUSPENDED: Currently suspended at an await expression.
- CORO_CLOSED: Execution has completed.

New in version 3.5.

The current internal state of the generator can also be queried. This is mostly useful for testing purposes, to ensure that internal state is being updated as expected:

```python
inspect.getgeneratorlocals(generator)
```

Get the mapping of live local variables in `generator` to their current values. A dictionary is returned that maps from variable names to values. This is the equivalent of calling `locals()` in the body of the generator, and all the same caveats apply.

If `generator` is a `generator` with no currently associated frame, then an empty dictionary is returned. `TypeError` is raised if `generator` is not a Python generator object.

**CPython implementation detail:** This function relies on the generator exposing a Python stack frame for introspection, which isn’t guaranteed to be the case in all implementations of Python. In such cases, this function will always return an empty dictionary. New in version 3.3.

```python
inspect.getcoroutinelocals(coroutine)
```

This function is analogous to `getgeneratorlocals()`, but works for coroutine objects created by `async def` functions.

New in version 3.5.
29.12.8. Command Line Interface

The `inspect` module also provides a basic introspection capability from the command line.

By default, accepts the name of a module and prints the source of that module. A class or function within the module can be printed instead by appended a colon and the qualified name of the target object.

```bash
--details
Print information about the specified object rather than the source code
```

29.13. **site** — Site-specific configuration hook

**Source code:** Lib/site.py

This module is automatically imported during initialization. The automatic import can be suppressed using the interpreter’s `-S` option.

Importing this module will append site-specific paths to the module search path and add a few builtins, unless `-S` was used. In that case, this module can be safely imported with no automatic modifications to the module search path or additions to the builtins. To explicitly trigger the usual site-specific additions, call the `site.main()` function.

*Changed in version 3.3:* Importing the module used to trigger paths manipulation even when using `-S`.

It starts by constructing up to four directories from a head and a tail part. For the head part, it uses `sys.prefix` and `sys.exec_prefix`; empty heads are skipped. For the tail part, it uses the empty string and then `lib/site-packages` (on Windows) or `lib/pythonX.Y/site-packages` (on Unix and Macintosh). For each of the distinct head-tail combinations, it sees if it refers to an existing directory, and if so, adds it to `sys.path` and also inspects the newly added path for configuration files.

*Changed in version 3.5:* Support for the “site-python” directory has been removed.

If a file named “pyvenv.cfg” exists one directory above `sys.executable`,
sys.prefix and sys.exec_prefix are set to that directory and it is also checked for site-packages (sys.base_prefix and sys.base_exec_prefix will always be the “real” prefixes of the Python installation). If “pyvenv.cfg” (a bootstrap configuration file) contains the key “includem system-site-packages” set to anything other than “false” (case-insensitive), the system-level prefixes will still also be searched for site-packages; otherwise they won’t.

A path configuration file is a file whose name has the form name.pth and exists in one of the four directories mentioned above; its contents are additional items (one per line) to be added to sys.path. Non-existing items are never added to sys.path, and no check is made that the item refers to a directory rather than a file. No item is added to sys.path more than once. Blank lines and lines beginning with # are skipped. Lines starting with import (followed by space or tab) are executed.

For example, suppose sys.prefix and sys.exec_prefix are set to /usr/local. The Python X.Y library is then installed in /usr/local/lib/pythonX.Y. Suppose this has a subdirectory /usr/local/lib/pythonX.Y/site-packages with three subsubdirectories, foo, bar and spam, and two path configuration files, foo.pth and bar.pth. Assume foo.pth contains the following:

```
# foo package configuration
foo
bar
bletch
```

and bar.pth contains:
# bar package configuration

bar

Then the following version-specific directories are added to sys.path, in this order:

```
/usr/local/lib/pythonX.Y/site-packages/bar
/usr/local/lib/pythonX.Y/site-packages/foo
```

Note that bletch is omitted because it doesn’t exist; the bar directory precedes the foo directory because bar.pth comes alphabetically before foo.pth; and spam is omitted because it is not mentioned in either path configuration file.

After these path manipulations, an attempt is made to import a module named sitecustomize, which can perform arbitrary site-specific customizations. It is typically created by a system administrator in the site-packages directory. If this import fails with an ImportError exception, it is silently ignored. If Python is started without output streams available, as with pythonw.exe on Windows (which is used by default to start IDLE), attempted output from sitecustomize is ignored. Any exception other than ImportError causes a silent and perhaps mysterious failure of the process.

After this, an attempt is made to import a module named usercustomize, which can perform arbitrary user-specific customizations, if ENABLE_USER_SITE is true. This file is intended to be created in the user site-packages directory (see below), which is part of sys.path unless disabled by -s. An ImportError will be silently ignored.
Note that for some non-Unix systems, sys.prefix and sys.exec_prefix are empty, and the path manipulations are skipped; however the import of sitecustomize and usercustomize is still attempted.
29.13.1. Readline configuration

On systems that support `readline`, this module will also import and configure the `rlcompleter` module, if Python is started in interactive mode and without the `-S` option. The default behavior is enable tab-completion and to use `~/.python_history` as the history save file. To disable it, delete (or override) the `sys.__interactivehook__` attribute in your `sitecustomize` or `usercustomize` module or your `PYTHONSTARTUP` file.

*Changed in version 3.4:* Activation of rlcompleter and history was made automatic.
29.13.2. Module contents

**site.PREFIXES**

A list of prefixes for site-packages directories.

**site.ENABLE_USER_SITE**

Flag showing the status of the user site-packages directory. True means that it is enabled and was added to sys.path. False means that it was disabled by user request (with `-s` or `PYTHONNOUSERSITE`). None means it was disabled for security reasons (mismatch between user or group id and effective id) or by an administrator.

**site.USER_SITE**

Path to the user site-packages for the running Python. Can be None if `getusersitepackages()` hasn’t been called yet. Default value is `~/.local/lib/pythonX.Y/site-packages` for UNIX and non-framework Mac OS X builds, `~/Library/Python/X.Y/lib/python/site-packages` for Mac framework builds, and `%APPDATA%\Python\PythonXY\site-packages` on Windows. This directory is a site directory, which means that .pth files in it will be processed.

**site.USER_BASE**

Path to the base directory for the user site-packages. Can be None if `getuserbase()` hasn’t been called yet. Default value is `~/.local` for UNIX and Mac OS X non-framework builds, `~/Library/Python/X.Y` for Mac framework builds, and `%APPDATA%\Python` for Windows. This value is used by Distutils
to compute the installation directories for scripts, data files, Python modules, etc. for the user installation scheme. See also PYTHONUSERBASE.

site.main()
Adds all the standard site-specific directories to the module search path. This function is called automatically when this module is imported, unless the Python interpreter was started with the -S flag.

*Changed in version 3.3:* This function used to be called unconditionally.

site.addsitedir(sitedir, known_paths=None)
Add a directory to sys.path and process its .pth files. Typically used in sitecustomize or usercustomize (see above).

site.getsitepackages()
Return a list containing all global site-packages directories.

*New in version 3.2.*

site.getuserbase()
Return the path of the user base directory, USER_BASE. If it is not initialized yet, this function will also set it, respecting PYTHONUSERBASE.

*New in version 3.2.*

site.getusersitepackages()
Return the path of the user-specific site-packages directory, USER_SITE. If it is not initialized yet, this function will also set it, respecting PYTHONNOUSERSITE and USER_BASE.
New in version 3.2.

The site module also provides a way to get the user directories from the command line:

```
$ python3 -m site --user-site
/home/user/.local/lib/python3.3/site-packages
```

If it is called without arguments, it will print the contents of `sys.path` on the standard output, followed by the value of `USER_BASE` and whether the directory exists, then the same thing for `USER_SITE`, and finally the value of `ENABLE_USER_SITE`.

--user-base

Print the path to the user base directory.

--user-site

Print the path to the user site-packages directory.

If both options are given, user base and user site will be printed (always in this order), separated by `os.pathsep`.

If any option is given, the script will exit with one of these values: 0 if the user site-packages directory is enabled, 1 if it was disabled by the user, 2 if it is disabled for security reasons or by an administrator, and a value greater than 2 if there is an error.

See also: PEP 370 – Per user site-packages directory
29.14. \texttt{fpectl} — Floating point exception control

\textbf{Note:} The \texttt{fpectl} module is not built by default, and its usage is discouraged and may be dangerous except in the hands of experts. See also the section Limitations and other considerations on limitations for more details.

Most computers carry out floating point operations in conformance with the so-called IEEE-754 standard. On any real computer, some floating point operations produce results that cannot be expressed as a normal floating point value. For example, try

\begin{verbatim}
>>> import math
>>> math.exp(1000)
inf
>>> math.exp(1000) / math.exp(1000)
nan
\end{verbatim}

(The example above will work on many platforms. DEC Alpha may be one exception.) “Inf” is a special, non-numeric value in IEEE-754 that stands for “infinity”, and “nan” means “not a number.” Note that, other than the non-numeric results, nothing special happened when you asked Python to carry out those calculations. That is in fact the default behaviour prescribed in the IEEE-754 standard, and if it works for you, stop reading now.

In some circumstances, it would be better to raise an exception and stop processing at the point where the faulty operation was attempted. The \texttt{fpectl} module is for use in that situation. It provides control over floating point units from several hardware manufacturers, allowing the
user to turn on the generation of SIGFPE whenever any of the IEEE-754 exceptions Division by Zero, Overflow, or Invalid Operation occurs. In tandem with a pair of wrapper macros that are inserted into the C code comprising your python system, SIGFPE is trapped and converted into the Python `FloatingPointError` exception.

The `fpectl` module defines the following functions and may raise the given exception:

```python
def turnon_sigfpe():
    # Turn on the generation of SIGFPE, and set up an appropriate
    # signal handler.

def turnoff_sigfpe():
    # Reset default handling of floating point exceptions.

exception FloatingPointError
    # After `turnon_sigfpe()` has been executed, a floating point
    # operation that raises one of the IEEE-754 exceptions Division by
    # Zero, Overflow, or Invalid operation will in turn raise this standard
    # Python exception.
```
29.14.1. Example

The following example demonstrates how to start up and test operation of the `fpectl` module.

```python
>>> import fpectl
>>> import fpetest
>>> fpectl.turnon_sigfpe()
>>> fpetest.test()
overflow PASS
FloatingPointError: Overflow

div by 0 PASS
FloatingPointError: Division by zero
   [ more output from test elided ]
>>> import math
>>> math.exp(1000)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
FloatingPointError: in math_1
```
29.14.2. Limitations and other considerations

Setting up a given processor to trap IEEE-754 floating point errors currently requires custom code on a per-architecture basis. You may have to modify `fpectl` to control your particular hardware.

Conversion of an IEEE-754 exception to a Python exception requires that the wrapper macros `PyFPE_START_PROTECT` and `PyFPE_END_PROTECT` be inserted into your code in an appropriate fashion. Python itself has been modified to support the `fpectl` module, but many other codes of interest to numerical analysts have not.

The `fpectl` module is not thread-safe.

**See also:** Some files in the source distribution may be interesting in learning more about how this module operates. The include file `Include/pyfpe.h` discusses the implementation of this module at some length. Modules/fpetestmodule.c gives several examples of use. Many additional examples can be found in Objects/floatobject.c.
30. Custom Python Interpreters

The modules described in this chapter allow writing interfaces similar to Python’s interactive interpreter. If you want a Python interpreter that supports some special feature in addition to the Python language, you should look at the code module. (The codeop module is lower-level, used to support compiling a possibly-incomplete chunk of Python code.)

The full list of modules described in this chapter is:

- **30.1. code — Interpreter base classes**
  - 30.1.1. Interactive Interpreter Objects
  - 30.1.2. Interactive Console Objects
- **30.2. codeop — Compile Python code**
30.1. **code** — Interpreter base classes

**Source code:** Lib/code.py

The code module provides facilities to implement read-eval-print loops in Python. Two classes and convenience functions are included which can be used to build applications which provide an interactive interpreter prompt.

```python
class code.InteractiveInterpreter(locals=None)
    This class deals with parsing and interpreter state (the user’s namespace); it does not deal with input buffering or prompting or input file naming (the filename is always passed in explicitly). The optional `locals` argument specifies the dictionary in which code will be executed; it defaults to a newly created dictionary with key '__name__' set to '__console__' and key '__doc__' set to None.
```

```python
class code.InteractiveConsole(locals=None, filename="<console>")
    Closely emulate the behavior of the interactive Python interpreter. This class builds on `InteractiveInterpreter` and adds prompting using the familiar `sys.ps1` and `sys.ps2`, and input buffering.
```

```python
code.interact(banner=None, readfunc=None, local=None)
    Convenience function to run a read-eval-print loop. This creates a new instance of `InteractiveConsole` and sets `readfunc` to be used as the `InteractiveConsole.raw_input()` method, if
```
provided. If `local` is provided, it is passed to the `InteractiveConsole` constructor for use as the default namespace for the interpreter loop. The `interact()` method of the instance is then run with `banner` passed as the banner to use, if provided. The console object is discarded after use.

code`compile_command(source, filename="<input>", symbol="single")

This function is useful for programs that want to emulate Python's interpreter main loop (a.k.a. the read-eval-print loop). The tricky part is to determine when the user has entered an incomplete command that can be completed by entering more text (as opposed to a complete command or a syntax error). This function `almost` always makes the same decision as the real interpreter main loop.

`source` is the source string; `filename` is the optional filename from which source was read, defaulting to '<input>'; and `symbol` is the optional grammar start symbol, which should be either 'single' (the default) or 'eval'.

Returns a code object (the same as `compile(source, filename, symbol)`) if the command is complete and valid; None if the command is incomplete; raises `SyntaxError` if the command is complete and contains a syntax error, or raises `OverflowError` or `ValueError` if the command contains an invalid literal.
30.1.1. Interactive Interpreter Objects

InteractiveInterpreter.runsource(source, filename="<input>", symbol="single")

Compile and run some source in the interpreter. Arguments are the same as for compile_command(); the default for filename is '<input>', and for symbol is 'single'. One several things can happen:

- The input is incorrect; compile_command() raised an exception (SyntaxError or OverflowError). A syntax traceback will be printed by calling the showsyntaxerror() method. runsource() returns False.
- The input is incomplete, and more input is required; compile_command() returned None. runsource() returns True.
- The input is complete; compile_command() returned a code object. The code is executed by calling the runcode() (which also handles run-time exceptions, except for SystemExit). runsource() returns False.

The return value can be used to decide whether to use sys.ps1 or sys.ps2 to prompt the next line.

InteractiveInterpreter.runcode(code)

Execute a code object. When an exception occurs, showtraceback() is called to display a traceback. All exceptions are caught except SystemExit, which is allowed to propagate.

A note about KeyboardInterrupt: this exception may occur elsewhere in this code, and may not always be caught. The caller should be prepared to deal with it.
InteractiveInterpreter.\texttt{showsyntaxerror}(\textit{filename}=None)

Display the syntax error that just occurred. This does not display a stack trace because there isn't one for syntax errors. If \textit{filename} is given, it is stuffed into the exception instead of the default filename provided by Python's parser, because it always uses '⟨string⟩' when reading from a string. The output is written by the \texttt{write()} method.

InteractiveInterpreter.\texttt{showtraceback}()

Display the exception that just occurred. We remove the first stack item because it is within the interpreter object implementation. The output is written by the \texttt{write()} method.

\textit{Changed in version 3.5}: The full chained traceback is displayed instead of just the primary traceback.

InteractiveInterpreter.\texttt{write}(\textit{data})

Write a string to the standard error stream (\texttt{sys.stderr}). Derived classes should override this to provide the appropriate output handling as needed.
30.1.2. Interactive Console Objects

The  `InteractiveConsole`  class is a subclass of `InteractiveInterpreter`, and so offers all the methods of the interpreter objects as well as the following additions.

**`InteractiveConsole.interact(banner=None)`**

Closely emulate the interactive Python console. The optional `banner` argument specify the banner to print before the first interaction; by default it prints a banner similar to the one printed by the standard Python interpreter, followed by the class name of the console object in parentheses (so as not to confuse this with the real interpreter – since it’s so close!).

*Changed in version 3.4:* To suppress printing any banner, pass an empty string.

**`InteractiveConsole.push(line)`**

Push a line of source text to the interpreter. The line should not have a trailing newline; it may have internal newlines. The line is appended to a buffer and the interpreter’s `runsource()` method is called with the concatenated contents of the buffer as source. If this indicates that the command was executed or invalid, the buffer is reset; otherwise, the command is incomplete, and the buffer is left as it was after the line was appended. The return value is `True` if more input is required, `False` if the line was dealt with in some way (this is the same as `runsource()`).

**`InteractiveConsole.resetbuffer()`**

Remove any unhandled source text from the input buffer.
`InteractiveConsole.raw_input(prompt='')`

Write a prompt and read a line. The returned line does not include the trailing newline. When the user enters the EOF key sequence, `EOFError` is raised. The base implementation reads from `sys.stdin`; a subclass may replace this with a different implementation.
30.2. codeop — Compile Python code

The codeop module provides utilities upon which the Python read-eval-print loop can be emulated, as is done in the code module. As a result, you probably don’t want to use the module directly; if you want to include such a loop in your program you probably want to use the code module instead.

There are two parts to this job:

1. Being able to tell if a line of input completes a Python statement: in short, telling whether to print ‘>>>’ or ‘...‘ next.
2. Remembering which future statements the user has entered, so subsequent input can be compiled with these in effect.

The codeop module provides a way of doing each of these things, and a way of doing them both.

To do just the former:

```python
codeop.compile_command(source, filename="<input>", symbol="single")
```

Tries to compile source, which should be a string of Python code and return a code object if source is valid Python code. In that case, the filename attribute of the code object will be filename, which defaults to '<input>'. Returns None if source is not valid Python code, but is a prefix of valid Python code.

If there is a problem with source, an exception will be raised. `SyntaxError` is raised if there is invalid Python syntax, and
**OverflowError** or **ValueError** if there is an invalid literal.

The **symbol** argument determines whether **source** is compiled as a statement ('single', the default) or as an **expression** ('eval'). Any other value will cause **ValueError** to be raised.

**Note:** It is possible (but not likely) that the parser stops parsing with a successful outcome before reaching the end of the source; in this case, trailing symbols may be ignored instead of causing an error. For example, a backslash followed by two newlines may be followed by arbitrary garbage. This will be fixed once the API for the parser is better.

**class codeop.Compile**

Instances of this class have **__call__()** methods identical in signature to the built-in function **compile()**, but with the difference that if the instance compiles program text containing a **__future__** statement, the instance ‘remembers’ and compiles all subsequent program texts with the statement in force.

**class codeop.CommandCompiler**

Instances of this class have **__call__()** methods identical in signature to **compile_command()**; the difference is that if the instance compiles program text containing a **__future__** statement, the instance ‘remembers’ and compiles all subsequent program texts with the statement in force.
31. Importing Modules

The modules described in this chapter provide new ways to import other Python modules and hooks for customizing the import process.

The full list of modules described in this chapter is:

- **31.1. zipimport** — Import modules from Zip archives
  - 31.1.1. zipimporter Objects
  - 31.1.2. Examples
- **31.2. pkgutil** — Package extension utility
- **31.3. modulefinder** — Find modules used by a script
  - 31.3.1. Example usage of ModuleFinder
- **31.4. runpy** — Locating and executing Python modules
- **31.5. importlib** — The implementation of import
  - 31.5.1. Introduction
  - 31.5.2. Functions
  - 31.5.3. importlib.abc — Abstract base classes related to import
  - 31.5.4. importlib.machinery — Importers and path hooks
  - 31.5.5. importlib.util — Utility code for importers
31.1. zipimport — Import modules from Zip archives

This module adds the ability to import Python modules (*.py, *.py[co]) and packages from ZIP-format archives. It is usually not needed to use the `zipimport` module explicitly; it is automatically used by the built-in `import` mechanism for `sys.path` items that are paths to ZIP archives.

Typically, `sys.path` is a list of directory names as strings. This module also allows an item of `sys.path` to be a string naming a ZIP file archive. The ZIP archive can contain a subdirectory structure to support package imports, and a path within the archive can be specified to only import from a subdirectory. For example, the path `example.zip/lib/` would only import from the `lib/` subdirectory within the archive.

Any files may be present in the ZIP archive, but only files .py and .pyc are available for import. ZIP import of dynamic modules (.pyd, .so) is disallowed. Note that if an archive only contains .py files, Python will not attempt to modify the archive by adding the corresponding .pyc file, meaning that if a ZIP archive doesn't contain .pyc files, importing may be rather slow.

ZIP archives with an archive comment are currently not supported.

See also:

**PKZIP Application Note**

Documentation on the ZIP file format by Phil Katz, the creator of
the format and algorithms used.

**PEP 273 - Import Modules from Zip Archives**
Written by James C. Ahlstrom, who also provided an implementation. Python 2.3 follows the specification in PEP 273, but uses an implementation written by Just van Rossum that uses the import hooks described in PEP 302.

**PEP 302 - New Import Hooks**
The PEP to add the import hooks that help this module work.

This module defines an exception:

```python
exception zipimport.ZipImportError
    Exception raised by zipimporter objects. It's a subclass of ImportError, so it can be caught as ImportError, too.
```
31.1.1. zipimporter Objects

`zipimporter` is the class for importing ZIP files.

```python
class zipimport.zipimporter(archivepath)
```

Create a new zipimporter instance. `archivepath` must be a path to a ZIP file, or to a specific path within a ZIP file. For example, an `archivepath` of `foo/bar.zip/lib` will look for modules in the `lib` directory inside the ZIP file `foo/bar.zip` (provided that it exists).

`ZipImportError` is raised if `archivepath` doesn't point to a valid ZIP archive.

```python
find_module(fullname[, path])
```

Search for a module specified by `fullname`. `fullname` must be the fully qualified (dotted) module name. It returns the zipimporter instance itself if the module was found, or `None` if it wasn't. The optional `path` argument is ignored—it's there for compatibility with the importer protocol.

```python
get_code(fullname)
```

Return the code object for the specified module. Raise `ZipImportError` if the module couldn't be found.

```python
get_data(pathname)
```

Return the data associated with `pathname`. Raise `OSError` if the file wasn’t found.

*Changed in version 3.3:* `IOError` used to be raised instead of `OSError`.
get_filename(fullname)
    Return the value __file__ would be set to if the specified module was imported. Raise ZipImportError if the module couldn't be found.

    New in version 3.1.

get_source(fullname)
    Return the source code for the specified module. Raise ZipImportError if the module couldn't be found, return None if the archive does contain the module, but has no source for it.

is_package(fullname)
    Return True if the module specified by fullname is a package. Raise ZipImportError if the module couldn't be found.

load_module(fullname)
    Load the module specified by fullname. fullname must be the fully qualified (dotted) module name. It returns the imported module, or raises ZipImportError if it wasn't found.

archive
    The file name of the importer's associated ZIP file, without a possible subpath.

prefix
    The subpath within the ZIP file where modules are searched. This is the empty string for zipimporter objects which point to the root of the ZIP file.

    The archive and prefix attributes, when combined with a slash, equal the original archivepath argument given to the
zipimporter constructor.
31.1.2. Examples

Here is an example that imports a module from a ZIP archive - note that the `zipimport` module is not explicitly used.

```
$ unzip -l example.zip
Archive:  example.zip
         Length  Date     Time    Name
          ------  ----      ----    ----
          8467  11-26-02 22:30  jwzthreading.py
          ------  ------    ------
          8467
$ ./python
Python 2.3 (#1, Aug 1 2003, 19:54:32)
>>> import sys
>>> sys.path.insert(0, 'example.zip')  # Add .zip file
>>> import jwzthreading
>>> jwzthreading.__file__
'example.zip/jwzthreading.py'
```
This module provides utilities for the import system, in particular package support.

`pkgutil.extend_path(path, name)`

Extend the search path for the modules which comprise a package. Intended use is to place the following code in a package's `__init__.py`:

```
from pkgutil import extend_path
__path__ = extend_path(__path__, __name__)
```

This will add to the package's `__path__` all subdirectories of directories on `sys.path` named after the package. This is useful if one wants to distribute different parts of a single logical package as multiple directories.

It also looks for `*.pkg` files beginning where `*` matches the `name` argument. This feature is similar to `*.pth` files (see the `site` module for more information), except that it doesn’t special-case lines starting with `import`. A `*.pkg` file is trusted at face value: apart from checking for duplicates, all entries found in a `*.pkg` file are added to the path, regardless of whether they exist on the filesystem. (This is a feature.)

If the input path is not a list (as is the case for frozen packages) it is
returned unchanged. The input path is not modified; an extended copy is returned. Items are only appended to the copy at the end.

It is assumed that `sys.path` is a sequence. Items of `sys.path` that are not strings referring to existing directories are ignored. Unicode items on `sys.path` that cause errors when used as filenames may cause this function to raise an exception (in line with `os.path.isdir()` behavior).

```python
class pkgutil.ImpImporter(dirname=None)

PEP 302 Importer that wraps Python’s “classic” import algorithm.
```

If `dirname` is a string, a **PEP 302** importer is created that searches that directory. If `dirname` is None, a **PEP 302** importer is created that searches the current `sys.path`, plus any modules that are frozen or built-in.

Note that `ImpImporter` does not currently support being used by placement on `sys.meta_path`.

**Deprecated since version 3.3:** This emulation is no longer needed, as the standard import mechanism is now fully PEP 302 compliant and available in `importlib`.

```python
class pkgutil.ImpLoader(fullname, file, filename, etc)

PEP 302 Loader that wraps Python’s “classic” import algorithm.
```

**Deprecated since version 3.3:** This emulation is no longer needed, as the standard import mechanism is now fully PEP 302 compliant and available in `importlib`.

```python
pkgutil.find_loader(fullname)

Retrieve a **PEP 302** module loader for the given `fullname`.
This is a backwards compatibility wrapper around `importlib.util.find_spec()` that converts most failures to `ImportError` and only returns the loader rather than the full ModuleSpec.

*Changed in version 3.3:* Updated to be based directly on `importlib` rather than relying on the package internal PEP 302 import emulation.

*Changed in version 3.4:* Updated to be based on PEP 451

`pkgutil.get_importer(path_item)`

Retrieve a PEP 302 importer for the given `path_item`.

The returned importer is cached in `sys.path_importer_cache` if it was newly created by a path hook.

The cache (or part of it) can be cleared manually if a rescan of `sys.path_hooks` is necessary.

*Changed in version 3.3:* Updated to be based directly on `importlib` rather than relying on the package internal PEP 302 import emulation.

`pkgutil.get_loader(module_or_name)`

Get a PEP 302 “loader” object for `module_or_name`.

If the module or package is accessible via the normal import mechanism, a wrapper around the relevant part of that machinery is returned. Returns None if the module cannot be found or imported. If the named module is not already imported, its containing package (if any) is imported, in order to establish the package __path__. 
Changed in version 3.3: Updated to be based directly on *importlib* rather than relying on the package internal PEP 302 import emulation.

*Changed in version 3.4:* Updated to be based on **PEP 451**

```python
cpkgutil.iter_importers(fullname="")
```

Yield **PEP 302** importers for the given module name.

If `fullname` contains a `.'`, the importers will be for the package containing `fullname`, otherwise they will be all registered top level importers (i.e. those on both `sys.meta_path` and `sys.path_hooks`).

If the named module is in a package, that package is imported as a side effect of invoking this function.

If no module name is specified, all top level importers are produced.

*Changed in version 3.3:* Updated to be based directly on *importlib* rather than relying on the package internal PEP 302 import emulation.

```python
cpkgutil.iter_modules(path=None, prefix="")
```

Yields `(module_finder, name, ispkg)` for all submodules on `path`, or, if `path` is `None`, all top-level modules on `sys.path`.

`path` should be either `None` or a list of paths to look for modules in.

`prefix` is a string to output on the front of every module name on output.

**Note:** Only works for a `finder` which defines an `iter_modules()` method. This interface is non-standard, so the
module also provides implementations for
importlib.machinery.FileFinder
and
zipimport.zipimporter.

*Changed in version 3.3:* Updated to be based directly on
importlib rather than relying on the package internal PEP 302
import emulation.

pkgutil.walk_packages(path=None, prefix='', onerror=None)
Yields (module_finder, name, ispkg) for all modules
recursively on path, or, if path is None, all accessible modules.

*path* should be either None or a list of paths to look for modules in.

*prefix* is a string to output on the front of every module name on
output.

Note that this function must import all *packages* (*not* all modules!)
on the given *path*, in order to access the __path__ attribute to find
submodules.

*onerror* is a function which gets called with one argument (the
name of the package which was being imported) if any exception
occurs while trying to import a package. If no *onerror* function is
supplied, *ImportErrors* are caught and ignored, while all other
exceptions are propagated, terminating the search.

Examples:

```python
# list all modules python can access
walk_packages()

# list all submodules of ctypes
walk_packages(ctypes.__path__, ctypes.__name__ +
```
Note: Only works for a finder which defines an `iter_modules()` method. This interface is non-standard, so the module also provides implementations for `importlib.machinery.FileFinder` and `zipimport.zipimporter`.

*Changed in version 3.3:* Updated to be based directly on `importlib` rather than relying on the package internal PEP 302 import emulation.

`pkgutil.get_data(package, resource)`

Get a resource from a package.

This is a wrapper for the **PEP 302** loader `get_data()` API. The `package` argument should be the name of a package, in standard module format (`foo.bar`). The `resource` argument should be in the form of a relative filename, using `/` as the path separator. The parent directory name `..` is not allowed, and nor is a rooted name (starting with a `/`).

The function returns a binary string that is the contents of the specified resource.

For packages located in the filesystem, which have already been imported, this is the rough equivalent of:

```python
d = os.path.dirname(sys.modules[package].__file__)  
data = open(os.path.join(d, resource), 'rb').read
```

If the package cannot be located or loaded, or it uses a **PEP 302** loader which does not support `get_data()`, then `None` is
returned.
31.3. modulefinder — Find modules used by a script

Source code: Lib/modulefinder.py

This module provides a ModuleFinder class that can be used to determine the set of modules imported by a script. modulefinder.py can also be run as a script, giving the filename of a Python script as its argument, after which a report of the imported modules will be printed.

modulefinder.\texttt{AddPackagePath}(pkg\_name, path)

Record that the package named \texttt{pkg\_name} can be found in the specified \texttt{path}.

modulefinder.\texttt{ReplacePackage}(oldname, newname)

Allows specifying that the module named \texttt{oldname} is in fact the package named \texttt{newname}.

class modulefinder.\texttt{ModuleFinder}(path=None, debug=0, excludes=[], replace\_paths=[])

This class provides \texttt{run\_script()} and \texttt{report()} methods to determine the set of modules imported by a script. \texttt{path} can be a list of directories to search for modules; if not specified, \texttt{sys.path} is used. \texttt{debug} sets the debugging level; higher values make the class print debugging messages about what it's doing. \texttt{excludes} is a list of module names to exclude from the analysis. \texttt{replace\_paths} is a list of (oldpath, newpath) tuples that will be replaced in module paths.
report()
    Print a report to standard output that lists the modules imported by the script and their paths, as well as modules that are missing or seem to be missing.

run_script(pathname)
    Analyze the contents of the pathname file, which must contain Python code.

modules
    A dictionary mapping module names to modules. See Example usage of ModuleFinder.
31.3.1. Example usage of ModuleFinder

The script that is going to get analyzed later on (bacon.py):

```python
import re, itertools

try:
    import baconhameggs
except ImportError:
    pass

try:
    import guido.python.ham
except ImportError:
    pass
```

The script that will output the report of bacon.py:

```python
from modulefinder import ModuleFinder

finder = ModuleFinder()
finder.run_script('bacon.py')

print('Loaded modules:')
for name, mod in finder.modules.items():
    print('%s: ' % name, end='')
    print(',', ''.join(list(mod.globalnames.keys()))[:3])

print('-'*50)
print('Modules not imported: ')
print('\n'.join(finder.badmodules.keys()))
```

Sample output (may vary depending on the architecture):
Loaded modules:
_types:
copyreg: _inverted_registry, _slotnames, __all__
sre_compile: isstring, _sre, _optimize_unicode
_sre:
sre_constants: REPEAT_ONE, makedict, AT_END_LINE
sys:
re: __module__, finditer, _expand
itertools:
__main__: re, itertools, baconhameggs
sre_parse: _PATTERNENDERS, SRE_FLAG_UNICODE
array:
types: __module__, IntType, TypeType

---------------------------------------------------

Modules not imported:
guido.python.ham
baconhameggs
The `runpy` module is used to locate and run Python modules without importing them first. Its main use is to implement the `-m` command line switch that allows scripts to be located using the Python module namespace rather than the filesystem.

Note that this is not a sandbox module - all code is executed in the current process, and any side effects (such as cached imports of other modules) will remain in place after the functions have returned.

Furthermore, any functions and classes defined by the executed code are not guaranteed to work correctly after a `runpy` function has returned. If that limitation is not acceptable for a given use case, `importlib` is likely to be a more suitable choice than this module.

The `runpy` module provides two functions:

```
runpy.run_module(mod_name, init_globals=None, run_name=None, alter_sys=False)
```

Execute the code of the specified module and return the resulting module globals dictionary. The module’s code is first located using the standard import mechanism (refer to PEP 302 for details) and then executed in a fresh module namespace.

If the supplied module name refers to a package rather than a normal module, then that package is imported and the `__main__`
submodule within that package is then executed and the resulting module globals dictionary returned.

The optional dictionary argument `init_globals` may be used to pre-populate the module's globals dictionary before the code is executed. The supplied dictionary will not be modified. If any of the special global variables below are defined in the supplied dictionary, those definitions are overridden by `run_module()`.

The special global variables `__name__`, `__spec__`, `__file__`, `__cached__`, `__loader__` and `__package__` are set in the globals dictionary before the module code is executed (Note that this is a minimal set of variables - other variables may be set implicitly as an interpreter implementation detail).

`__name__` is set to `run_name` if this optional argument is not `None`, to `mod_name + '.__main__'` if the named module is a package and to the `mod_name` argument otherwise.

`__spec__` will be set appropriately for the actually imported module (that is, `__spec__.name` will always be `mod_name` or `mod_name + '.__main__`, never `run_name`).

`__file__`, `__cached__`, `__loader__` and `__package__` are set as normal based on the module spec.

If the argument `alter_sys` is supplied and evaluates to `True`, then `sys.argv[0]` is updated with the value of `__file__` and `sys.modules[__name__]` is updated with a temporary module object for the module being executed. Both `sys.argv[0]` and `sys.modules[__name__]` are restored to their original values before the function returns.
Note that this manipulation of `sys` is not thread-safe. Other threads may see the partially initialised module, as well as the altered list of arguments. It is recommended that the `sys` module be left alone when invoking this function from threaded code.

**See also:** The `-m` option offering equivalent functionality from the command line.

*Changed in version 3.1:* Added ability to execute packages by looking for a `__main__` submodule.

*Changed in version 3.2:* Added `__cached__` global variable (see PEP 3147).

*Changed in version 3.4:* Updated to take advantage of the module spec feature added by PEP 451. This allows `__cached__` to be set correctly for modules run this way, as well as ensuring the real module name is always accessible as `__spec__.name`.

```python
runpy.run_path(file_path, init_globals=None, run_name=None)
```

Execute the code at the named filesystem location and return the resulting module globals dictionary. As with a script name supplied to the CPython command line, the supplied path may refer to a Python source file, a compiled bytecode file or a valid `sys.path` entry containing a `__main__` module (e.g. a zipfile containing a top-level `__main__.py` file).

For a simple script, the specified code is simply executed in a fresh module namespace. For a valid `sys.path` entry (typically a zipfile or directory), the entry is first added to the beginning of `sys.path`. The function then looks for and executes a `__main__` module using the updated path. Note that there is no special protection
against invoking an existing __main__ entry located elsewhere on sys.path if there is no such module at the specified location.

The optional dictionary argument init_globals may be used to pre-populate the module’s globals dictionary before the code is executed. The supplied dictionary will not be modified. If any of the special global variables below are defined in the supplied dictionary, those definitions are overridden by run_path().

The special global variables __name__, __spec__, __file__, __cached__, __loader__ and __package__ are set in the globals dictionary before the module code is executed (Note that this is a minimal set of variables - other variables may be set implicitly as an interpreter implementation detail).

__name__ is set to run_name if this optional argument is not None and to '<run_path>' otherwise.

If the supplied path directly references a script file (whether as source or as precompiled byte code), then __file__ will be set to the supplied path, and __spec__, __cached__, __loader__ and __package__ will all be set to None.

If the supplied path is a reference to a valid sys.path entry, then __spec__ will be set appropriately for the imported __main__ module (that is, __spec__.name will always be __main__). __file__, __cached__, __loader__ and __package__ will be set as normal based on the module spec.

A number of alterations are also made to the sys module. Firstly, sys.path may be altered as described above. sys.argv[0] is updated with the value of file_path and
sys.modules[\_\_\_name\_\_\_] is updated with a temporary module object for the module being executed. All modifications to items in sys are reverted before the function returns.

Note that, unlike run_module(), the alterations made to sys are not optional in this function as these adjustments are essential to allowing the execution of sys.path entries. As the thread-safety limitations still apply, use of this function in threaded code should be either serialised with the import lock or delegated to a separate process.

See also: Interface options for equivalent functionality on the command line (python path/to/script).

New in version 3.2.

Changed in version 3.4: Updated to take advantage of the module spec feature added by PEP 451. This allows \_\_cached\_\_ to be set correctly in the case where \_\_main\_\_ is imported from a valid sys.path entry rather than being executed directly.

See also:

PEP 338 – Executing modules as scripts
   PEP written and implemented by Nick Coghlan.

PEP 366 – Main module explicit relative imports
   PEP written and implemented by Nick Coghlan.

PEP 451 – A ModuleSpec Type for the Import System
   PEP written and implemented by Eric Snow

Command line and environment - CPython command line details

The importlib.import_module() function
31.5. `importlib` – The implementation of `import`

*New in version 3.1.*
31.5.1. Introduction

The purpose of the importlib package is two-fold. One is to provide the implementation of the import statement (and thus, by extension, the __import__() function) in Python source code. This provides an implementation of import which is portable to any Python interpreter. This also provides an implementation which is easier to comprehend than one implemented in a programming language other than Python.

Two, the components to implement import are exposed in this package, making it easier for users to create their own custom objects (known generically as an importer) to participate in the import process.

See also:

The import statement
The language reference for the import statement.

Packages specification
Original specification of packages. Some semantics have changed since the writing of this document (e.g. redirecting based on None in sys.modules).

The __import__() function
The import statement is syntactic sugar for this function.

PEP 235
Import on Case-Insensitive Platforms

PEP 263
Defining Python Source Code Encodings

PEP 302
New Import Hooks

PEP 328
Imports: Multi-Line and Absolute/Relative

**PEP 366**
- Main module explicit relative imports

**PEP 451**
- A ModuleSpec Type for the Import System

**PEP 488**
- Elimination of PYO files

**PEP 489**
- Multi-phase extension module initialization

**PEP 3120**
- Using UTF-8 as the Default Source Encoding

**PEP 3147**
- PYC Repository Directories
31.5.2. Functions

importlib.__import__(name, globals=None, locals=None, fromlist=(), level=0)

An implementation of the built-in __import__() function.

**Note:** Programmatic importing of modules should use import_module() instead of this function.

importlib.import_module(name, package=None)

Import a module. The name argument specifies what module to import in absolute or relative terms (e.g. either pkg.mod or ..mod). If the name is specified in relative terms, then the package argument must be set to the name of the package which is to act as the anchor for resolving the package name (e.g. import_module('..mod', 'pkg.subpkg') will import pkg.mod).

The import_module() function acts as a simplifying wrapper around importlib.__import__(). This means all semantics of the function are derived from importlib.__import__(). The most important difference between these two functions is that import_module() returns the specified package or module (e.g. pkg.mod), while __import__() returns the top-level package or module (e.g. pkg).

If you are dynamically importing a module that was created since the interpreter began execution (e.g., created a Python source file), you may need to call invalidate_caches() in order for the new module to be noticed by the import system.
Changed in version 3.3: Parent packages are automatically imported.

importlib.find_loader(name, path=None)

Find the loader for a module, optionally within the specified path. If the module is in sys.modules, then sys.modules[name].__loader__ is returned (unless the loader would be None or is not set, in which case ValueError is raised). Otherwise a search using sys.meta_path is done. None is returned if no loader is found.

A dotted name does not have its parent's implicitly imported as that requires loading them and that may not be desired. To properly import a submodule you will need to import all parent packages of the submodule and use the correct argument to path.

New in version 3.3.

Changed in version 3.4: If __loader__ is not set, raise ValueError, just like when the attribute is set to None.

Deprecated since version 3.4: Use importlib.util.find_spec() instead.

importlib.invalidate_caches()

Invalidate the internal caches of finders stored at sys.meta_path. If a finder implements invalidate_caches() then it will be called to perform the invalidation. This function should be called if any modules are created/installed while your program is running to guarantee all finders will notice the new module's existence.

New in version 3.3.
importlib.reload(module)

Reload a previously imported module. The argument must be a module object, so it must have been successfully imported before. This is useful if you have edited the module source file using an external editor and want to try out the new version without leaving the Python interpreter. The return value is the module object (which can be different if re-importing causes a different object to be placed in sys.modules).

When reload() is executed:

- Python module's code is recompiled and the module-level code re-executed, defining a new set of objects which are bound to names in the module's dictionary by reusing the loader which originally loaded the module. The init function of extension modules is not called a second time.
- As with all other objects in Python the old objects are only reclaimed after their reference counts drop to zero.
- The names in the module namespace are updated to point to any new or changed objects.
- Other references to the old objects (such as names external to the module) are not rebound to refer to the new objects and must be updated in each namespace where they occur if that is desired.

There are a number of other caveats:

When a module is reloaded, its dictionary (containing the module's global variables) is retained. Redefinitions of names will override the old definitions, so this is generally not a problem. If the new version of a module does not define a name that was defined by the old version, the old definition remains. This feature can be used to the module's advantage if it maintains a global table or cache of objects — with a try statement it can test for the table's presence
and skip its initialization if desired:

```python
try:
    cache
except NameError:
    cache = {}
```

It is generally not very useful to reload built-in or dynamically loaded modules. Reloading `sys`, `__main__`, `builtins` and other key modules is not recommended. In many cases extension modules are not designed to be initialized more than once, and may fail in arbitrary ways when reloaded.

If a module imports objects from another module using `from ... import ...`, calling `reload()` for the other module does not redefine the objects imported from it — one way around this is to re-execute the `from` statement, another is to use `import` and qualified names (`module.name`) instead.

If a module instantiates instances of a class, reloading the module that defines the class does not affect the method definitions of the instances — they continue to use the old class definition. The same is true for derived classes.

*New in version 3.4.*
31.5.3. `importlib.abc` – Abstract base classes related to import

The `importlib.abc` module contains all of the core abstract base classes used by `import`. Some subclasses of the core abstract base classes are also provided to help in implementing the core ABCs.

ABC hierarchy:

```
object
    +-- Finder (deprecated)
    |    +-- MetaPathFinder
    |    +-- PathEntryFinder
    +-- Loader
        +-- ResourceLoader ---------+
        +-- InspectLoader         |
        |    +-- ExecutionLoader   --+
        |                       +-- FileLoader
        |                       +-- SourceLoader
```

**class importlib.abc.Finder**

An abstract base class representing a `finder`.

*Deprecated since version 3.3:* Use `MetaPathFinder` or `PathEntryFinder` instead.

**find_module**(fullname, path=None)

An abstract method for finding a `loader` for the specified module. Originally specified in PEP 302, this method was meant for use in `sys.meta_path` and in the path-based import subsystem.

*Changed in version 3.4:* Returns None when called instead of
class importlib.abc.MetaPathFinder

An abstract base class representing a meta path finder. For compatibility, this is a subclass of Finder.

New in version 3.3.

find_spec(fullname, path, target=None)

An abstract method for finding a spec for the specified module. If this is a top-level import, path will be None. Otherwise, this is a search for a subpackage or module and path will be the value of __path__ from the parent package. If a spec cannot be found, None is returned. When passed in, target is a module object that the finder may use to make a more educated about what spec to return.

New in version 3.4.

find_module(fullname, path)

A legacy method for finding a loader for the specified module. If this is a top-level import, path will be None. Otherwise, this is a search for a subpackage or module and path will be the value of __path__ from the parent package. If a loader cannot be found, None is returned.

If find_spec() is defined, backwards-compatible functionality is provided.

Changed in version 3.4: Returns None when called instead of raising NotImplementedException. Can use find_spec() to provide functionality.
Deprecated since version 3.4: Use `find_spec()` instead.

**invalidate_caches()**

An optional method which, when called, should invalidate any internal cache used by the finder. Used by `importlib.invalidate_caches()` when invalidating the caches of all finders on `sys.meta_path`.

*Changed in version 3.4:* Returns `None` when called instead of `NotImplemented`.

**class importlib.abc.PathEntryFinder**

An abstract base class representing a path entry finder. Though it bears some similarities to `MetaPathFinder`, `PathEntryFinder` is meant for use only within the path-based import subsystem provided by `PathFinder`. This ABC is a subclass of `Finder` for compatibility reasons only.

*New in version 3.3.*

**find_spec(fullname, target=None)**

An abstract method for finding a spec for the specified module. The finder will search for the module only within the path entry to which it is assigned. If a spec cannot be found, `None` is returned. When passed in, `target` is a module object that the finder may use to make a more educated about what spec to return.

*New in version 3.4.*

**find_loader(fullname)**

A legacy method for finding a loader for the specified module.
Returns a 2-tuple of (loader, portion) where portion is a sequence of file system locations contributing to part of a namespace package. The loader may be None while specifying portion to signify the contribution of the file system locations to a namespace package. An empty list can be used for portion to signify the loader is not part of a namespace package. If loader is None and portion is the empty list then no loader or location for a namespace package were found (i.e. failure to find anything for the module).

If find_spec() is defined then backwards-compatible functionality is provided.

*Changed in version 3.4:* Returns (None, []) instead of raising NotImplementedError. Uses find_spec() when available to provide functionality.

*Deprecated since version 3.4:* Use find_spec() instead.

**find_module** *(fullname)*

A concrete implementation of Finder.find_module() which is equivalent to self.find_loader(fullname)[0].

*Deprecated since version 3.4:* Use find_spec() instead.

**invalidate_caches** *

An optional method which, when called, should invalidate any internal cache used by the finder. Used by PathFinder.invalidate_caches() when invalidating the caches of all cached finders.

```python
class importlib.abc.Loader
```
An abstract base class for a loader. See PEP 302 for the exact definition for a loader.

**create_module**(spec)
A method that returns the module object to use when importing a module. This method may return None, indicating that default module creation semantics should take place.

*New in version 3.4.*

*Changed in version 3.5:* Starting in Python 3.6, this method will not be optional when **exec_module()** is defined.

**exec_module**(module)
An abstract method that executes the module in its own namespace when a module is imported or reloaded. The module should already be initialized when **exec_module()** is called.

*New in version 3.4.*

**load_module**(fullname)
A legacy method for loading a module. If the module cannot be loaded, **ImportError** is raised, otherwise the loaded module is returned.

If the requested module already exists in **sys.modules**, that module should be used and reloaded. Otherwise the loader should create a new module and insert it into **sys.modules** before any loading begins, to prevent recursion from the import. If the loader inserted a module and the load fails, it must be removed by the loader from **sys.modules**; modules already in **sys.modules** before the loader began execution should be left
alone (see `importlib.util.module_for_loader()`).

The loader should set several attributes on the module. (Note that some of these attributes can change when a module is reloaded):

- **__name__**
  The name of the module.

- **__file__**
  The path to where the module data is stored (not set for built-in modules).

- **__cached__**
  The path to where a compiled version of the module is/should be stored (not set when the attribute would be inappropriate).

- **__path__**
  A list of strings specifying the search path within a package. This attribute is not set on modules.

- **__package__**
  The parent package for the module/package. If the module is top-level then it has a value of the empty string. The `importlib.util.module_for_loader()` decorator can handle the details for **__package__**.

- **__loader__**
  The loader used to load the module. The `importlib.util.module_for_loader()` decorator can handle the details for **__package__**.
When `exec_module()` is available then backwards-compatible functionality is provided.

*Changed in version 3.4:* Raise `ImportError` when called instead of `NotImplementedError`. Functionality provided when `exec_module()` is available.

*Deprecated since version 3.4:* The recommended API for loading a module is `exec_module()` (and `create_module()`). Loaders should implement it instead of `load_module()`. The import machinery takes care of all the other responsibilities of `load_module()` when `exec_module()` is implemented.

```
module_repr(module)
```

A legacy method which when implemented calculates and returns the given module’s repr, as a string. The module type’s default repr() will use the result of this method as appropriate.

*New in version 3.3.*

*Changed in version 3.4:* Made optional instead of an abstractmethod.

*Deprecated since version 3.4:* The import machinery now takes care of this automatically.

```
class importlib.abc.ResourceLoader
```

An abstract base class for a `loader` which implements the optional PEP 302 protocol for loading arbitrary resources from the storage back-end.

```
get_data(path)
```
An abstract method to return the bytes for the data located at *path*. Loaders that have a file-like storage back-end that allows storing arbitrary data can implement this abstract method to give direct access to the data stored. *OSError* is to be raised if the *path* cannot be found. The *path* is expected to be constructed using a module's __file__ attribute or an item from a package's __path__.

*Changed in version 3.4:* Raises *OSError* instead of *NotImplementedError*.

class importlib.abc.InspectLoader

An abstract base class for a loader which implements the optional PEP 302 protocol for loaders that inspect modules.

**get_code**(fullname)

Return the code object for a module, or None if the module does not have a code object (as would be the case, for example, for a built-in module). Raise an *ImportError* if loader cannot find the requested module.

**Note:** While the method has a default implementation, it is suggested that it be overridden if possible for performance.

*Changed in version 3.4:* No longer abstract and a concrete implementation is provided.

**get_source**(fullname)

An abstract method to return the source of a module. It is returned as a text string using universal newlines, translating all recognized line separators into '*
' characters. Returns None if no source is available (e.g. a built-in module). Raises
**ImportError** if the loader cannot find the module specified.

*Changed in version 3.4:* Raises **ImportError** instead of **NotImplementedError**.

**is_package(fullname)**

An abstract method to return a true value if the module is a package, a false value otherwise. **ImportError** is raised if the **loader** cannot find the module.

*Changed in version 3.4:* Raises **ImportError** instead of **NotImplementedError**.

**static source_to_code(data, path='<string>')**

Create a code object from Python source.

The *data* argument can be whatever the `compile()` function supports (i.e. string or bytes). The *path* argument should be the “path” to where the source code originated from, which can be an abstract concept (e.g. location in a zip file).

With the subsequent code object one can execute it in a module by running `exec(code, module.__dict__)`.

*New in version 3.4.*

*Changed in version 3.5:* Made the method static.

**exec_module(module)**

Implementation of **Loader.exec_module()**.

*New in version 3.4.*

**load_module(fullname)**
Implementation of `Loader.load_module()`.

*Deprecated since version 3.4:* use `exec_module()` instead.

**class importlib.abc.ExecutionLoader**

An abstract base class which inherits from `InspectLoader` that, when implemented, helps a module to be executed as a script. The ABC represents an optional PEP 302 protocol.

**get_filename(fullname)**

An abstract method that is to return the value of `__file__` for the specified module. If no path is available, `ImportError` is raised.

If source code is available, then the method should return the path to the source file, regardless of whether a bytecode was used to load the module.

*Changed in version 3.4:* Raises `ImportError` instead of `NotImplementedError`.

**class importlib.abc.FileLoader(fullname, path)**

An abstract base class which inherits from `ResourceLoader` and `ExecutionLoader`, providing concrete implementations of `ResourceLoader.get_data()` and `ExecutionLoader.get_filename()`.

The `fullname` argument is a fully resolved name of the module the loader is to handle. The `path` argument is the path to the file for the module.

*New in version 3.3.*
name
The name of the module the loader can handle.

path
Path to the file of the module.

load_module(fullname)
Calls super’s load_module().

Deprecated since version 3.4: Use Loader.exec_module() instead.

get_filename(fullname)
Returns path.

get_data(path)
Reads path as a binary file and returns the bytes from it.

class importlib.abc.SourceLoader
An abstract base class for implementing source (and optionally bytecode) file loading. The class inherits from both ResourceLoader and ExecutionLoader, requiring the implementation of:

- ResourceLoader.get_data()
- ExecutionLoader.get_filename()
  Should only return the path to the source file; sourceless loading is not supported.

The abstract methods defined by this class are to add optional bytecode file support. Not implementing these optional methods (or causing them to raise NotImplementedError) causes the loader
to only work with source code. Implementing the methods allows the loader to work with source and bytecode files; it does not allow for sourceless loading where only bytecode is provided. Bytecode files are an optimization to speed up loading by removing the parsing step of Python’s compiler, and so no bytecode-specific API is exposed.

**path_stats(path)**

Optional abstract method which returns a `dict` containing metadata about the specified path. Supported dictionary keys are:

- `'mtime'` (mandatory): an integer or floating-point number representing the modification time of the source code;
- `'size'` (optional): the size in bytes of the source code.

Any other keys in the dictionary are ignored, to allow for future extensions. If the path cannot be handled, `OSError` is raised.

*New in version 3.3.*

*Changed in version 3.4:* Raise `OSError` instead of `NotImplementedError`.

**path_mtime(path)**

Optional abstract method which returns the modification time for the specified path.

*Deprecated since version 3.3:* This method is deprecated in favour of `path_stats()`. You don’t have to implement it, but it is still available for compatibility purposes. Raise `OSError` if the path cannot be handled.

*Changed in version 3.4:* Raise `OSError` instead of
set_data(path, data)
Optional abstract method which writes the specified bytes to a file path. Any intermediate directories which do not exist are to be created automatically.

When writing to the path fails because the path is read-only (errno.EACCES/PermissionError), do not propagate the exception.

Changed in version 3.4: No longer raises NotImplementedError when called.

get_code(fullname)
Concrete implementation of InspectLoader.get_code().

exec_module(module)
Concrete implementation of Loader.exec_module().

New in version 3.4.

load_module(fullname)
Concrete implementation of Loader.load_module().

Deprecated since version 3.4: Use exec_module() instead.

get_source(fullname)
Concrete implementation of InspectLoader.get_source().

is_package(fullname)
Concrete implementation of
InspectLoader.is_package(). A module is determined to be a package if its file path (as provided by ExecutionLoader.get_filename()) is a file named __init__ when the file extension is removed and the module name itself does not end in __init__. 
31.5.4. **importlib.machinery** – Importers and path hooks

This module contains the various objects that help `import` find and load modules.

**importlib.machinery.SOURCE_SUFFIXES**
A list of strings representing the recognized file suffixes for source modules.

*New in version 3.3.*

**importlib.machinery.DEBUG_BYTECODE_SUFFIXES**
A list of strings representing the file suffixes for non-optimized bytecode modules.

*New in version 3.3.*

*Deprecated since version 3.5:* Use `BYTECODE_SUFFIXES` instead.

**importlib.machinery.OPTIMIZED_BYTECODE_SUFFIXES**
A list of strings representing the file suffixes for optimized bytecode modules.

*New in version 3.3.*

*Deprecated since version 3.5:* Use `BYTECODE_SUFFIXES` instead.

**importlib.machinery.BYTECODE_SUFFIXES**
A list of strings representing the recognized file suffixes for bytecode modules (including the leading dot).

*New in version 3.3.*
Changed in version 3.5: The value is no longer dependent on \_\_debug\_.

importlib.machinery.\texttt{EXTENSION\_SUFFIXES}
A list of strings representing the recognized file suffixes for extension modules.

New in version 3.3.

importlib.machinery.\texttt{all\_suffixes()}
Returns a combined list of strings representing all file suffixes for modules recognized by the standard import machinery. This is a helper for code which simply needs to know if a filesystem path potentially refers to a module without needing any details on the kind of module (for example, \texttt{inspect.getmodulename()}).

New in version 3.3.

class importlib.machinery.\texttt{BuiltinImporter}
An importer for built-in modules. All known built-in modules are listed in \texttt{sys.builtin\_module\_names}. This class implements the \texttt{importlib.abc.MetaPathFinder} and \texttt{importlib.abc.InspectLoader} ABCs.

Only class methods are defined by this class to alleviate the need for instantiation.

Changed in version 3.5: As part of PEP 489, the builtin importer now implements \texttt{Loader.create\_module()} and \texttt{Loader.exec\_module()}

class importlib.machinery.\texttt{FrozenImporter}
An importer for frozen modules. This class implements the
importlib.abc.MetaPathFinder and importlib.abc.InspectLoader ABCs.

Only class methods are defined by this class to alleviate the need for instantiation.

class importlib.machinery.WindowsRegistryFinder
Finder for modules declared in the Windows registry. This class implements the importlib.abc.Finder ABC.

Only class methods are defined by this class to alleviate the need for instantiation.

New in version 3.3.

class importlib.machinery.PathFinder
A Finder for sys.path and package __path__ attributes. This class implements the importlib.abc.MetaPathFinder ABC.

Only class methods are defined by this class to alleviate the need for instantiation.

classmethod find_spec(fullname, path=None, target=None)
Class method that attempts to find a spec for the module specified by fullname on sys.path or, if defined, on path. For each path entry that is searched, sys.path_importer_cache is checked. If a non-false object is found then it is used as the path entry finder to look for the module being searched for. If no entry is found in sys.path_importer_cache, then sys.path_hooks is searched for a finder for the path entry and, if found, is stored in sys.path_importer_cache along with being queried about the module. If no finder is ever found then None is both stored
in the cache and returned.

*New in version 3.4.*

*Changed in version 3.5:* If the current working directory – represented by an empty string – is no longer valid then `None` is returned but no value is cached in `sys.path_importer_cache`.

*classmethod* `find_module(fullname, path=None)`

A legacy wrapper around `find_spec()`.

*Deprecated since version 3.4:* Use `find_spec()` instead.

*classmethod* `invalidate_caches()`

Calls

`importlib.abc.PathEntryFinder.invalidate_caches()` on all finders stored in `sys.path_importer_cache`.

*Changed in version 3.4:* Calls objects in `sys.path_hooks` with the current working directory for '' (i.e. the empty string).

`class importlib.machinery.FileFinder(path, *loader_details)`

A concrete implementation of `importlib.abc.PathEntryFinder` which caches results from the file system.

The `path` argument is the directory for which the finder is in charge of searching.

The `loader_details` argument is a variable number of 2-item tuples each containing a loader and a sequence of file suffixes the loader
recognizes. The loaders are expected to be callables which accept two arguments of the module's name and the path to the file found.

The finder will cache the directory contents as necessary, making stat calls for each module search to verify the cache is not outdated. Because cache staleness relies upon the granularity of the operating system's state information of the file system, there is a potential race condition of searching for a module, creating a new file, and then searching for the module the new file represents. If the operations happen fast enough to fit within the granularity of stat calls, then the module search will fail. To prevent this from happening, when you create a module dynamically, make sure to call `importlib.invalidate_caches()`.

*New in version 3.3.*

**path**

The path the finder will search in.

**find_spec**(fullname, target=None)

Attempt to find the spec to handle `fullname` within `path`.

*New in version 3.4.*

**find_loader**(fullname)

Attempt to find the loader to handle `fullname` within `path`.

**invalidate_caches()**

Clear out the internal cache.

*classmethod path_hook*(*loader_details*)

A class method which returns a closure for use on `sys.path_hooks`. An instance of `FileFinder` is returned by
the closure using the path argument given to the closure directly and \textit{loader_details} indirectly.

If the argument to the closure is not an existing directory, \texttt{ImportError} is raised.

\begin{verbatim}
class importlib.machinery.SourceFileLoader(fullname, path)
    A concrete implementation of \texttt{importlib.abc.SourceLoader} by subclassing \texttt{importlib.abc.FileLoader} and providing some concrete implementations of other methods.

    \textit{New in version 3.3.}

    \texttt{name}
    The name of the module that this loader will handle.

    \texttt{path}
    The path to the source file.

    \texttt{is_package(fullname)}
    Return true if \texttt{path} appears to be for a package.

    \texttt{path_stats(path)}
    Concrete implementation of \texttt{importlib.abc.SourceLoader.path_stats()}.  

    \texttt{set_data(path, data)}
    Concrete implementation of \texttt{importlib.abc.SourceLoader.set_data()}.  

    \texttt{load_module(name=None)}
    Concrete implementation of
importlib.abc.Loader.load_module() where specifying the name of the module to load is optional.

class importlib.machinery.SourcelessFileLoader(fullname, path)
    A concrete implementation of importlib.abc.FileLoader which can import bytecode files (i.e. no source code files exist).

    Please note that direct use of bytecode files (and thus not source code files) inhibits your modules from being usable by all Python implementations or new versions of Python which change the bytecode format.

    New in version 3.3.

name
    The name of the module the loader will handle.

path
    The path to the bytecode file.

is_package(fullname)
    Determines if the module is a package based on path.

get_code(fullname)
    Returns the code object for name created from path.

get_source(fullname)
    Returns None as bytecode files have no source when this loader is used.

load_module(name=None)
Concrete implementation of `importlib.abc.Loader.load_module()` where specifying the name of the module to load is optional.

```python
class importlib.machinery.ExtensionFileLoader(fullname, path)
    A concrete implementation of `importlib.abc.ExecutionLoader` for extension modules.
```

The `fullname` argument specifies the name of the module the loader is to support. The `path` argument is the path to the extension module's file.

*New in version 3.3.*

**name**

Name of the module the loader supports.

**path**

Path to the extension module.

**create_module**(spec)

Creates the module object from the given specification in accordance with [PEP 489](https://www.python.org/dev/peps/pep-0489/).

*New in version 3.5.*

**exec_module**(module)

Initializes the given module object in accordance with [PEP 489](https://www.python.org/dev/peps/pep-0489/).

*New in version 3.5.*

**is_package**(fullname)
Returns True if the file path points to a package's __init__ module based on EXTENSION_SUFFIXES.

get_code(fullname)
Returns None as extension modules lack a code object.

get_source(fullname)
Returns None as extension modules do not have source code.

get_filename(fullname)
Returns path.

New in version 3.4.

class importlib.machinery.ModuleSpec(name, loader, *,
origin=None, loader_state=None, is_package=None)
A specification for a module's import-system-related state.

New in version 3.4.

name
(__name__)
A string for the fully-qualified name of the module.

loader
(__loader__)
The loader to use for loading. For namespace packages this should be set to None.

origin
(\_\_file\_\_)

Name of the place from which the module is loaded, e.g. “builtin” for built-in modules and the filename for modules loaded from source. Normally “origin” should be set, but it may be None (the default) which indicates it is unspecified.

**submodule_search_locations**

(\_\_path\_\_)

List of strings for where to find submodules, if a package (None otherwise).

**loader_state**

Container of extra module-specific data for use during loading (or None).

**cached**

(\_\_cached\_\_)

String for where the compiled module should be stored (or None).

**parent**

(\_\_package\_\_)

(Read-only) Fully-qualified name of the package to which the module belongs as a submodule (or None).

**has_location**

Boolean indicating whether or not the module’s “origin” attribute refers to a loadable location.
31.5.5. **importlib.util** – Utility code for importers

This module contains the various objects that help in the construction of an importer.

**importlib.util.MAGIC_NUMBER**

The bytes which represent the bytecode version number. If you need help with loading/writing bytecode then consider `importlib.abc.SourceLoader`.

*New in version 3.4.*

**importlib.util.cache_from_source**(path, debug_override=None, *, optimization=None)

Return the PEP 3147/PEP 488 path to the byte-compiled file associated with the source path. For example, if path is `/foo/bar/baz.py` the return value would be `/foo/bar/__pycache__/baz.cpython-32.pyc` for Python 3.2. The cpython-32 string comes from the current magic tag (see `get_tag()`; if `sys.implementation.cache_tag` is not defined then `NotImplementedError` will be raised).

The *optimization* parameter is used to specify the optimization level of the bytecode file. An empty string represents no optimization, so `/foo/bar/baz.py` with an *optimization* of `' '` will result in a bytecode path of `/foo/bar/__pycache__/baz.cpython-32.pyc`. None causes the interpreter's optimization level to be used. Any other value's string representation being used, so `/foo/bar/baz.py` with an *optimization* of 2 will lead to the bytecode path of `/foo/bar/__pycache__/baz.cpython-`
The string representation of `optimization` can only be alphanumeric, else `ValueError` is raised.

The `debug_override` parameter is deprecated and can be used to override the system's value for `__debug__`. A True value is the equivalent of setting `optimization` to the empty string. A False value is the same as setting `optimization` to 1. If both `debug_override` an `optimization` are not None then `TypeError` is raised.

*New in version 3.4.*

`importlib.util.source_from_cache(path)`

Given the `path` to a [PEP 3147](https://www.python.org/dev/peps/pep-03147/) file name, return the associated source code file path. For example, if `path` is `/foo/bar/__pycache__/baz.cpython-32.pyc` the returned path would be `/foo/bar/baz.py`. `path` need not exist, however if it does not conform to [PEP 3147](https://www.python.org/dev/peps/pep-03147/) or [PEP 488](https://www.python.org/dev/peps/pep-0488/) format, a `ValueError` is raised. If `sys.implementation.cache_tag` is not defined, `NotImplementedError` is raised.

*New in version 3.4.*

`importlib.util.decode_source(source_bytes)`

Decode the given bytes representing source code and return it as a string with universal newlines (as required by `importlib.abc.InspectLoader.get_source()`).

*New in version 3.4.*

`importlib.util.resolve_name(name, package)`

Resolve a relative module name to an absolute one.
If `name` has no leading dots, then `name` is simply returned. This allows for usage such as `importlib.util.resolve_name('sys', __package__)` without doing a check to see if the `package` argument is needed.

`ValueError` is raised if `name` is a relative module name but `package` is a false value (e.g. None or the empty string). `ValueError` is also raised a relative name would escape its containing package (e.g. requesting ..bacon from within the spam package).

*New in version 3.3.*

`importlib.util.find_spec(name, package=None)`

Find the `spec` for a module, optionally relative to the specified `package` name. If the module is in `sys.modules`, then `sys.modules[name].__spec__` is returned (unless the spec would be None or is not set, in which case `ValueError` is raised). Otherwise a search using `sys.meta_path` is done. None is returned if no spec is found.

If `name` is for a submodule (contains a dot), the parent module is automatically imported.

`name` and `package` work the same as for `import_module()`.

*New in version 3.4.*

`importlib.util.module_from_spec(spec)`

Create a new module based on `spec` and `spec.loader.create_module()`.

If `spec.loader.create_module()` does not return None, then
any pre-existing attributes will not be reset. Also, no AttributeError will be raised if triggered while accessing spec or setting an attribute on the module.

This function is preferred over using types.ModuleType to create a new module as spec is used to set as many import-controlled attributes on the module as possible.

New in version 3.5.

@importlib.util.module_for_loader
A decorator for importlib.abc.Loader.load_module() to handle selecting the proper module object to load with. The decorated method is expected to have a call signature taking two positional arguments (e.g. load_module(self, module)) for which the second argument will be the module object to be used by the loader. Note that the decorator will not work on static methods because of the assumption of two arguments.

The decorated method will take in the name of the module to be loaded as expected for a loader. If the module is not found in sys.modules then a new one is constructed. Regardless of where the module came from, __loader__ set to self and __package__ is set based on what importlib.abc.InspectLoader.is_package() returns (if available). These attributes are set unconditionally to support reloading.

If an exception is raised by the decorated method and a module was added to sys.modules, then the module will be removed to prevent a partially initialized module from being in left in sys.modules. If the module was already in sys.modules then it
is left alone.

*Changed in version 3.3:* __loader__ and __package__ are automatically set (when possible).

*Changed in version 3.4:* Set __name__, __loader__, __package__ unconditionally to support reloading.

*Deprecated since version 3.4:* The import machinery now directly performs all the functionality provided by this function.

@importlib.util.set_loader
A decorator for importlib.abc.Loader.load_module() to set the __loader__ attribute on the returned module. If the attribute is already set the decorator does nothing. It is assumed that the first positional argument to the wrapped method (i.e. self) is what __loader__ should be set to.

*Changed in version 3.4:* Set __loader__ if set to None, as if the attribute does not exist.

*Deprecated since version 3.4:* The import machinery takes care of this automatically.

@importlib.util.set_package
A decorator for importlib.abc.Loader.load_module() to set the __package__ attribute on the returned module. If __package__ is set and has a value other than None it will not be changed.

*Deprecated since version 3.4:* The import machinery takes care of this automatically.
importlib.util.spec_from_loader(name, loader, *, origin=None, is_package=None)

A factory function for creating a ModuleSpec instance based on a loader. The parameters have the same meaning as they do for ModuleSpec. The function uses available loader APIs, such as InspectLoader.is_package(), to fill in any missing information on the spec.

*New in version 3.4.*

importlib.util.spec_from_file_location(name, location, *, loader=None, submodule_search_locations=None)

A factory function for creating a ModuleSpec instance based on the path to a file. Missing information will be filled in on the spec by making use of loader APIs and by the implication that the module will be file-based.

*New in version 3.4.*

class importlib.util.LazyLoader(loader)

A class which postpones the execution of the loader of a module until the module has an attribute accessed.

This class **only** works with loaders that define exec_module() as control over what module type is used for the module is required. For those same reasons, the loader’s create_module() method will be ignored (i.e., the loader’s method should only return None). Finally, modules which substitute the object placed into sys.modules will not work as there is no way to properly replace the module references throughout the interpreter safely; **ValueError** is raised if such a substitution is detected.
**Note:** For projects where startup time is critical, this class allows for potentially minimizing the cost of loading a module if it is never used. For projects where startup time is not essential then use of this class is heavily discouraged due to error messages created during loading being postponed and thus occurring out of context.

*New in version 3.5.*

**classmethod `factory(loader)`**

A static method which returns a callable that creates a lazy loader. This is meant to be used in situations where the loader is passed by class instead of by instance.

```python
suffixes = importlib.machinery.SOURCE_SUFFIXES
loader = importlib.machinery.SourceFileLoader
lazy_loader = importlib.util.LazyLoader.factory
finder = importlib.machinery.FileFinder(path, [...])
```
32. Python Language Services

Python provides a number of modules to assist in working with the Python language. These modules support tokenizing, parsing, syntax analysis, bytecode disassembly, and various other facilities.

These modules include:

- **32.1. parser — Access Python parse trees**
  - 32.1.1. Creating ST Objects
  - 32.1.2. Converting ST Objects
  - 32.1.3. Queries on ST Objects
  - 32.1.4. Exceptions and Error Handling
  - 32.1.5. ST Objects
  - 32.1.6. Example: Emulation of compile()

- **32.2. ast — Abstract Syntax Trees**
  - 32.2.1. Node classes
  - 32.2.2. Abstract Grammar
  - 32.2.3. ast Helpers

- **32.3. symtable — Access to the compiler’s symbol tables**
  - 32.3.1. Generating Symbol Tables
  - 32.3.2. Examining Symbol Tables

- **32.4. symbol — Constants used with Python parse trees**
- **32.5. token — Constants used with Python parse trees**
- **32.6. keyword — Testing for Python keywords**
- **32.7. tokenize — Tokenizer for Python source**
  - 32.7.1. Tokenizing Input
  - 32.7.2. Command-Line Usage
  - 32.7.3. Examples

- **32.8. tabnanny — Detection of ambiguous indentation**

- **32.9. pyclbr — Python class browser support**
  - 32.9.1. Class Objects
- 32.9.2. Function Objects
- 32.10. `py_compile` — Compile Python source files
- 32.11. `compileall` — Byte-compile Python libraries
  - 32.11.1. Command-line use
  - 32.11.2. Public functions
- 32.12. `dis` — Disassembler for Python bytecode
  - 32.12.1. Bytecode analysis
  - 32.12.2. Analysis functions
  - 32.12.3. Python Bytecode Instructions
  - 32.12.4. Opcode collections
- 32.13. `pickletools` — Tools for pickle developers
  - 32.13.1. Command line usage
    - 32.13.1.1. Command line options
  - 32.13.2. Programmatic Interface
32.1. **parser** — Access Python parse trees

The **parser** module provides an interface to Python’s internal parser and byte-code compiler. The primary purpose for this interface is to allow Python code to edit the parse tree of a Python expression and create executable code from this. This is better than trying to parse and modify an arbitrary Python code fragment as a string because parsing is performed in a manner identical to the code forming the application. It is also faster.

**Note:** From Python 2.5 onward, it’s much more convenient to cut in at the Abstract Syntax Tree (AST) generation and compilation stage, using the **ast** module.

There are a few things to note about this module which are important to making use of the data structures created. This is not a tutorial on editing the parse trees for Python code, but some examples of using the **parser** module are presented.

Most importantly, a good understanding of the Python grammar processed by the internal parser is required. For full information on the language syntax, refer to *The Python Language Reference*. The parser itself is created from a grammar specification defined in the file Grammar/Grammar in the standard Python distribution. The parse trees stored in the ST objects created by this module are the actual output from the internal parser when created by the **expr()** or **suite()** functions, described below. The ST objects created by **sequence2st()** faithfully simulate those structures. Be aware that
the values of the sequences which are considered “correct” will vary from one version of Python to another as the formal grammar for the language is revised. However, transporting code from one Python version to another as source text will always allow correct parse trees to be created in the target version, with the only restriction being that migrating to an older version of the interpreter will not support more recent language constructs. The parse trees are not typically compatible from one version to another, whereas source code has always been forward-compatible.

Each element of the sequences returned by `st2list()` or `st2tuple()` has a simple form. Sequences representing non-terminal elements in the grammar always have a length greater than one. The first element is an integer which identifies a production in the grammar. These integers are given symbolic names in the C header file `Include/graminit.h` and the Python module `symbol`. Each additional element of the sequence represents a component of the production as recognized in the input string: these are always sequences which have the same form as the parent. An important aspect of this structure which should be noted is that keywords used to identify the parent node type, such as the keyword `if` in an `if_stmt`, are included in the node tree without any special treatment. For example, the `if` keyword is represented by the tuple `(1, 'if')`, where 1 is the numeric value associated with all NAME tokens, including variable and function names defined by the user. In an alternate form returned when line number information is requested, the same token might be represented as `(1, 'if', 12)`, where the 12 represents the line number at which the terminal symbol was found.

Terminal elements are represented in much the same way, but without any child elements and the addition of the source text which was identified. The example of the `if` keyword above is representative.
The various types of terminal symbols are defined in the C header file `Include/token.h` and the Python module `token`.

The ST objects are not required to support the functionality of this module, but are provided for three purposes: to allow an application to amortize the cost of processing complex parse trees, to provide a parse tree representation which conserves memory space when compared to the Python list or tuple representation, and to ease the creation of additional modules in C which manipulate parse trees. A simple “wrapper” class may be created in Python to hide the use of ST objects.

The `parser` module defines functions for a few distinct purposes. The most important purposes are to create ST objects and to convert ST objects to other representations such as parse trees and compiled code objects, but there are also functions which serve to query the type of parse tree represented by an ST object.

**See also:**

**Module symbol**

Useful constants representing internal nodes of the parse tree.

**Module token**

Useful constants representing leaf nodes of the parse tree and functions for testing node values.
32.1.1. Creating ST Objects

ST objects may be created from source code or from a parse tree. When creating an ST object from source, different functions are used to create the 'eval' and 'exec' forms.

parser.expr(source)

The expr() function parses the parameter source as if it were an input to compile(source, 'file.py', 'eval'). If the parse succeeds, an ST object is created to hold the internal parse tree representation, otherwise an appropriate exception is raised.

parser.suite(source)

The suite() function parses the parameter source as if it were an input to compile(source, 'file.py', 'exec'). If the parse succeeds, an ST object is created to hold the internal parse tree representation, otherwise an appropriate exception is raised.

parser.sequence2st(sequence)

This function accepts a parse tree represented as a sequence and builds an internal representation if possible. If it can validate that the tree conforms to the Python grammar and all nodes are valid node types in the host version of Python, an ST object is created from the internal representation and returned to the called. If there is a problem creating the internal representation, or if the tree cannot be validated, a ParserError exception is raised. An ST object created this way should not be assumed to compile correctly; normal exceptions raised by compilation may still be initiated when the ST object is passed to compilest(). This may indicate problems not related to syntax (such as a MemoryError exception), but may also be due to constructs such as the result of
parsing del f(0), which escapes the Python parser but is checked by the bytecode compiler.

Sequences representing terminal tokens may be represented as either two-element lists of the form \((1, \ 'name'\)\) or as three-element lists of the form \((1, \ 'name', \ 56)\). If the third element is present, it is assumed to be a valid line number. The line number may be specified for any subset of the terminal symbols in the input tree.

```python
tuple2st(sequence)
```
This is the same function as `sequence2st()` . This entry point is maintained for backward compatibility.
32.1.2. Converting ST Objects

ST objects, regardless of the input used to create them, may be converted to parse trees represented as list- or tuple- trees, or may be compiled into executable code objects. Parse trees may be extracted with or without line numbering information.

\texttt{parser.st2list(st, line\_info=False, col\_info=False)}

This function accepts an ST object from the caller in \texttt{st} and returns a Python list representing the equivalent parse tree. The resulting list representation can be used for inspection or the creation of a new parse tree in list form. This function does not fail so long as memory is available to build the list representation. If the parse tree will only be used for inspection, \texttt{st2tuple()} should be used instead to reduce memory consumption and fragmentation. When the list representation is required, this function is significantly faster than retrieving a tuple representation and converting that to nested lists.

If \texttt{line\_info} is true, line number information will be included for all terminal tokens as a third element of the list representing the token. Note that the line number provided specifies the line on which the token \textit{ends}. This information is omitted if the flag is false or omitted.

\texttt{parser.st2tuple(st, line\_info=False, col\_info=False)}

This function accepts an ST object from the caller in \texttt{st} and returns a Python tuple representing the equivalent parse tree. Other than returning a tuple instead of a list, this function is identical to \texttt{st2list()}.

If \texttt{line\_info} is true, line number information will be included for all
terminal tokens as a third element of the list representing the token. This information is omitted if the flag is false or omitted.

```
parser.compilest(st, filename='<syntax-tree>')
```

The Python byte compiler can be invoked on an ST object to produce code objects which can be used as part of a call to the built-in `exec()` or `eval()` functions. This function provides the interface to the compiler, passing the internal parse tree from `st` to the parser, using the source file name specified by the `filename` parameter. The default value supplied for `filename` indicates that the source was an ST object.

Compiling an ST object may result in exceptions related to compilation; an example would be a `SyntaxError` caused by the parse tree for `del f(0)`: this statement is considered legal within the formal grammar for Python but is not a legal language construct. The `SyntaxError` raised for this condition is actually generated by the Python byte-compiler normally, which is why it can be raised at this point by the `parser` module. Most causes of compilation failure can be diagnosed programmatically by inspection of the parse tree.
32.1.3. Queries on ST Objects

Two functions are provided which allow an application to determine if an ST was created as an expression or a suite. Neither of these functions can be used to determine if an ST was created from source code via `expr()` or `suite()` or from a parse tree via `sequence2st()`.

`parser.isexpr(st)`
When `st` represents an 'eval' form, this function returns true, otherwise it returns false. This is useful, since code objects normally cannot be queried for this information using existing built-in functions. Note that the code objects created by `compilest()` cannot be queried like this either, and are identical to those created by the built-in `compile()` function.

`parser.issuite(st)`
This function mirrors `isexpr()` in that it reports whether an ST object represents an 'exec' form, commonly known as a “suite.” It is not safe to assume that this function is equivalent to not `isexpr(st)`, as additional syntactic fragments may be supported in the future.
32.1.4. Exceptions and Error Handling

The parser module defines a single exception, but may also pass other built-in exceptions from other portions of the Python runtime environment. See each function for information about the exceptions it can raise.

*exception* parser.*ParserError*

Exception raised when a failure occurs within the parser module. This is generally produced for validation failures rather than the built-in *SyntaxError* raised during normal parsing. The exception argument is either a string describing the reason of the failure or a tuple containing a sequence causing the failure from a parse tree passed to *sequence2st()* and an explanatory string. Calls to *sequence2st()* need to be able to handle either type of exception, while calls to other functions in the module will only need to be aware of the simple string values.

Note that the functions *compilest(), expr(),* and *suite()* may raise exceptions which are normally raised by the parsing and compilation process. These include the built in exceptions *MemoryError, OverflowError, SyntaxError,* and *SystemError.* In these cases, these exceptions carry all the meaning normally associated with them. Refer to the descriptions of each function for detailed information.
32.1.5. ST Objects

Ordered and equality comparisons are supported between ST objects. Pickling of ST objects (using the pickle module) is also supported.

parser.**STType**

The type of the objects returned by `expr()`, `suite()` and `sequence2st()`.

ST objects have the following methods:

**ST.compile**(filename='<syntax-tree>')</n>

Same as `compilest(st, filename)`.

**ST.isexpr()**

Same as `isexpr(st)`.

**ST.issuite()**

Same as `issuite(st)`.

**ST.tolist**(line_info=False, col_info=False)

Same as `st2list(st, line_info, col_info)`.

**ST.totuple**(line_info=False, col_info=False)

Same as `st2tuple(st, line_info, col_info)`.
32.1.6. Example: Emulation of `compile()`

While many useful operations may take place between parsing and bytecode generation, the simplest operation is to do nothing. For this purpose, using the `parser` module to produce an intermediate data structure is equivalent to the code

```python
>>> code = compile('a + 5', 'file.py', 'eval')
>>> a = 5
>>> eval(code)
10
```

The equivalent operation using the `parser` module is somewhat longer, and allows the intermediate internal parse tree to be retained as an ST object:

```python
>>> import parser
>>> st = parser.expr('a + 5')
>>> code = st.compile('file.py')
>>> a = 5
>>> eval(code)
10
```

An application which needs both ST and code objects can package this code into readily available functions:

```python
import parser

def load_suite(source_string):
    st = parser.suite(source_string)
    return st, st.compile()
```
```python
def load_expression(source_string):
    st = parser.expr(source_string)
    return st, st.compile()
```
32.2. ast — Abstract Syntax Trees

Source code: Lib/ast.py

The ast module helps Python applications to process trees of the Python abstract syntax grammar. The abstract syntax itself might change with each Python release; this module helps to find out programmatically what the current grammar looks like.

An abstract syntax tree can be generated by passing ast.PyCF_ONLY_AST as a flag to the compile() built-in function, or using the parse() helper provided in this module. The result will be a tree of objects whose classes all inherit from ast.AST. An abstract syntax tree can be compiled into a Python code object using the built-in compile() function.
32.2.1. Node classes

class ast.AST

This is the base of all AST node classes. The actual node classes are derived from the Parser/Python.asdl file, which is reproduced below. They are defined in the _ast C module and re-exported in ast.

There is one class defined for each left-hand side symbol in the abstract grammar (for example, ast.stmt or ast.expr). In addition, there is one class defined for each constructor on the right-hand side; these classes inherit from the classes for the left-hand side trees. For example, ast.BinOp inherits from ast.expr. For production rules with alternatives (aka “sums”), the left-hand side class is abstract: only instances of specific constructor nodes are ever created.

_fields

Each concrete class has an attribute _fields which gives the names of all child nodes.

Each instance of a concrete class has one attribute for each child node, of the type as defined in the grammar. For example, ast.BinOp instances have an attribute left of type ast.expr.

If these attributes are marked as optional in the grammar (using a question mark), the value might be None. If the attributes can have zero-or-more values (marked with an asterisk), the values are represented as Python lists. All possible attributes must be present and have valid values when compiling an AST with
compile().

**lineno**

**col_offset**

Instances of `ast.expr` and `ast.stmt` subclasses have `lineno` and `col_offset` attributes. The `lineno` is the line number of source text (1-indexed so the first line is line 1) and the `col_offset` is the UTF-8 byte offset of the first token that generated the node. The UTF-8 offset is recorded because the parser uses UTF-8 internally.

The constructor of a class `ast.T` parses its arguments as follows:

- If there are positional arguments, there must be as many as there are items in `T._fields`; they will be assigned as attributes of these names.
- If there are keyword arguments, they will set the attributes of the same names to the given values.

For example, to create and populate an `ast.UnaryOp` node, you could use

```python
node = ast.UnaryOp()
node.op = ast.USub()
node.operand = ast.Num()
node.operand.n = 5
node.operand.lineno = 0
node.operand.col_offset = 0
node.lineno = 0
node.col_offset = 0
```

or the more compact

```python
node = ast.UnaryOp(ast.USub(), ast.Num(5, lineno=0, col_offset=0))
```
32.2.2. Abstract Grammar

The abstract grammar is currently defined as follows:

```python
module Python {
    mod = Module(stmt* body)
    | Interactive(stmt* body)
    | Expression(expr body)

    -- not really an actual node but useful in Jython's typesystem.
    | Suite(stmt* body)

    stmt = FunctionDef(identifier name, arguments arg, stmt* body, expr* decorator_list)
    | AsyncFunctionDef(identifier name, arguments arg, stmt* body, expr* decorator_list)
    | ClassDef(identifier name, expr* bases, keyword* keywords, stmt* body, expr* decorator_list)
    | Return(expr? value)
    | Delete(expr* targets)
    | Assign(expr* targets, expr value)
    | AugAssign(expr target, operator op, expr value)

    -- use 'orelse' because else is a keyword
    | For(expr target, expr iter, stmt* body, stmt* orelse)
    | AsyncFor(expr target, expr iter, stmt* body, stmt* orelse)
    | While(expr test, stmt* body, stmt* orelse)
}
```
If(expr test, stmt* body, stmt* orelse)
With(withitem* items, stmt* body)
AsyncWith(withitem* items, stmt* body)
Raise(expr? exc, expr? cause)
Try(stmt* body, excepthandler* handlers, stmt* orelse, stmt* finalbody)
Assert(expr test, expr? msg)
Import(alias* names)
ImportFrom(identifier? module, alias* names)
Global(identifier* names)
Nonlocal(identifier* names)
Expr(expr value)
Pass | Break | Continue

-- XXX Jython will be different
-- col_offset is the byte offset in the utf8 string the parser uses
attributes (int lineno, int col_offset)

-- BoolOp() can use left & right?
expr = BoolOp(boolop op, expr* values)
BinOp(expr left, operator op, expr right)
UnaryOp(unaryop op, expr operand)
Lambda(arguments args, expr body)
IfExp(expr test, expr body, expr orelse)
Dict(expr* keys, expr* values)
Set(expr* elts)
ListComp(expr elt, comprehension* generators)
SetComp(expr elt, comprehension* generators)
DictComp(expr key, expr value, comprehension* generators)
GeneratorExp(expr elt, comprehension* generators)
-- the grammar constrains where yield expressions can occur
Await(expr value)
Yield(expr? value)
YieldFrom(expr value)
-- need sequences for compare to distinguish
-- x < 4 < 3 and (x < 4) < 3
| Compare(expr left, cmpop* ops, expr* comparators)
| Call(expr func, expr* args, keyword* keywords)
| Num(object n) -- a number as a PyObject.
| Str(string s) -- need to specify raw, unicode, etc?
| Bytes(bytes s)
| NameConstant(singleton value)
| Ellipsis

-- the following expression can appear in an assignment context
| Attribute(expr value, identifier attr, expr_context ctx)
| Subscript(expr value, slice slice, expr_context ctx)
| Starred(expr value, expr_context ctx)
| Name(identifier id, expr_context ctx)
| List(expr* els, expr_context ctx)
| Tuple(expr* els, expr_context ctx)

-- col_offset is the byte offset in the utf8 string the parser uses
attributes (int lineno, int col_offset)

equiv_context = Load | Store | Del | AugLoad | AugStore

slice = Slice(expr? lower, expr? upper, expr? step)
| ExtSlice(slice* dims)
| Index(expr value)

boolop = And | Or

operator = Add | Sub | Mult | MatMult | Div | Mod | Pow | LShift | RShift | BitOr | BitXor | BitAnd

unaryop = Invert | Not | UAdd | USub

cmpop = Eq | NotEq | Lt | LtE | Gt | GtE | Is | IsNot | In | NotIn

comprehension = (expr target, expr iter, expr* ifs)
excepthandler = ExceptHandler(expr? type, identifier? name, stmt* body)

attributes (int lineno, int col_offset)

arguments = (arg* args, arg? vararg, arg* kwonly
arg? kwarg, expr* defaults)

arg = (identifier arg, expr? annotation)

attributes (int lineno, int col_offset)

-- keyword arguments supplied to call (NULL identifier for **kwargs)
keyword = (identifier? arg, expr value)

-- import name with optional 'as' alias.
alias = (identifier name, identifier? asname)

withitem = (expr context_expr, expr? optional_vars)

}
32.2.3. ast Helpers

Apart from the node classes, the ast module defines these utility functions and classes for traversing abstract syntax trees:

```python
ast.parse(source, filename='<unknown>', mode='exec')
```
Parse the source into an AST node. Equivalent to `compile(source, filename, mode, ast.PyCF_ONLY_AST)`.

```python
ast.literal_eval(node_or_string)
```
Safely evaluate an expression node or a string containing a Python literal or container display. The string or node provided may only consist of the following Python literal structures: strings, bytes, numbers, tuples, lists, dicts, sets, booleans, and None.

This can be used for safely evaluating strings containing Python values from untrusted sources without the need to parse the values oneself. It is not capable of evaluating arbitrarily complex expressions, for example involving operators or indexing.

*Changed in version 3.2:* Now allows bytes and set literals.

```python
ast.get_docstring(node, clean=True)
```
Return the docstring of the given node (which must be a FunctionDef, ClassDef or Module node), or None if it has no docstring. If clean is true, clean up the docstring’s indentation with `inspect.cleandoc()`.

```python
ast.fix_missing_locations(node)
```
When you compile a node tree with `compile()`, the compiler
expects lineno and col_offset attributes for every node that supports them. This is rather tedious to fill in for generated nodes, so this helper adds these attributes recursively where not already set, by setting them to the values of the parent node. It works recursively starting at node.

```
ast.increment_lineno(node, n=1)
```
Increment the line number of each node in the tree starting at node by \( n \). This is useful to “move code” to a different location in a file.

```
ast.copy_location(new_node, old_node)
```
Copy source location (lineno and col_offset) from old_node to new_node if possible, and return new_node.

```
ast.iter_fields(node)
```
Yield a tuple of (fieldname, value) for each field in node._fields that is present on node.

```
ast.iter_child_nodes(node)
```
Yield all direct child nodes of node, that is, all fields that are nodes and all items of fields that are lists of nodes.

```
ast.walk(node)
```
Recursively yield all descendant nodes in the tree starting at node (including node itself), in no specified order. This is useful if you only want to modify nodes in place and don’t care about the context.

```
class ast.NodeVisitor
```
A node visitor base class that walks the abstract syntax tree and calls a visitor function for every node found. This function may return a value which is forwarded by the visit() method.
This class is meant to be subclassed, with the subclass adding visitor methods.

**visit(node)**
Visit a node. The default implementation calls the method called `self.visit_classname` where `classname` is the name of the node class, or `generic_visit()` if that method doesn’t exist.

**generic_visit(node)**
This visitor calls `visit()` on all children of the node.

Note that child nodes of nodes that have a custom visitor method won’t be visited unless the visitor calls `generic_visit()` or visits them itself.

Don’t use the `NodeVisitor` if you want to apply changes to nodes during traversal. For this a special visitor exists (NodeTransformer) that allows modifications.

**class ast.NodeTransformer**
A `NodeVisitor` subclass that walks the abstract syntax tree and allows modification of nodes.

The `NodeTransformer` will walk the AST and use the return value of the visitor methods to replace or remove the old node. If the return value of the visitor method is `None`, the node will be removed from its location, otherwise it is replaced with the return value. The return value may be the original node in which case no replacement takes place.

Here is an example transformer that rewrites all occurrences of name lookups (foo) to `data['foo']:`
class RewriteName(NodeTransformer):

    def visit_Name(self, node):
        return copy_location(Subscript(
            value=Name(id='data', ctx=Load()),
            slice=Index(value=Str(s=node.id)),
            ctx=node.ctx), node)

Keep in mind that if the node you're operating on has child nodes you must either transform the child nodes yourself or call the generic_visit() method for the node first.

For nodes that were part of a collection of statements (that applies to all statement nodes), the visitor may also return a list of nodes rather than just a single node.

Usually you use the transformer like this:

    node = YourTransformer().visit(node)

ast.dump(node, annotate_fields=True, include_attributes=False)

Return a formatted dump of the tree in node. This is mainly useful for debugging purposes. The returned string will show the names and the values for fields. This makes the code impossible to evaluate, so if evaluation is wanted annotate_fields must be set to False. Attributes such as line numbers and column offsets are not dumped by default. If this is wanted, include_attributes can be set to True.
32.3. `symtable` — Access to the compiler’s symbol tables

**Source code:** Lib/symtable.py

Symbol tables are generated by the compiler from AST just before bytecode is generated. The symbol table is responsible for calculating the scope of every identifier in the code. `symtable` provides an interface to examine these tables.
32.3.1. Generating Symbol Tables

`symtable.symtable(code, filename, compile_type)`

Return the toplevel SymbolTable for the Python source code. `filename` is the name of the file containing the code. `compile_type` is like the mode argument to `compile()`.
32.3.2. Examining Symbol Tables

```python
class symtable.SymbolTable
    A namespace table for a block. The constructor is not public.

    get_type()
    Return the type of the symbol table. Possible values are 'class', 'module', and 'function'.

    get_id()
    Return the table's identifier.

    get_name()
    Return the table's name. This is the name of the class if the table is for a class, the name of the function if the table is for a function, or 'top' if the table is global (get_type() returns 'module').

    get_lineno()
    Return the number of the first line in the block this table represents.

    is_optimized()
    Return True if the locals in this table can be optimized.

    is_nested()
    Return True if the block is a nested class or function.

    has_children()
    Return True if the block has nested namespaces within it. These can be obtained with get_children().
```
has_exec()
    Return True if the block uses exec.

get_identifiers()
    Return a list of names of symbols in this table.

lookup(name)
    Lookup name in the table and return a Symbol instance.

get_symbols()
    Return a list of Symbol instances for names in the table.

get_children()
    Return a list of the nested symbol tables.

class symtable.Function
    A namespace for a function or method. This class inherits SymbolTable.

get_parameters()
    Return a tuple containing names of parameters to this function.

getlocals()
    Return a tuple containing names of locals in this function.

get_globals()
    Return a tuple containing names of globals in this function.

get_frees()
    Return a tuple containing names of free variables in this function.

class symtable.Class
A namespace of a class. This class inherits `SymbolTable`.

`get_methods()`  
Return a tuple containing the names of methods declared in the class.

`class symtable.Symbol`  
An entry in a `SymbolTable` corresponding to an identifier in the source. The constructor is not public.

`get_name()`  
Return the symbol's name.

`is_referenced()`  
Return True if the symbol is used in its block.

`is_imported()`  
Return True if the symbol is created from an import statement.

`is_parameter()`  
Return True if the symbol is a parameter.

`is_global()`  
Return True if the symbol is global.

`is_declared_global()`  
Return True if the symbol is declared global with a `global` statement.

`is_local()`  
Return True if the symbol is local to its block.

`is_free()`
Return True if the symbol is referenced in its block, but not assigned to.

**is_assigned()**
Return True if the symbol is assigned to in its block.

**is_namespace()**
Return True if name binding introduces new namespace.

If the name is used as the target of a function or class statement, this will be true.

For example:

```python
>>> table = symtable.symtable("def some_func():
>>> table.lookup("some_func").is_namespace()
True
```

Note that a single name can be bound to multiple objects. If the result is True, the name may also be bound to other objects, like an int or list, that does not introduce a new namespace.

**get_namespaces()**
Return a list of namespaces bound to this name.

**get_namespace()**
Return the namespace bound to this name. If more than one namespace is bound, `ValueError` is raised.
The Python Software Foundation is a non-profit corporation. Please donate.
Last updated on Dec 06, 2015. Found a bug?
Created using Sphinx 1.3.1.
32.4. symbol — Constants used with Python parse trees

Source code: Lib/symbol.py

This module provides constants which represent the numeric values of internal nodes of the parse tree. Unlike most Python constants, these use lower-case names. Refer to the file Grammar/Grammar in the Python distribution for the definitions of the names in the context of the language grammar. The specific numeric values which the names map to may change between Python versions.

This module also provides one additional data object:

```
symbol.sym_name
```

Dictionary mapping the numeric values of the constants defined in this module back to name strings, allowing more human-readable representation of parse trees to be generated.
32.5. **token** — Constants used with Python parse trees

**Source code: Lib/token.py**

This module provides constants which represent the numeric values of leaf nodes of the parse tree (terminal tokens). Refer to the file Grammar/Grammar in the Python distribution for the definitions of the names in the context of the language grammar. The specific numeric values which the names map to may change between Python versions.

The module also provides a mapping from numeric codes to names and some functions. The functions mirror definitions in the Python C header files.

**token.** *tok_name*

Dictionary mapping the numeric values of the constants defined in this module back to name strings, allowing more human-readable representation of parse trees to be generated.

**token.** *ISTERMINAL*(x)

Return true for terminal token values.

**token.** *ISNONTERMINAL*(x)

Return true for non-terminal token values.

**token.** *ISEOF*(x)

Return true if x is the marker indicating the end of input.
The token constants are:

token.ENDMARKER
token.NAME
token.NUMBER
token.STRING
token.NEWLINE
token.INDENT
token.DEDENT
token.LPAR
token.RPAR
token.LSQB
token.RSQB
token.COLON
token.COMMA
token.SEMI
token.PLUS
token.MINUS
token.STAR
token.SLASH
token.VBAR
token.AMPER
token.LESS
token.GREATER
token.EQUAL
token.DOT
token.PERCENT
token.LBRACE
token.RBRACE
token.EQEQUAL
token.NOTEQUAL
token.LESSEQUAL
token.GREATEREQUAL
See also:

**Module** parser

The second example for the parser module shows how to use the symbol module.
This module allows a Python program to determine if a string is a keyword.

**keyword**.iskeyword(s)

Return true if s is a Python keyword.

**keyword**.kwlist

Sequence containing all the keywords defined for the interpreter. If any keywords are defined to only be active when particular __future__ statements are in effect, these will be included as well.
32.7. `tokenize` — Tokenizer for Python source

**Source code:** Lib/tokenize.py

The `tokenize` module provides a lexical scanner for Python source code, implemented in Python. The scanner in this module returns comments as tokens as well, making it useful for implementing “pretty-printers,” including colorizers for on-screen displays.

To simplify token stream handling, all `Operators` and `Delimiters` tokens are returned using the generic `token.OP` token type. The exact type can be determined by checking the `exact_type` property on the `named tuple` returned from `tokenize.tokenize()`.
32.7.1. Tokenizing Input

The primary entry point is a generator:

tokenize(tokenize(readline))

The `tokenize()` generator requires one argument, `readline`, which must be a callable object which provides the same interface as the `io.IOBase.readline()` method of file objects. Each call to the function should return one line of input as bytes.

The generator produces 5-tuples with these members: the token type; the token string; a 2-tuple (`srow, scol`) of ints specifying the row and column where the token begins in the source; a 2-tuple (`erow, ecol`) of ints specifying the row and column where the token ends in the source; and the line on which the token was found. The line passed (the last tuple item) is the logical line; continuation lines are included. The 5 tuple is returned as a named tuple with the field names: `type`, `string`, `start`, `end`, `line`.

The returned named tuple has an additional property named `exact_type` that contains the exact operator type for `token.OP` tokens. For all other token types `exact_type` equals the named tuple `type` field.

*Changed in version 3.1:* Added support for named tuples.

*Changed in version 3.3:* Added support for `exact_type`.

`tokenize()` determines the source encoding of the file by looking for a UTF-8 BOM or encoding cookie, according to PEP 263.

All constants from the `token` module are also exported from
The `tokenize` function includes the following token type values:

- **tokenize.COMMENT**: Token value used to indicate a comment.
- **tokenize.NL**: Token value used to indicate a non-terminating newline. The NEWLINE token indicates the end of a logical line of Python code; NL tokens are generated when a logical line of code is continued over multiple physical lines.
- **tokenize.ENCODING**: Token value that indicates the encoding used to decode the source bytes into text. The first token returned by `tokenize()` will always be an ENCODING token.

Another function is provided to reverse the tokenization process. This is useful for creating tools that tokenize a script, modify the token stream, and write back the modified script.

**tokenize.untokenize(iterable)**

Converts tokens back into Python source code. The `iterable` must return sequences with at least two elements, the token type and the token string. Any additional sequence elements are ignored.

The reconstructed script is returned as a single string. The result is guaranteed to tokenize back to match the input so that the conversion is lossless and round-trips are assured. The guarantee applies only to the token type and token string as the spacing between tokens (column positions) may change.

It returns bytes, encoded using the ENCODING token, which is the first token sequence output by `tokenize()`.
**tokenize()** needs to detect the encoding of source files it tokenizes. The function it uses to do this is available:

**tokenize.** detect_encoding(readline)

The **detect_encoding()** function is used to detect the encoding that should be used to decode a Python source file. It requires one argument, readline, in the same way as the **tokenize()** generator.

It will call readline a maximum of twice, and return the encoding used (as a string) and a list of any lines (not decoded from bytes) it has read in.

It detects the encoding from the presence of a UTF-8 BOM or an encoding cookie as specified in **PEP 263**. If both a BOM and a cookie are present, but disagree, a SyntaxError will be raised. Note that if the BOM is found, 'utf-8-sig' will be returned as an encoding.

If no encoding is specified, then the default of 'utf-8' will be returned.

Use **open()** to open Python source files: it uses **detect_encoding()** to detect the file encoding.

**tokenize.** open(filename)

Open a file in read only mode using the encoding detected by **detect_encoding()**.

*New in version 3.2.*

**exception** tokenize.**TokenError**

Raised when either a docstring or expression that may be split over
several lines is not completed anywhere in the file, for example:

```
"""Beginning of docstring
```

or:

```
[1,
  2,
  3
```

Note that unclosed single-quoted strings do not cause an error to be raised. They are tokenized as `ERRORTOKEN`, followed by the tokenization of their contents.
32.7.2. Command-Line Usage

*New in version 3.3.*

The `tokenize` module can be executed as a script from the command line. It is as simple as:

```
python -m tokenize [-e] [filename.py]
```

The following options are accepted:

- **-h, --help**
  - show this help message and exit

- **-e, --exact**
  - display token names using the exact type

If `filename.py` is specified its contents are tokenized to stdout. Otherwise, tokenization is performed on stdin.
32.7.3. Examples

Example of a script rewriter that transforms float literals into Decimal objects:

```python
from tokenize import tokenize, untokenize, NUMBER, STRING
from io import BytesIO

def decistmt(s):
    """Substitute Decimals for floats in a string of statements."

    >>> from decimal import Decimal
    >>> s = 'print(+21.3e-5*-.1234/81.7)'
    >>> decistmt(s)
    "print (+Decimal ('21.3e-5')*-Decimal ('.1234')/Decimal ('81.7'))"

    The format of the exponent is inherited from the platform C library. Known cases are "e-007" (Windows) and "e-07" (not Windows). Since we're only showing 12 digits, and the 13th isn't close to 5, the rest of the output should be platform-independent.

    >>> exec(s) # doctest: +ELLIPSIS
    -3.21716034272e-0...7

    Output from calculations with Decimal should be identical across all platforms.

    >>> exec(decistmt(s))
    -3.217160342717258261933904529E-7

    ""

    result = []
g = tokenize(BytesIO(s.encode('utf-8')).readline)
for toknum, tokval, _, _, _ in g:
    if toknum == NUMBER and '.' in tokval:  # replace NUMBER tokens
        result.extend([...]
```
Example of tokenizing from the command line. The script:

```python
def say_hello():
    print("Hello, World!")
say_hello()
```

will be tokenized to the following output where the first column is the range of the line/column coordinates where the token is found, the second column is the name of the token, and the final column is the value of the token (if any)

```
$ python -m tokenize hello.py
0,0-0,0: ENCODING 'utf-8'
1,0-1,3: NAME 'def'
1,4-1,13: NAME 'say_hello'
1,13-1,14: OP '('
1,14-1,15: OP ')
1,15-1,16: OP ':'
1,16-1,17: NEWLINE '\n'
2,0-2,4: INDENT '    '
2,4-2,9: NAME 'print'
2,9-2,10: OP '('
2,10-2,25: STRING '"Hello, World!"'
2,25-2,26: OP ')
2,26-2,27: NEWLINE '\n'
```
The exact token type names can be displayed using the -e option:

```bash
$ python -m tokenize -e hello.py
```

```
0,0-0,0: ENCODING 'utf-8'
1,0-1,3: NAME 'def'
1,4-1,13: NAME 'say_hello'
1,13-1,14: LPAR '
1,14-1,15: RPAR ')
1,15-1,16: COLON ':'
1,16-1,17: NEWLINE '
2,0-2,4: INDENT '
2,4-2,9: NAME 'print'
2,9-2,10: LPAR '
2,10-2,25: STRING "Hello, World!"
2,25-2,26: RPAR ')
2,26-2,27: NEWLINE '
3,0-3,1: NL '
4,0-4,0: DEDENT '
4,0-4,9: NAME 'say_hello'
4,9-4,10: LPAR '
4,10-4,11: RPAR ')
4,11-4,12: NEWLINE '
5,0-5,0: ENDMARKER '''
```
32.8. **tabnanny** — Detection of ambiguous indentation

**Source code:** Lib/tabnanny.py

For the time being this module is intended to be called as a script. However it is possible to import it into an IDE and use the function `check()` described below.

**Note:** The API provided by this module is likely to change in future releases; such changes may not be backward compatible.

`tabnanny.check(file_or_dir)`

If `file_or_dir` is a directory and not a symbolic link, then recursively descend the directory tree named by `file_or_dir`, checking all `.py` files along the way. If `file_or_dir` is an ordinary Python source file, it is checked for whitespace related problems. The diagnostic messages are written to standard output using the `print()` function.

`tabnanny.verbose`

Flag indicating whether to print verbose messages. This is incremented by the `-v` option if called as a script.

`tabnanny.filename_only`

Flag indicating whether to print only the filenames of files containing whitespace related problems. This is set to true by the `-q` option if called as a script.
exception tabnanny. **NannyNag**

Raised by *tokeneater()* if detecting an ambiguous indent. Captured and handled in *check()*.

tabnanny. **tokeneater**(type, token, start, end, line)

This function is used by *check()* as a callback parameter to the function *tokenize.tokenize()*.

**See also:**

**Module tokenize**

Lexical scanner for Python source code.
The `pyclbr` module can be used to determine some limited information about the classes, methods and top-level functions defined in a module. The information provided is sufficient to implement a traditional three-pane class browser. The information is extracted from the source code rather than by importing the module, so this module is safe to use with untrusted code. This restriction makes it impossible to use this module with modules not implemented in Python, including all standard and optional extension modules.

`pyclbr.readmodule(module, path=None)`

Read a module and return a dictionary mapping class names to class descriptor objects. The parameter `module` should be the name of a module as a string; it may be the name of a module within a package. The `path` parameter should be a sequence, and is used to augment the value of `sys.path`, which is used to locate module source code.

`pyclbr.readmodule_ex(module, path=None)`

Like `readmodule()`, but the returned dictionary, in addition to mapping class names to class descriptor objects, also maps top-level function names to function descriptor objects. Moreover, if the module being read is a package, the key '__path__' in the returned dictionary has as its value a list which contains the package search path.
32.9.1. Class Objects

The Class objects used as values in the dictionary returned by \texttt{readmodule()} and \texttt{readmodule\_ex()} provide the following data attributes:

\textbf{Class.\texttt{module}}

The name of the module defining the class described by the class descriptor.

\textbf{Class.\texttt{name}}

The name of the class.

\textbf{Class.\texttt{super}}

A list of Class objects which describe the immediate base classes of the class being described. Classes which are named as superclasses but which are not discoverable by \texttt{readmodule()} are listed as a string with the class name instead of as Class objects.

\textbf{Class.\texttt{methods}}

A dictionary mapping method names to line numbers.

\textbf{Class.\texttt{file}}

Name of the file containing the class statement defining the class.

\textbf{Class.\texttt{lineno}}

The line number of the class statement within the file named by \texttt{file}.
32.9.2. Function Objects

The Function objects used as values in the dictionary returned by `readmodule_ex()` provide the following attributes:

**Function.module**

The name of the module defining the function described by the function descriptor.

**Function.name**

The name of the function.

**Function.file**

Name of the file containing the `def` statement defining the function.

**Function.lineno**

The line number of the `def` statement within the file named by `file`.
32.10. **py_compile** — Compile Python source files

**Source code:** Lib/py_compile.py

The **py_compile** module provides a function to generate a byte-code file from a source file, and another function used when the module source file is invoked as a script.

Though not often needed, this function can be useful when installing modules for shared use, especially if some of the users may not have permission to write the byte-code cache files in the directory containing the source code.

**exception py_compile.PyCompileError**

Exception raised when an error occurs while attempting to compile the file.

**py_compile.compile(file, cfile=None, dfile=None, dorrase=False, optimize=-1)**

Compile a source file to byte-code and write out the byte-code cache file. The source code is loaded from the file name `file`. The byte-code is written to `cfile`, which defaults to the PEP 3147/PEP 488 path, ending in `.pyc`. For example, if `file` is `/foo/bar/baz.py` `cfile` will default to `/foo/bar/__pycache__/baz.cpython-32.pyc` for Python 3.2. If `dfile` is specified, it is used as the name of the source file in error messages when instead of `file`. If `dorrase` is true, a **PyCompileError** is raised when an error is encountered while
compiling *file*. If *doraise* is false (the default), an error string is written to `sys.stderr`, but no exception is raised. This function returns the path to byte-compiled file, i.e. whatever *cfile* value was used.

If the path that *cfile* becomes (either explicitly specified or computed) is a symlink or non-regular file, *FileExistsError* will be raised. This is to act as a warning that import will turn those paths into regular files if it is allowed to write byte-compiled files to those paths. This is a side-effect of import using file renaming to place the final byte-compiled file into place to prevent concurrent file writing issues.

*optimize* controls the optimization level and is passed to the built-in `compile()` function. The default of -1 selects the optimization level of the current interpreter.

*Changed in version 3.2:* Changed default value of *cfile* to be PEP 3147-compliant. Previous default was *file* + 'c' ('o' if optimization was enabled). Also added the *optimize* parameter.

*Changed in version 3.4:* Changed code to use *importlib* for the byte-code cache file writing. This means file creation/writing semantics now match what *importlib* does, e.g. permissions, write-and-move semantics, etc. Also added the caveat that *FileExistsError* is raised if *cfile* is a symlink or non-regular file.

**py_compile.main**(args=None)

Compile several source files. The files named in *args* (or on the command line, if *args* is None) are compiled and the resulting byte-code is cached in the normal manner. This function does not search a directory structure to locate source files; it only compiles
files named explicitly. If ' - ' is the only parameter in args, the list of files is taken from standard input.

*Changed in version 3.2:* Added support for ' - '.

When this module is run as a script, the `main()` is used to compile all the files named on the command line. The exit status is nonzero if one of the files could not be compiled.

**See also:**

**Module** **compileall**

Utilities to compile all Python source files in a directory tree.
32.11. `compileall` — Byte-compile Python libraries

**Source code:** `Lib/compileall.py`

This module provides some utility functions to support installing Python libraries. These functions compile Python source files in a directory tree. This module can be used to create the cached bytecode files at library installation time, which makes them available for use even by users who don't have write permission to the library directories.
32.11.1. Command-line use

This module can work as a script (using `python -m compileall`) to compile Python sources.

directory ...
file ...

Positional arguments are files to compile or directories that contain source files, traversed recursively. If no argument is given, behave as if the command line was `-l <directories from sys.path>`.

-\l

Do not recurse into subdirectories, only compile source code files directly contained in the named or implied directories.

-\f

Force rebuild even if timestamps are up-to-date.

-\q

Do not print the list of files compiled. If passed once, error messages will still be printed. If passed twice (-qq), all output is suppressed.

-\d destdir

Directory prepended to the path to each file being compiled. This will appear in compilation time tracebacks, and is also compiled into the byte-code file, where it will be used in tracebacks and other messages in cases where the source file does not exist at the time the byte-code file is executed.

-\x regex
regex is used to search the full path to each file considered for compilation, and if the regex produces a match, the file is skipped.

-\texttt{\textbf{i}} list
Read the file list and add each line that it contains to the list of files and directories to compile. If list is -, read lines from stdin.

-\texttt{\textbf{b}}
Write the byte-code files to their legacy locations and names, which may overwrite byte-code files created by another version of Python. The default is to write files to their \texttt{PEP 3147} locations and names, which allows byte-code files from multiple versions of Python to coexist.

-\texttt{\textbf{r}}
Control the maximum recursion level for subdirectories. If this is given, then -\texttt{l} option will not be taken into account. \texttt{python \textminus m compileall <directory> -r 0} is equivalent to \texttt{python \textminus m compileall <directory> -l}.

-\texttt{\textbf{j}} \texttt{N}
Use \texttt{N} workers to compile the files within the given directory. If 0 is used, then the result of \texttt{os.cpu_count()} will be used.

\textit{Changed in version 3.2:} Added the -\texttt{i}, -\texttt{b} and -\texttt{h} options.

\textit{Changed in version 3.5:} Added the -\texttt{j}, -\texttt{r}, and -\texttt{qq} options. -\texttt{q} option was changed to a multilevel value. -\texttt{b} will always produce a byte-code file ending in .\texttt{pyc}, never .\texttt{pyo}.

There is no command-line option to control the optimization level used by the \texttt{compile()} function, because the Python interpreter itself
already provides the option: `python -O -m compileall`. 
32.11.2. Public functions

```
compileall.compile_dir(dir, maxlevels=10, ddir=None, force=False, rx=None, quiet=0, legacy=False, optimize=-1, workers=1)
```

Recursively descend the directory tree named by `dir`, compiling all `.py` files along the way.

The `maxlevels` parameter is used to limit the depth of the recursion; it defaults to 10.

If `ddir` is given, it is prepended to the path to each file being compiled for use in compilation time tracebacks, and is also compiled in to the byte-code file, where it will be used in tracebacks and other messages in cases where the source file does not exist at the time the byte-code file is executed.

If `force` is true, modules are re-compiled even if the timestamps are up to date.

If `rx` is given, its search method is called on the complete path to each file considered for compilation, and if it returns a true value, the file is skipped.

If `quiet` is False or 0 (the default), the filenames and other information are printed to standard out. Set to 1, only errors are printed. Set to 2, all output is suppressed.

If `legacy` is true, byte-code files are written to their legacy locations and names, which may overwrite byte-code files created by another version of Python. The default is to write files to their PEP 3147 locations and names, which allows byte-code files from multiple versions of Python to coexist.
optimize specifies the optimization level for the compiler. It is passed to the built-in compile() function.

The argument workers specifies how many workers are used to compile files in parallel. The default is to not use multiple workers. If the platform can’t use multiple workers and workers argument is given, then sequential compilation will be used as a fallback. If workers is lower than 0, a `ValueError` will be raised.

*Changed in version 3.2:* Added the legacy and optimize parameter.

*Changed in version 3.5:* Added the workers parameter.

*Changed in version 3.5:* quiet parameter was changed to a multilevel value.

*Changed in version 3.5:* The legacy parameter only writes out .pyc files, not .pyo files no matter what the value of optimize is.

`compileall.compile_file(fullname, ddir=None, force=False, rx=None, quiet=0, legacy=False, optimize=-1)`

Compile the file with path `fullname`.

If `ddir` is given, it is prepended to the path to the file being compiled for use in compilation time tracebacks, and is also compiled in to the byte-code file, where it will be used in tracebacks and other messages in cases where the source file does not exist at the time the byte-code file is executed.

If `rx` is given, its search method is passed the full path name to the file being compiled, and if it returns a true value, the file is not compiled and True is returned.

If `quiet` is False or 0 (the default), the filenames and other
information are printed to standard out. Set to 1, only errors are printed. Set to 2, all output is suppressed.

If legacy is true, byte-code files are written to their legacy locations and names, which may overwrite byte-code files created by another version of Python. The default is to write files to their PEP 3147 locations and names, which allows byte-code files from multiple versions of Python to coexist.

optimize specifies the optimization level for the compiler. It is passed to the built-in compile() function.

*New in version 3.2.*

*Changed in version 3.5: quiet parameter was changed to a multilevel value.*

*Changed in version 3.5: The legacy parameter only writes out .pyc files, not .pyo files no matter what the value of optimize is.*

**compileall.compile_path**

```python
compileall.compile_path(skip_curdir=True, maxlevels=0, force=False, quiet=0, legacy=False, optimize=-1)
```  
Byte-compile all the .py files found along sys.path. If skip_curdir is true (the default), the current directory is not included in the search. All other parameters are passed to the compile_dir() function. Note that unlike the other compile functions, maxlevels defaults to 0.

*Changed in version 3.2: Added the legacy and optimize parameter.*

*Changed in version 3.5: quiet parameter was changed to a multilevel value.*

*Changed in version 3.5: The legacy parameter only writes out...*
.pyc files, not .pyo files no matter what the value of optimize is.

To force a recompile of all the .py files in the Lib/ subdirectory and all its subdirectories:

```python
import compileall
closeall.compile_dir('Lib/', force=True)
```

```python
# Perform same compilation, excluding files in .svn
don't need.
import re
closeall.compile_dir('Lib/', rx=re.compile(r'[\/]\.svn'))
```

See also:

**Module py_compile**

Byte-compile a single source file.
32.12. **dis** — Disassembler for Python bytecode

**Source code:** Lib/dis.py

The *dis* module supports the analysis of CPython bytecode by disassembling it. The CPython bytecode which this module takes as an input is defined in the file `Include/opcode.h` and used by the compiler and the interpreter.

**CPython implementation detail:** Bytecode is an implementation detail of the CPython interpreter. No guarantees are made that bytecode will not be added, removed, or changed between versions of Python. Use of this module should not be considered to work across Python VMs or Python releases.

Example: Given the function `myfunc()`:

```python
def myfunc(alist):
    return len(alist)
```

the following command can be used to display the disassembly of `myfunc()`:

```bash
>>> dis.dis(myfunc)
   2           0 LOAD_GLOBAL    0 (len)
   3 LOAD_FAST    0 (alist)
   6 CALL_FUNCTION 1
   9 RETURN_VALUE
```

(The “2” is a line number).
32.12.1. Bytecode analysis

*New in version 3.4.*

The bytecode analysis API allows pieces of Python code to be wrapped in a `Bytecode` object that provides easy access to details of the compiled code.

```python
class dis.Bytecode(x, *, first_line=None, current_offset=None)
```

Analyse the bytecode corresponding to a function, generator, method, string of source code, or a code object (as returned by `compile()`).

This is a convenience wrapper around many of the functions listed below, most notably `get_instructions()`, as iterating over a `Bytecode` instance yields the bytecode operations as `Instruction` instances.

If `first_line` is not None, it indicates the line number that should be reported for the first source line in the disassembled code. Otherwise, the source line information (if any) is taken directly from the disassembled code object.

If `current_offset` is not None, it refers to an instruction offset in the disassembled code. Setting this means `dis()` will display a “current instruction” marker against the specified opcode.

```python
classmethod from_traceback(tb)
```

Construct a `Bytecode` instance from the given traceback, setting `current_offset` to the instruction responsible for the exception.
**codeobj**

The compiled code object.

**first_line**

The first source line of the code object (if available)

**dis()**

Return a formatted view of the bytecode operations (the same as printed by `dis.dis()`, but returned as a multi-line string).

**info()**

Return a formatted multi-line string with detailed information about the code object, like `code_info()`.

Example:

```python
>>> bytecode = dis.Bytecode(myfunc)
>>> for instr in bytecode:
...     print(instr.opname)
...
LOAD_GLOBAL
LOAD_FAST
CALL_FUNCTION
RETURN_VALUE
```
32.12.2. Analysis functions

The `dis` module also defines the following analysis functions that convert the input directly to the desired output. They can be useful if only a single operation is being performed, so the intermediate analysis object isn’t useful:

`dis.code_info(x)`
Return a formatted multi-line string with detailed code object information for the supplied function, generator, method, source code string or code object.

Note that the exact contents of code info strings are highly implementation dependent and they may change arbitrarily across Python VMs or Python releases.

*New in version 3.2.*

`dis.show_code(x, *, file=None)`
Print detailed code object information for the supplied function, method, source code string or code object to `file` (or `sys.stdout` if `file` is not specified).

This is a convenient shorthand for `print(code_info(x), file=file)`, intended for interactive exploration at the interpreter prompt.

*New in version 3.2.*

*Changed in version 3.4: Added `file` parameter.*

`dis.dis(x=None, *, file=None)`
Disassemble the \( x \) object. \( x \) can denote either a module, a class, a method, a function, a generator, a code object, a string of source code or a byte sequence of raw bytecode. For a module, it disassembles all functions. For a class, it disassembles all methods. For a code object or sequence of raw bytecode, it prints one line per bytecode instruction. Strings are first compiled to code objects with the \texttt{compile()}\ built-in function before being disassembled. If no object is provided, this function disassembles the last traceback.

The disassembly is written as text to the supplied \texttt{file} argument if provided and to \texttt{sys.stdout} otherwise.

\textit{Changed in version 3.4: Added \texttt{file} parameter.}

\texttt{dis.distb(tb=None, *, file=None)}

Disassemble the top-of-stack function of a traceback, using the last traceback if none was passed. The instruction causing the exception is indicated.

The disassembly is written as text to the supplied \texttt{file} argument if provided and to \texttt{sys.stdout} otherwise.

\textit{Changed in version 3.4: Added \texttt{file} parameter.}

\texttt{dis.disassemble(code, lasti=-1, *, file=None)}
\texttt{dis.disco(code, lasti=-1, *, file=None)}

Disassemble a code object, indicating the last instruction if \texttt{lasti} was provided. The output is divided in the following columns:

1. the line number, for the first instruction of each line
2. the current instruction, indicated as \texttt{ -->},
3. a labelled instruction, indicated with \texttt{>>},
4. the address of the instruction,
5. the operation code name,
6. operation parameters, and
7. interpretation of the parameters in parentheses.

The parameter interpretation recognizes local and global variable names, constant values, branch targets, and compare operators.

The disassembly is written as text to the supplied file argument if provided and to sys.stdout otherwise.

*Changed in version 3.4:* Added file parameter.

```python
dis.get_instructions(x, *, first_line=None)
```

Return an iterator over the instructions in the supplied function, method, source code string or code object.

The iterator generates a series of Instruction named tuples giving the details of each operation in the supplied code.

If first_line is not None, it indicates the line number that should be reported for the first source line in the disassembled code. Otherwise, the source line information (if any) is taken directly from the disassembled code object.

*New in version 3.4.*

```python
dis.findlinestarts(code)
```

This generator function uses the co_firstlineno and co_lnotab attributes of the code object code to find the offsets which are starts of lines in the source code. They are generated as (offset, lineno) pairs.

```python
dis.findlabels(code)
```
Detect all offsets in the code object `code` which are jump targets, and return a list of these offsets.

```

dis.stack_effect(opcode[, oparg])
```

Compute the stack effect of `opcode` with argument `oparg`.

*New in version 3.4.*
32.12.3. Python Bytecode Instructions

The `get_instructions()` function and `Bytecode` class provide details of bytecode instructions as `Instruction` instances:

```python
class dis/Instruction

Details for a bytecode operation

opcode
numeric code for operation, corresponding to the opcode values listed below and the bytecode values in the Opcode collections.

opname
human readable name for operation

arg
numeric argument to operation (if any), otherwise None

argval
resolved arg value (if known), otherwise same as arg

argrepr
human readable description of operation argument

offset
start index of operation within bytecode sequence

starts_line
line started by this opcode (if any), otherwise None

is_jump_target
True if other code jumps to here, otherwise False
```
New in version 3.4.

The Python compiler currently generates the following bytecode instructions.

**General instructions**

**NOP**

Do nothing code. Used as a placeholder by the bytecode optimizer.

**POP_TOP**

Removes the top-of-stack (TOS) item.

**ROT_TWO**

Swaps the two top-most stack items.

**ROT_THREE**

Lifts second and third stack item one position up, moves top down to position three.

**DUP_TOP**

Duplicates the reference on top of the stack.

**DUP_TOP_TWO**

Duplicates the two references on top of the stack, leaving them in the same order.

**Unary operations**

Unary operations take the top of the stack, apply the operation, and push the result back on the stack.

**UNARY_POSITIVE**

Implements TOS = +TOS.
**UNARY_NEGATIVE**
Implements TOS = -TOS.

**UNARY_NOT**
Implements TOS = not TOS.

**UNARY_INVERT**
Implements TOS = ~TOS.

**GET_ITER**
Implements TOS = iter(TOS).

**GET_YIELD_FROM_ITER**
If TOS is a generator iterator or coroutine object it is left as is. Otherwise, implements TOS = iter(TOS).

*New in version 3.5.*

**Binary operations**

Binary operations remove the top of the stack (TOS) and the second top-most stack item (TOS1) from the stack. They perform the operation, and put the result back on the stack.

**BINARY_POWER**
Implements TOS = TOS1 ** TOS.

**BINARY_MULTIPLY**
Implements TOS = TOS1 * TOS.

**BINARY_MATRIX_MULTIPLY**
Implements TOS = TOS1 @ TOS.

*New in version 3.5.*
**BINARY_FLOOR_DIVIDE**

Implements TOS = TOS1 // TOS.

**BINARY_TRUE_DIVIDE**

Implements TOS = TOS1 / TOS.

**BINARY_MODULO**

Implements TOS = TOS1 % TOS.

**BINARY_ADD**

Implements TOS = TOS1 + TOS.

**BINARY_SUBTRACT**

Implements TOS = TOS1 - TOS.

**BINARY_SUBSCR**

Implements TOS = TOS1[TOS].

**BINARY_LSHIFT**

Implements TOS = TOS1 << TOS.

**BINARY_RSHIFT**

Implements TOS = TOS1 >> TOS.

**BINARY_AND**

Implements TOS = TOS1 & TOS.

**BINARY_XOR**

Implements TOS = TOS1 ^ TOS.

**BINARY_OR**

Implements TOS = TOS1 | TOS.
In-place operations

In-place operations are like binary operations, in that they remove TOS and TOS1, and push the result back on the stack, but the operation is done in-place when TOS1 supports it, and the resulting TOS may be (but does not have to be) the original TOS1.

**INPLACE_POWER**
Implements in-place $TOS = TOS1 \times TOS$.

**INPLACE_MULTIPLY**
Implements in-place $TOS = TOS1 \times TOS$.

**INPLACE_MATRIX_MULTIPLY**
Implements in-place $TOS = TOS1 \times TOS$.

*New in version 3.5.*

**INPLACE_FLOOR_DIVIDE**
Implements in-place $TOS = TOS1 \div TOS$.

**INPLACE_TRUE_DIVIDE**
Implements in-place $TOS = TOS1 \div TOS$.

**INPLACE_MODULO**
Implements in-place $TOS = TOS1 \mod TOS$.

**INPLACE_ADD**
Implements in-place $TOS = TOS1 + TOS$.

**INPLACE_SUBTRACT**
Implements in-place $TOS = TOS1 - TOS$.

**INPLACE_LSHIFT**
Implements in-place TOS = TOS1 << TOS.

**INPLACE_RSHIFT**
Implements in-place TOS = TOS1 >> TOS.

**INPLACE_AND**
Implements in-place TOS = TOS1 & TOS.

**INPLACE_XOR**
Implements in-place TOS = TOS1 ^ TOS.

**INPLACE_OR**
Implements in-place TOS = TOS1 | TOS.

**STORE_SUBSCR**
Implements TOS1[TOS] = TOS2.

**DELETE_SUBSCR**
Implements del TOS1[TOS].

**Coroutine opcodes**

**GET_AWAITABLE**
Implements TOS = get_awaitable(TOS), where get_awaitable(o) returns o if o is a coroutine object or a generator object with the CO_ITERABLE_COROUTINE flag, or resolves o.__await__.

**GET_AITER**
Implements TOS = get_awaitable(TOS.__aiter__()). See GET_AWAITABLE for details about get_awaitable

**GET_ANEXT**
Implements `PUSH(get_awaitable(TOS.__anext__()))`. See `GET_AWAITABLE` for details about `get_awaitable`.

**BEFORE_ASYNC_WITH**
Resolves `__aenter__` and `__aexit__` from the object on top of the stack. Pushes `__aexit__` and result of `__aenter__()` to the stack.

**SETUP_ASYNC_WITH**
Creates a new frame object.

**Miscellaneous opcodes**

**PRINT_EXPR**
Implements the expression statement for the interactive mode. TOS is removed from the stack and printed. In non-interactive mode, an expression statement is terminated with `POP_TOP`.

**BREAK_LOOP**
Terminates a loop due to a `break` statement.

**CONTINUE_LOOP**(target)
Continues a loop due to a `continue` statement. `target` is the address to jump to (which should be a `FOR_ITER` instruction).

**SET_ADD**(i)
Calls `set.add(TOS1[-i], TOS)`. Used to implement set comprehensions.

**LIST_APPEND**(i)
Calls `list.append(TOS[-i], TOS)`. Used to implement list comprehensions.
**MAP_ADD(i)**

Calls `dict.setitem(TOS1[-i], TOS, TOS1)`. Used to implement dict comprehensions.

For all of the **SET_ADD**, **LIST_APPEND** and **MAP_ADD** instructions, while the added value or key/value pair is popped off, the container object remains on the stack so that it is available for further iterations of the loop.

**RETURN_VALUE**

Returns with TOS to the caller of the function.

**YIELD_VALUE**

Pops TOS and yields it from a generator.

**YIELD_FROM**

Pops TOS and delegates to it as a subiterator from a generator.

*New in version 3.3.*

**IMPORT_STAR**

Loads all symbols not starting with '_' directly from the module TOS to the local namespace. The module is popped after loading all names. This opcode implements `from module import *`.

**POP_BLOCK**

Removes one block from the block stack. Per frame, there is a stack of blocks, denoting nested loops, try statements, and such.

**POP_EXCEPT**

Removes one block from the block stack. The popped block must be an exception handler block, as implicitly created when entering an except handler. In addition to popping extraneous values from
the frame stack, the last three popped values are used to restore
the exception state.

**END FINALLY**

Terminates a *finally* clause. The interpreter recalls whether the
exception has to be re-raised, or whether the function returns, and
continues with the outer-next block.

**LOAD_BUILD_CLASS**

Pushes `builtins.__build_class__()` onto the stack. It is
later called by `CALL_FUNCTION` to construct a class.

**SETUP_WITH**(*delta*)

This opcode performs several operations before a with block starts. First, it loads `__exit__()` from the context manager and pushes it onto the stack for later use by `WITH_CLEANUP`. Then, `__enter__()` is called, and a finally block pointing to *delta* is pushed. Finally, the result of calling the enter method is pushed onto the stack. The next opcode will either ignore it (`POP_TOP`), or store it in (a) variable(s) (`STORE_FAST`, `STORE_NAME`, or `UNPACK_SEQUENCE`).

**WITH_CLEANUP_START**

 Cleans up the stack when a *with* statement block exits. TOS is the context manager’s `__exit__()` bound method. Below TOS are 1–3 values indicating how/why the finally clause was entered:

- SECOND = None
- (SECOND, THIRD) = (WHY_{{RETURN, CONTINUE}}), retval
- SECOND = WHY_*; no retval below it
- (SECOND, THIRD, FOURTH) = exc_info()

In the last case, TOS(SECOND, THIRD, FOURTH) is called,
otherwise TOS(None, None, None). Pushes SECOND and result of the call to the stack.

**WITH_CLEANUP_FINISH**

Pops exception type and result of ‘exit’ function call from the stack.

If the stack represents an exception, *and* the function call returns a ‘true’ value, this information is “zapped” and replaced with a single WHY_SILENCED to prevent **END_FINALLY** from re-raising the exception. (But non-local gotos will still be resumed.)

All of the following opcodes expect arguments. An argument is two bytes, with the more significant byte last.

**STORE_NAME**(namei)

Implements name = TOS. namei is the index of name in the attribute co_names of the code object. The compiler tries to use **STORE_FAST** or **STORE_GLOBAL** if possible.

**DELETE_NAME**(namei)

Implements del name, where namei is the index into co_names attribute of the code object.

**UNPACK_SEQUENCE**(count)

Unpacks TOS into count individual values, which are put onto the stack right-to-left.

**UNPACK_EX**(counts)

Implements assignment with a starred target: Unpacks an iterable in TOS into individual values, where the total number of values can be smaller than the number of items in the iterable: one the new values will be a list of all leftover items.
The low byte of \textit{counts} is the number of values before the list value, the high byte of \textit{counts} the number of values after it. The resulting values are put onto the stack right-to-left.

\textbf{STORE\_ATTR}(namei)
Implementes TOS.name = TOS1, where namei is the index of name in co_names.

\textbf{DELETE\_ATTR}(namei)
Implementes del TOS.name, using namei as index into co_names.

\textbf{STORE\_GLOBAL}(namei)
Works as \textbf{STORE\_NAME}, but stores the name as a global.

\textbf{DELETE\_GLOBAL}(namei)
Works as \textbf{DELETE\_NAME}, but deletes a global name.

\textbf{LOAD\_CONST}(consti)
Pushes co_consts[consti] onto the stack.

\textbf{LOAD\_NAME}(namei)
Pushes the value associated with co_names[namei] onto the stack.

\textbf{BUILD\_TUPLE}(count)
Creates a tuple consuming \textit{count} items from the stack, and pushes the resulting tuple onto the stack.

\textbf{BUILD\_LIST}(count)
Works as \textbf{BUILD\_TUPLE}, but creates a list.
**BUILD_SET**(count)

Works as **BUILD_TUPLE**, but creates a set.

**BUILD_MAP**(count)

Pushes a new dictionary object onto the stack. The dictionary is pre-sized to hold *count* entries.

**LOAD_ATTR**(namei)

Replaces TOS with `getattr(TOS, co_names[namei])`.

**COMPARE_OP**(opname)

Performs a Boolean operation. The operation name can be found in `cmp_op[opname]`.

**IMPORT_NAME**(namei)

Imports the module `co_names[namei]`. TOS and TOS1 are popped and provide the `fromlist` and `level` arguments of `__import__()`. The module object is pushed onto the stack. The current namespace is not affected: for a proper import statement, a subsequent **STORE_FAST** instruction modifies the namespace.

**IMPORT_FROM**(namei)

Loads the attribute `co_names[namei]` from the module found in TOS. The resulting object is pushed onto the stack, to be subsequently stored by a **STORE_FAST** instruction.

**JUMP_FORWARD**(delta)

Increments bytecode counter by *delta*.

**POP_JUMP_IF_TRUE**(target)

If TOS is true, sets the bytecode counter to *target*. TOS is popped.
**POP_JUMP_IF_FALSE**(*target*)

If TOS is false, sets the bytecode counter to *target*. TOS is popped.

**JUMP_IF_TRUE_OR_POP**(*target*)

If TOS is true, sets the bytecode counter to *target* and leaves TOS on the stack. Otherwise (TOS is false), TOS is popped.

**JUMP_IF_FALSE_OR_POP**(*target*)

If TOS is false, sets the bytecode counter to *target* and leaves TOS on the stack. Otherwise (TOS is true), TOS is popped.

**JUMP_ABSOLUTE**(*target*)

Set bytecode counter to *target*.

**FOR_ITER**(*delta*)

TOS is an *iterator*. Call its **_next_** method. If this yields a new value, push it on the stack (leaving the iterator below it). If the iterator indicates it is exhausted TOS is popped, and the byte code counter is incremented by *delta*.

**LOAD_GLOBAL**(*namei*)

Loads the global named co_names[*namei*] onto the stack.

**SETUP_LOOP**(*delta*)

Pushes a block for a loop onto the block stack. The block spans from the current instruction with a size of *delta* bytes.

**SETUP_EXCEPT**(*delta*)

Pushes a try block from a try-except clause onto the block stack. *delta* points to the first except block.

**SETUP_FINALLY**(*delta*)

Pushes a try block from a try-except clause onto the block stack.
\(\text{delta}\) points to the finally block.

**LOAD\_FAST(var\_num)**

Pushes a reference to the local co\_varnames[var\_num] onto the stack.

**STORE\_FAST(var\_num)**

Stores TOS into the local co\_varnames[var\_num].

**DELETE\_FAST(var\_num)**

Deletes local co\_varnames[var\_num].

**LOAD\_CLOSURE(i)**

Pushes a reference to the cell contained in slot \(i\) of the cell and free variable storage. The name of the variable is co\_cellvars[i] if \(i\) is less than the length of co\_cellvars. Otherwise it is co\_freevars[i - len(co\_cellvars)].

**LOAD\_DEREF(i)**

Loads the cell contained in slot \(i\) of the cell and free variable storage. Pushes a reference to the object the cell contains on the stack.

**LOAD\_CLASSDEREF(i)**

Much like **LOAD\_DEREF** but first checks the locals dictionary before consulting the cell. This is used for loading free variables in class bodies.

**STORE\_DEREF(i)**

Stores TOS into the cell contained in slot \(i\) of the cell and free variable storage.
DELETE_DEREF(i)

Empties the cell contained in slot i of the cell and free variable storage. Used by the `del` statement.

RAISE_VARARGS(argc)

Raises an exception. `argc` indicates the number of parameters to the raise statement, ranging from 0 to 3. The handler will find the traceback as TOS2, the parameter as TOS1, and the exception as TOS.

CALL_FUNCTION(argc)

Calls a function. The low byte of `argc` indicates the number of positional parameters, the high byte the number of keyword parameters. On the stack, the opcode finds the keyword parameters first. For each keyword argument, the value is on top of the key. Below the keyword parameters, the positional parameters are on the stack, with the right-most parameter on top. Below the parameters, the function object to call is on the stack. Pops all function arguments, and the function itself off the stack, and pushes the return value.

MAKE_FUNCTION(argc)

Pushes a new function object on the stack. From bottom to top, the consumed stack must consist of

- `argc & 0xFF` default argument objects in positional order
- `(argc >> 8) & 0xFF` pairs of name and default argument, with the name just below the object on the stack, for keyword-only parameters
- `(argc >> 16) & 0x7FFF` parameter annotation objects
- a tuple listing the parameter names for the annotations (only if there are any annotation objects)
- the code associated with the function (at TOS1)
• the qualified name of the function (at TOS)

MAKE_CLOSURE(argc)

Creates a new function object, sets its __closure__ slot, and pushes it on the stack. TOS is the qualified name of the function, TOS1 is the code associated with the function, and TOS2 is the tuple containing cells for the closure’s free variables. argc is interpreted as in MAKE_FUNCTION; the annotations and defaults are also in the same order below TOS2.

BUILD_SLICE(argc)

Pushes a slice object on the stack. argc must be 2 or 3. If it is 2, slice(TOS1, TOS) is pushed; if it is 3, slice(TOS2, TOS1, TOS) is pushed. See the slice() built-in function for more information.

EXTENDED_ARG(ext)

Prefixes any opcode which has an argument too big to fit into the default two bytes. ext holds two additional bytes which, taken together with the subsequent opcode’s argument, comprise a four-byte argument, ext being the two most-significant bytes.

CALL_FUNCTION_VAR(argc)

Calls a function. argc is interpreted as in CALL_FUNCTION. The top element on the stack contains the variable argument list, followed by keyword and positional arguments.

CALL_FUNCTION_KW(argc)

Calls a function. argc is interpreted as in CALL_FUNCTION. The top element on the stack contains the keyword arguments dictionary, followed by explicit keyword and positional arguments.
**CALL_FUNCTION_VAR_KW**(argc)

Calls a function. *argc* is interpreted as in **CALL_FUNCTION**. The top element on the stack contains the keyword arguments dictionary, followed by the variable-arguments tuple, followed by explicit keyword and positional arguments.

**HAVE_ARGUMENT**

This is not really an opcode. It identifies the dividing line between opcodes which don’t take arguments < HAVE_ARGUMENT and those which do >= HAVE_ARGUMENT.
32.12.4. Opcode collections

These collections are provided for automatic introspection of bytecode instructions:

**dis.opname**
Sequence of operation names, indexable using the bytecode.

**dis.opmap**
Dictionary mapping operation names to bytecodes.

**dis.cmp_op**
Sequence of all compare operation names.

**dis.hasconst**
Sequence of bytecodes that have a constant parameter.

**dis.hasfree**
Sequence of bytecodes that access a free variable (note that ‘free’ in this context refers to names in the current scope that are referenced by inner scopes or names in outer scopes that are referenced from this scope. It does *not* include references to global or builtin scopes).

**dis.hasname**
Sequence of bytecodes that access an attribute by name.

**dis.hasjrel**
Sequence of bytecodes that have a relative jump target.

**dis.hasjabs**
Sequence of bytecodes that have an absolute jump target.
dis.**haslocal**
Sequence of bytecodes that access a local variable.

dis.**hascompare**
Sequence of bytecodes of Boolean operations.
32.13. pickletools — Tools for pickle developers

Source code: Lib/pickletools.py

This module contains various constants relating to the intimate details of the pickle module, some lengthy comments about the implementation, and a few useful functions for analyzing pickled data. The contents of this module are useful for Python core developers who are working on the pickle; ordinary users of the pickle module probably won't find the pickletools module relevant.
32.13.1. Command line usage

New in version 3.2.

When invoked from the command line, python -m pickletools will disassemble the contents of one or more pickle files. Note that if you want to see the Python object stored in the pickle rather than the details of pickle format, you may want to use -m pickle instead. However, when the pickle file that you want to examine comes from an untrusted source, -m pickletools is a safer option because it does not execute pickle bytecode.

For example, with a tuple (1, 2) pickled in file x.pickle:

```
$ python -m pickle x.pickle
(1, 2)

$ python -m pickletools x.pickle
  0: \x80 PROTO 3
  2: K BININT1 1
  4: K BININT1 2
  6: \x86 TUPLE2
  7: q BININPUT 0
  9: . STOP
highest protocol among opcodes = 2
```
Name of a file where the output should be written.

- **l**, **--indentlevel**=<num>
  The number of blanks by which to indent a new MARK level.

- **m**, **--memo**
  When multiple objects are disassembled, preserve memo between disassemblies.

- **p**, **--preamble**=<preamble>
  When more than one pickle file are specified, print given preamble before each disassembly.
32.13.2. Programmatic Interface

```python
define pickletools.dis(pickle, out=None, memo=None, indentlevel=4, annotate=0)
```

Outputs a symbolic disassembly of the pickle to the file-like object `out`, defaulting to `sys.stdout`. `pickle` can be a string or a file-like object. `memo` can be a Python dictionary that will be used as the pickle’s memo; it can be used to perform disassemblies across multiple pickles created by the same pickler. Successive levels, indicated by MARK opcodes in the stream, are indented by `indentlevel` spaces. If a nonzero value is given to `annotate`, each opcode in the output is annotated with a short description. The value of `annotate` is used as a hint for the column where annotation should start.

*New in version 3.2:* The `annotate` argument.

```python
define pickletools.genops(pickle)
```

Provides an iterator over all of the opcodes in a pickle, returning a sequence of `(opcode, arg, pos)` triples. `opcode` is an instance of an OpcodeInfo class; `arg` is the decoded value, as a Python object, of the opcode’s argument; `pos` is the position at which this opcode is located. `pickle` can be a string or a file-like object.

```python
define pickletools.optimize(picklestring)
```

Returns a new equivalent pickle string after eliminating unused PUT opcodes. The optimized pickle is shorter, takes less transmission time, requires less storage space, and unpickles more efficiently.
33. Miscellaneous Services

The modules described in this chapter provide miscellaneous services that are available in all Python versions. Here's an overview:

- **33.1. formatter — Generic output formatting**
  - 33.1.1. The Formatter Interface
  - 33.1.2. Formatter Implementations
  - 33.1.3. The Writer Interface
  - 33.1.4. Writer Implementations
33.1. **formatter** — Generic output formatting

*Deprecated since version 3.4:* Due to lack of usage, the formatter module has been deprecated.

This module supports two interface definitions, each with multiple implementations: The *formatter* interface, and the *writer* interface which is required by the formatter interface.

Formatter objects transform an abstract flow of formatting events into specific output events on writer objects. Formatters manage several stack structures to allow various properties of a writer object to be changed and restored; writers need not be able to handle relative changes nor any sort of “change back” operation. Specific writer properties which may be controlled via formatter objects are horizontal alignment, font, and left margin indentations. A mechanism is provided which supports providing arbitrary, non-exclusive style settings to a writer as well. Additional interfaces facilitate formatting events which are not reversible, such as paragraph separation.

Writer objects encapsulate device interfaces. Abstract devices, such as file formats, are supported as well as physical devices. The provided implementations all work with abstract devices. The interface makes available mechanisms for setting the properties which formatter objects manage and inserting data into the output.
33.1.1. The Formatter Interface

Interfaces to create formatters are dependent on the specific formatter class being instantiated. The interfaces described below are the required interfaces which all formatters must support once initialized.

One data element is defined at the module level:

formatter.AS_IS

Value which can be used in the font specification passed to the push_font() method described below, or as the new value to any other push_property() method. Pushing the AS_IS value allows the corresponding pop_property() method to be called without having to track whether the property was changed.

The following attributes are defined for formatter instance objects:

formatter.writer

The writer instance with which the formatter interacts.

formatter.end_paragraph(blanklines)

Close any open paragraphs and insert at least blanklines before the next paragraph.

formatter.add_line_break()

Add a hard line break if one does not already exist. This does not break the logical paragraph.

formatter.add_hor_rule(*args, **kw)

Insert a horizontal rule in the output. A hard break is inserted if there is data in the current paragraph, but the logical paragraph is not broken. The arguments and keywords are passed on to the
writer's `send_line_break()` method.

**formatter.add_flowing_data(data)**

Provide data which should be formatted with collapsed whitespace. Whitespace from preceding and successive calls to `add_flowing_data()` is considered as well when the whitespace collapse is performed. The data which is passed to this method is expected to be word-wrapped by the output device. Note that any word-wrapping still must be performed by the writer object due to the need to rely on device and font information.

**formatter.add_literal_data(data)**

Provide data which should be passed to the writer unchanged. Whitespace, including newline and tab characters, are considered legal in the value of `data`.

**formatter.add_label_data(format, counter)**

Insert a label which should be placed to the left of the current left margin. This should be used for constructing bulleted or numbered lists. If the `format` value is a string, it is interpreted as a format specification for `counter`, which should be an integer. The result of this formatting becomes the value of the label; if `format` is not a string it is used as the label value directly. The label value is passed as the only argument to the writer’s `send_label_data()` method. Interpretation of non-string label values is dependent on the associated writer.

Format specifications are strings which, in combination with a counter value, are used to compute label values. Each character in the format string is copied to the label value, with some characters recognized to indicate a transform on the counter value. Specifically, the character '1' represents the counter value...
formatter as an Arabic number, the characters 'A' and 'a' represent alphabetic representations of the counter value in upper and lower case, respectively, and 'I' and 'i' represent the counter value in Roman numerals, in upper and lower case. Note that the alphabetic and roman transforms require that the counter value be greater than zero.

**formatter.flush_softspace()**
Send any pending whitespace buffered from a previous call to **add_flowing_data()** to the associated writer object. This should be called before any direct manipulation of the writer object.

**formatter.push_alignment(align)**
Push a new alignment setting onto the alignment stack. This may be **AS_IS** if no change is desired. If the alignment value is changed from the previous setting, the writer's **new_alignment()** method is called with the **align** value.

**formatter.pop_alignment()**
Restore the previous alignment.

**formatter.push_font((size, italic, bold, teletype))**
Change some or all font properties of the writer object. Properties which are not set to **AS_IS** are set to the values passed in while others are maintained at their current settings. The writer’s **new_font()** method is called with the fully resolved font specification.

**formatter.pop_font()**
Restore the previous font.

**formatter.push_margin(margin)**
Increase the number of left margin indentations by one, associating the logical tag `margin` with the new indentation. The initial margin level is 0. Changed values of the logical tag must be true values; false values other than `AS_IS` are not sufficient to change the margin.

```python
formatter.pop_margin()
Restore the previous margin.
```

```python
formatter.push_style(*styles)
Push any number of arbitrary style specifications. All styles are pushed onto the styles stack in order. A tuple representing the entire stack, including `AS_IS` values, is passed to the writer's `new_styles()` method.
```

```python
formatter.pop_style(n=1)
Pop the last `n` style specifications passed to `push_style()`. A tuple representing the revised stack, including `AS_IS` values, is passed to the writer's `new_styles()` method.
```

```python
formatter.set_spacing(spacing)
Set the spacing style for the writer.
```

```python
formatter.assert_line_data(flag=1)
Inform the formatter that data has been added to the current paragraph out-of-band. This should be used when the writer has been manipulated directly. The optional `flag` argument can be set to false if the writer manipulations produced a hard line break at the end of the output.
```
33.1.2. Formatter Implementations

Two implementations of formatter objects are provided by this module. Most applications may use one of these classes without modification or subclassing.

```python
class formatter.NullFormatter(writer=None)
    A formatter which does nothing. If writer is omitted, a NullWriter instance is created. No methods of the writer are called by NullFormatter instances. Implementations should inherit from this class if implementing a writer interface but don't need to inherit any implementation.
```

```python
class formatter(AbstractFormatter(writer)
    The standard formatter. This implementation has demonstrated wide applicability to many writers, and may be used directly in most circumstances. It has been used to implement a full-featured World Wide Web browser.
```
33.1.3. The Writer Interface

Interfaces to create writers are dependent on the specific writer class being instantiated. The interfaces described below are the required interfaces which all writers must support once initialized. Note that while most applications can use the AbstractFormatter class as a formatter, the writer must typically be provided by the application.

writer.flush()
Flush any buffered output or device control events.

writer.new_alignment(align)
Set the alignment style. The align value can be any object, but by convention is a string or None, where None indicates that the writer’s “preferred” alignment should be used. Conventional align values are 'left', 'center', 'right', and 'justify'.

writer.new_font(font)
Set the font style. The value of font will be None, indicating that the device’s default font should be used, or a tuple of the form (size, italic, bold, teletype). Size will be a string indicating the size of font that should be used; specific strings and their interpretation must be defined by the application. The italic, bold, and teletype values are Boolean values specifying which of those font attributes should be used.

writer.new_margin(margin, level)
Set the margin level to the integer level and the logical tag to margin. Interpretation of the logical tag is at the writer’s discretion; the only restriction on the value of the logical tag is that it not be a false value for non-zero values of level.
writer.new_spacing(spacing)
    Set the spacing style to spacing.

writer.new_styles(styles)
    Set additional styles. The styles value is a tuple of arbitrary values; the value AS_IS should be ignored. The styles tuple may be interpreted either as a set or as a stack depending on the requirements of the application and writer implementation.

writer.send_line_break()
    Break the current line.

writer.send_paragraph(blankline)
    Produce a paragraph separation of at least blankline blank lines, or the equivalent. The blankline value will be an integer. Note that the implementation will receive a call to send_line_break() before this call if a line break is needed; this method should not include ending the last line of the paragraph. It is only responsible for vertical spacing between paragraphs.

writer.send_hor_rule(*args, **kw)
    Display a horizontal rule on the output device. The arguments to this method are entirely application- and writer-specific, and should be interpreted with care. The method implementation may assume that a line break has already been issued via send_line_break().

writer.send_flowing_data(data)
    Output character data which may be word-wrapped and re-flowed as needed. Within any sequence of calls to this method, the writer may assume that spans of multiple whitespace characters have been collapsed to single space characters.
**writer.send_literal_data(data)**

Output character data which has already been formatted for display. Generally, this should be interpreted to mean that line breaks indicated by newline characters should be preserved and no new line breaks should be introduced. The data may contain embedded newline and tab characters, unlike data provided to the send_formatted_data() interface.

**writer.send_label_data(data)**

Set data to the left of the current left margin, if possible. The value of data is not restricted; treatment of non-string values is entirely application- and writer-dependent. This method will only be called at the beginning of a line.
33.1.4. Writer Implementations

Three implementations of the writer object interface are provided as examples by this module. Most applications will need to derive new writer classes from the NullWriter class.

class formatter.NullWriter
    A writer which only provides the interface definition; no actions are taken on any methods. This should be the base class for all writers which do not need to inherit any implementation methods.

class formatter.AbstractWriter
    A writer which can be used in debugging formatters, but not much else. Each method simply announces itself by printing its name and arguments on standard output.

class formatter.DumbWriter(file=None, maxcol=72)
    Simple writer class which writes output on the file object passed in as file or, if file is omitted, on standard output. The output is simply word-wrapped to the number of columns specified by maxcol. This class is suitable for reflowing a sequence of paragraphs.
34. MS Windows Specific Services

This chapter describes modules that are only available on MS Windows platforms.

- **34.1. msilib** — Read and write Microsoft Installer files
  - 34.1.1. Database Objects
  - 34.1.2. View Objects
  - 34.1.3. Summary Information Objects
  - 34.1.4. Record Objects
  - 34.1.5. Errors
  - 34.1.6. CAB Objects
  - 34.1.7. Directory Objects
  - 34.1.8. Features
  - 34.1.9. GUI classes
  - 34.1.10. Precomputed tables

- **34.2. msvcr** — Useful routines from the MS VC++ runtime
  - 34.2.1. File Operations
  - 34.2.2. Console I/O
  - 34.2.3. Other Functions

- **34.3. winreg** — Windows registry access
  - 34.3.1. Functions
  - 34.3.2. Constants
    - 34.3.2.1. HKEY_* Constants
    - 34.3.2.2. Access Rights
      - 34.3.2.2.1. 64-bit Specific
    - 34.3.2.3. Value Types
  - 34.3.3. Registry Handle Objects

- **34.4. winsound** — Sound-playing interface for Windows
34.1. *msilib* — Read and write Microsoft Installer files

The *msilib* supports the creation of Microsoft Installer (.msi) files. Because these files often contain an embedded “cabinet” file (.cab), it also exposes an API to create CAB files. Support for reading .cab files is currently not implemented; read support for the .msi database is possible.

This package aims to provide complete access to all tables in an .msi file, therefore, it is a fairly low-level API. Two primary applications of this package are the *distutils* command *bdist_msi*, and the creation of Python installer package itself (although that currently uses a different version of *msilib*).

The package contents can be roughly split into four parts: low-level CAB routines, low-level MSI routines, higher-level MSI routines, and standard table structures.

**msilib.FCICreate(cabname, files)**

Create a new CAB file named *cabname*. *files* must be a list of tuples, each containing the name of the file on disk, and the name of the file inside the CAB file.

The files are added to the CAB file in the order they appear in the list. All files are added into a single CAB file, using the MSZIP compression algorithm.

Callbacks to Python for the various steps of MSI creation are currently not exposed.
msilib.UuidCreate()

Return the string representation of a new unique identifier. This wraps the Windows API functions UuidCreate() and UuidToString().

msilib.OpenDatabase(path, persist)

Return a new database object by calling MsiOpenDatabase. path is the file name of the MSI file; persist can be one of the constants MSIDBOPEN_CREATEDIRECT, MSIDBOPEN_CREATE, MSIDBOPEN_DIRECT, MSIDBOPEN_READONLY, or MSIDBOPEN_TRANSACT, and may include the flag MSIDBOPEN_PATCHFILE. See the Microsoft documentation for the meaning of these flags; depending on the flags, an existing database is opened, or a new one created.

msilib.CreateRecord(count)

Return a new record object by calling MSICreateRecord(). count is the number of fields of the record.

msilib.init_database(name, schema, ProductName, ProductCode, ProductVersion, Manufacturer)

Create and return a new database name, initialize it with schema, and set the properties ProductName, ProductCode, ProductVersion, and Manufacturer.

schema must be a module object containing tables and _Validation_records attributes; typically, msilib.schema should be used.

The database will contain just the schema and the validation records when this function returns.
msilib.add_data(database, table, records)
Add all records to the table named table in database.

The table argument must be one of the predefined tables in the MSI schema, e.g. 'Feature', 'File', 'Component', 'Dialog', 'Control', etc.

records should be a list of tuples, each one containing all fields of a record according to the schema of the table. For optional fields, None can be passed.

Field values can be ints, strings, or instances of the Binary class.

class msilib.Binary(filename)
 Represents entries in the Binary table; inserting such an object using add_data() reads the file named filename into the table.

msilib.add_tables(database, module)
Add all table content from module to database. module must contain an attribute tables listing all tables for which content should be added, and one attribute per table that has the actual content.

This is typically used to install the sequence tables.

msilib.add_stream(database, name, path)
Add the file path into the _Stream table of database, with the stream name name.

msilib.gen_uuid()
Return a new UUID, in the format that MSI typically requires (i.e. in curly braces, and with all hexdigits in upper-case).

See also: FCICreateFile UuidCreate UuidToString
34.1.1. Database Objects

Database.**OpenView**(sql)

Return a view object, by calling MSIDatabaseOpenView(). *sql* is the SQL statement to execute.

Database.**Commit**()

Commit the changes pending in the current transaction, by calling MSIDatabaseCommit().

Database.**GetSummaryInformation**(count)

Return a new summary information object, by calling MsiGetSummaryInformation(). *count* is the maximum number of updated values.

**See also:** MSIDatabaseOpenView MSIDatabaseCommit MsiGetSummaryInformation
34.1.2. View Objects

View.**Execute**(params)
Execute the SQL query of the view, through MSIViewExecute(). If *params* is not None, it is a record describing actual values of the parameter tokens in the query.

View.**GetColumnInfo**(kind)
Return a record describing the columns of the view, through calling MsiViewGetColumnInfo(). *kind* can be either MSICOLINFO_NAMES or MSICOLINFO_TYPES.

View.**Fetch**()
Return a result record of the query, through calling MsiViewFetch().

View.**Modify**(kind, data)
Modify the view, by calling MsiViewModify(). *kind* can be one of MSIMODIFY_SEEK, MSIMODIFY_REFRESH, MSIMODIFY_INSERT, MSIMODIFY_UPDATE, MSIMODIFY_ASSIGN, MSIMODIFY_REPLACE, MSIMODIFY_MERGE, MSIMODIFY_DELETE, MSIMODIFY_INSERT_TEMPORARY, MSIMODIFY_VALIDATE, MSIMODIFY_VALIDATE_NEW, MSIMODIFY_VALIDATE_FIELD, or MSIMODIFY_VALIDATE_DELETE.

*data* must be a record describing the new data.

View.**Close**()
Close the view, through MsiViewClose().
See also:  MsiViewExecute MSIViewGetColumnInfo MsiViewFetch MsiViewModify MsiViewClose
34.1.3. Summary Information Objects

SummaryInformation.GetProperty(field)

Return a property of the summary, through MsiSummaryInfoGetProperty(). field is the name of the property, and can be one of the constants PID_CODEPAGE, PID_TITLE, PID_SUBJECT, PID_AUTHOR, PID_KEYWORDS, PID_COMMENTS, PID_TEMPLATE, PID_LASTAUTHOR, PID_REVNNUMBER, PID_LASTPRINTED, PID_CREATE_DTM, PID_LASTSAVE_DTM, PID_PAGECOUNT, PID_WORDCOUNT, PID_CHARCOUNT, PID_APPNAME, or PID_SECURITY.

SummaryInformation.GetPropertyCount()

Return the number of summary properties, through MsiSummaryInfoGetPropertyCount().

SummaryInformation.SetProperty(field, value)

Set a property through MsiSummaryInfoSetProperty(). field can have the same values as in GetProperty(), value is the new value of the property. Possible value types are integer and string.

SummaryInformation.Persistent()

Write the modified properties to the summary information stream, using MsiSummaryInfoPersist().

See also: MsiSummaryInfoGetProperty
MsiSummaryInfoGetPropertyCount MsiSummaryInfoSetProperty
MsiSummaryInfoPersist
34.1.4. Record Objects

Record.\texttt{GetFieldCount}()
Return the number of fields of the record, through MsiRecordGetFieldCount().

Record.\texttt{GetInteger}(field)
Return the value of \texttt{field} as an integer where possible. \texttt{field} must be an integer.

Record.\texttt{GetString}(field)
Return the value of \texttt{field} as a string where possible. \texttt{field} must be an integer.

Record.\texttt{SetString}(field, value)
Set \texttt{field} to \texttt{value} through MsiRecordSetString(). \texttt{field} must be an integer; \texttt{value} a string.

Record.\texttt{SetStream}(field, value)
Set \texttt{field} to the contents of the file named \texttt{value}, through MsiRecordSetStream(). \texttt{field} must be an integer; \texttt{value} a string.

Record.\texttt{SetInteger}(field, value)
Set \texttt{field} to \texttt{value} through MsiRecordSetInteger(). Both \texttt{field} and \texttt{value} must be an integer.

Record.\texttt{ClearData}()
Set all fields of the record to 0, through MsiRecordClearData().

\textbf{See also: } MsiRecordGetFieldCount MsiRecordSetString MsiRecordSetStream MsiRecordSetInteger MsiRecordClear
34.1.5. Errors

All wrappers around MSI functions raise MsiError; the string inside the exception will contain more detail.
34.1.6. CAB Objects

class msilib.CAB(name)

The class CAB represents a CAB file. During MSI construction, files will be added simultaneously to the Files table, and to a CAB file. Then, when all files have been added, the CAB file can be written, then added to the MSI file.

name is the name of the CAB file in the MSI file.

append(full, file, logical)

Add the file with the pathname full to the CAB file, under the name logical. If there is already a file named logical, a new file name is created.

Return the index of the file in the CAB file, and the new name of the file inside the CAB file.

commit(database)

Generate a CAB file, add it as a stream to the MSI file, put it into the Media table, and remove the generated file from the disk.
34.1.7. Directory Objects

class msilib.Directory(database, cab, basedir, physical, logical, default[, componentflags])

Create a new directory in the Directory table. There is a current component at each point in time for the directory, which is either explicitly created through start_component(), or implicitly when files are added for the first time. Files are added into the current component, and into the cab file. To create a directory, a base directory object needs to be specified (can be None), the path to the physical directory, and a logical directory name. default specifies the DefaultDir slot in the directory table. componentflags specifies the default flags that new components get.

start_component(component=None, feature=None, flags=None, keyfile=None, uuid=None)

Add an entry to the Component table, and make this component the current component for this directory. If no component name is given, the directory name is used. If no feature is given, the current feature is used. If no flags are given, the directory’s default flags are used. If no keyfile is given, the KeyPath is left null in the Component table.

add_file(file, src=None, version=None, language=None)

Add a file to the current component of the directory, starting a new one if there is no current component. By default, the file name in the source and the file table will be identical. If the src file is specified, it is interpreted relative to the current directory. Optionally, a version and a language can be specified for the entry in the File table.
**glob**(pattern, exclude=None)

Add a list of files to the current component as specified in the glob pattern. Individual files can be excluded in the exclude list.

**remove_pyc()**

Remove .pyc/.pyo files on uninstall.

**See also:** Directory Table File Table Component Table FeatureComponents Table
34.1.8. Features

```python
class msilib.Feature(db, id, title, desc, display, level=1, 
parent=None, directory= None, attributes=0)
```

Add a new record to the Feature table, using the values `id`, 
`parent.id`, `title`, `desc`, `display`, `level`, `directory`, and `attributes`. The 
resulting feature object can be passed to the 
`start_component()` method of `Directory`.

**set_current()**

Make this feature the current feature of `msilib`. New 
components are automatically added to the default feature, 
unless a feature is explicitly specified.

**See also:** Feature Table
msilib provides several classes that wrap the GUI tables in an MSI database. However, no standard user interface is provided; use bdist_msi to create MSI files with a user-interface for installing Python packages.

```python
class msilib.Control(dlg, name)
    Base class of the dialog controls. `dlg` is the dialog object the control belongs to, and `name` is the control's name.

    event(event, argument, condition=1, ordering=None)
        Make an entry into the ControlEvent table for this control.

    mapping(event, attribute)
        Make an entry into the EventMapping table for this control.

    condition(action, condition)
        Make an entry into the ControlCondition table for this control.
```

```python
class msilib.RadioButtonGroup(dlg, name, property)
    Create a radio button control named `name`. `property` is the installer property that gets set when a radio button is selected.

    add(name, x, y, width, height, text, value=None)
        Add a radio button named `name` to the group, at the coordinates `x, y, width, height`, and with the label `text`. If `value` is None, it defaults to `name`.
```

```python
class msilib.Dialog(db, name, x, y, w, h, attr, title, first, default, cancel)
```
Return a new Dialog object. An entry in the Dialog table is made, with the specified coordinates, dialog attributes, title, name of the first, default, and cancel controls.

control\(\text{name}, \text{type}, x, y, width, height, attributes, property, text, control\_next, help\)

Return a new Control object. An entry in the Control table is made with the specified parameters.

This is a generic method; for specific types, specialized methods are provided.

text\(\text{name}, x, y, width, height, attributes, text\)

Add and return a Text control.

bitmap\(\text{name}, x, y, width, height, text\)

Add and return a Bitmap control.

line\(\text{name}, x, y, width, height\)

Add and return a Line control.

pushbutton\(\text{name}, x, y, width, height, attributes, text, next\_control\)

Add and return a PushButton control.

radiogroup\(\text{name}, x, y, width, height, attributes, property, text, next\_control\)

Add and return a RadioButtonGroup control.

checkbox\(\text{name}, x, y, width, height, attributes, property, text, next\_control\)

Add and return a CheckBox control.
See also: Dialog Table Control Table Control Types
ControlCondition Table ControlEvent Table EventMapping Table
RadioButton Table
34.1.10. Precomputed tables

`msilib` provides a few subpackages that contain only schema and table definitions. Currently, these definitions are based on MSI version 2.0.

`msilib.schema`

This is the standard MSI schema for MSI 2.0, with the `tables` variable providing a list of table definitions, and `_Validation_records` providing the data for MSI validation.

`msilib.sequence`

This module contains table contents for the standard sequence tables: `AdminExecuteSequence`, `AdminUISequence`, `AdvtExecuteSequence`, `InstallExecuteSequence`, and `InstallUISequence`.

`msilib.text`

This module contains definitions for the UIText and ActionText tables, for the standard installer actions.
34.2. msvcr1 – Useful routines from the MS VC++ runtime

These functions provide access to some useful capabilities on Windows platforms. Some higher-level modules use these functions to build the Windows implementations of their services. For example, the getpass module uses this in the implementation of the getpass() function.

Further documentation on these functions can be found in the Platform API documentation.

The module implements both the normal and wide char variants of the console I/O api. The normal API deals only with ASCII characters and is of limited use for internationalized applications. The wide char API should be used wherever possible.

*Changed in version 3.3:* Operations in this module now raise OSError where IOError was raised.
34.2.1. File Operations

**`msvcrtd.locking(fd, mode, nbytes)`**

Lock part of a file based on file descriptor `fd` from the C runtime. Raises `OSError` on failure. The locked region of the file extends from the current file position for `nbytes` bytes, and may continue beyond the end of the file. `mode` must be one of the `LK_*` constants listed below. Multiple regions in a file may be locked at the same time, but may not overlap. Adjacent regions are not merged; they must be unlocked individually.

**`msvcrtd.LK_LOCK`**

**`msvcrtd.LK_RLCK`**

Locks the specified bytes. If the bytes cannot be locked, the program immediately tries again after 1 second. If, after 10 attempts, the bytes cannot be locked, `OSError` is raised.

**`msvcrtd.LK_NBLCK`**

**`msvcrtd.LK_NBRLCK`**

Locks the specified bytes. If the bytes cannot be locked, `OSError` is raised.

**`msvcrtd.LK_UNLCK`**

Unlocks the specified bytes, which must have been previously locked.

**`msvcrtd.setmode(fd, flags)`**

Set the line-end translation mode for the file descriptor `fd`. To set it to text mode, `flags` should be `os.O_TEXT`; for binary, it should be `os.O_BINARY`. 
msvcrt.\texttt{open\_osfhandle}(\textit{handle}, \textit{flags})

Create a C runtime file descriptor from the file handle \textit{handle}. The \textit{flags} parameter should be a bitwise OR of \texttt{os.0\_APPEND}, \texttt{os.0\_RDONLY}, and \texttt{os.0\_TEXT}. The returned file descriptor may be used as a parameter to \texttt{os.fdopen()} to create a file object.

msvcrt.\texttt{get\_osfhandle}(\textit{fd})

Return the file handle for the file descriptor \textit{fd}. Raises \texttt{OSError} if \textit{fd} is not recognized.
34.2.2. Console I/O

**msvcrth.kbhit()**
Return true if a keypress is waiting to be read.

**msvcrth.getch()**
Read a keypress and return the resulting character as a byte string. Nothing is echoed to the console. This call will block if a keypress is not already available, but will not wait for Enter to be pressed. If the pressed key was a special function key, this will return '\000' or '\xe0'; the next call will return the keycode. The Control-C keypress cannot be read with this function.

**msvcrth.getwch()**
Wide char variant of **getch()**, returning a Unicode value.

**msvcrth.getche()**
Similar to **getch()**, but the keypress will be echoed if it represents a printable character.

**msvcrth.getwche()**
Wide char variant of **getche()**, returning a Unicode value.

**msvcrth.putch(char)**
Print the byte string **char** to the console without buffering.

**msvcrth.putwch(unicode_char)**
Wide char variant of **putch()**, accepting a Unicode value.

**msvcrth.ungetchar(char)**
Cause the byte string **char** to be “pushed back” into the console
buffer; it will be the next character read by \texttt{getch()} or \texttt{getche()}.

\texttt{msvcrt.ungetwch(unicode\_char)}

Wide char variant of \texttt{ungetch()}, accepting a Unicode value.
34.2.3. Other Functions

**msvcrt.heapmin()**

Force the malloc() heap to clean itself up and return unused blocks to the operating system. On failure, this raises **OSError**.
34.3. **winreg** – Windows registry access

These functions expose the Windows registry API to Python. Instead of using an integer as the registry handle, a handle object is used to ensure that the handles are closed correctly, even if the programmer neglects to explicitly close them.

*Changed in version 3.3:* Several functions in this module used to raise a `WindowsError`, which is now an alias of `OSError`.
34.3.1. Functions

This module offers the following functions:

**winreg.CloseKey(hkey)**

Closes a previously opened registry key. The *hkey* argument specifies a previously opened key.

*Note:* If *hkey* is not closed using this method (or via *hkey.Close()*), it is closed when the *hkey* object is destroyed by Python.

**winreg.ConnectRegistry(computer_name, key)**

Establishes a connection to a predefined registry handle on another computer, and returns a *handle object*.

*computer_name* is the name of the remote computer, of the form *r"\\computername"*. If *None*, the local computer is used.

*key* is the predefined handle to connect to.

The return value is the handle of the opened key. If the function fails, an *OSError* exception is raised.

*Changed in version 3.3:* See *above*.

**winreg.CreateKey(key, sub_key)**

Creates or opens the specified key, returning a *handle object*.

*key* is an already open key, or one of the predefined *HKEY_* constants.
sub_key is a string that names the key this method opens or creates.

If key is one of the predefined keys, sub_key may be None. In that case, the handle returned is the same key handle passed in to the function.

If the key already exists, this function opens the existing key.

The return value is the handle of the opened key. If the function fails, an OSError exception is raised.

*Changed in version 3.3:* See above.

winreg.CreateKeyEx(key, sub_key, reserved=0, access=KEY_WRITE)

Creates or opens the specified key, returning a handle object.

key is an already open key, or one of the predefined HKEY_* constants.

sub_key is a string that names the key this method opens or creates.

reserved is a reserved integer, and must be zero. The default is zero.

access is an integer that specifies an access mask that describes the desired security access for the key. Default is KEY_WRITE. See Access Rights for other allowed values.

If key is one of the predefined keys, sub_key may be None. In that case, the handle returned is the same key handle passed in to the function.
If the key already exists, this function opens the existing key.

The return value is the handle of the opened key. If the function fails, an OSError exception is raised.

*New in version 3.2.*

*Changed in version 3.3:* See above.

```
winreg.DeleteKey(key, sub_key)
```

Deletes the specified key.

`key` is an already open key, or one of the predefined HKEY_* constants.

`sub_key` is a string that must be a subkey of the key identified by the `key` parameter. This value must not be None, and the key may not have subkeys.

*This method can not delete keys with subkeys.*

If the method succeeds, the entire key, including all of its values, is removed. If the method fails, an OSError exception is raised.

*Changed in version 3.3:* See above.

```
winreg.DeleteKeyEx(key, sub_key, access=KEY_WOW64_64KEY, reserved=0)
```

Deletes the specified key.

**Note:** The `DeleteKeyEx()` function is implemented with the RegDeleteKeyEx Windows API function, which is specific to 64-bit versions of Windows. See the RegDeleteKeyEx documentation.
key is an already open key, or one of the predefined HKEY_* constants.

sub_key is a string that must be a subkey of the key identified by the key parameter. This value must not be None, and the key may not have subkeys.

reserved is a reserved integer, and must be zero. The default is zero.

access is an integer that specifies an access mask that describes the desired security access for the key. Default is KEY_WOW64_64KEY. See Access Rights for other allowed values.

This method can not delete keys with subkeys.

If the method succeeds, the entire key, including all of its values, is removed. If the method fails, an OSError exception is raised.

On unsupported Windows versions, NotImplemented exception is raised.

New in version 3.2.

Changed in version 3.3: See above.

**winreg.DeleteValue**(key, value)

Removes a named value from a registry key.

key is an already open key, or one of the predefined HKEY_* constants.

value is a string that identifies the value to remove.

**winreg.EnumKey**(key, index)
Enumerates subkeys of an open registry key, returning a string.

`key` is an already open key, or one of the predefined `HKEY_*` constants.

`index` is an integer that identifies the index of the key to retrieve.

The function retrieves the name of one subkey each time it is called. It is typically called repeatedly until an `OSError` exception is raised, indicating, no more values are available.

*Changed in version 3.3:* See above.

`winreg.EnumValue(key, index)`

Enumerates values of an open registry key, returning a tuple.

`key` is an already open key, or one of the predefined `HKEY_*` constants.

`index` is an integer that identifies the index of the value to retrieve.

The function retrieves the name of one subkey each time it is called. It is typically called repeatedly, until an `OSError` exception is raised, indicating no more values.

The result is a tuple of 3 items:

<table>
<thead>
<tr>
<th>Index</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>A string that identifies the value name</td>
</tr>
<tr>
<td>1</td>
<td>An object that holds the value data, and whose type depends on the underlying registry type</td>
</tr>
<tr>
<td>2</td>
<td>An integer that identifies the type of the value data (see table in docs for <code>SetValueEx()</code></td>
</tr>
</tbody>
</table>
Changed in version 3.3: See above.

**winreg.\texttt{ExpandEnvironmentStrings}(str)**

Expands environment variable placeholders %NAME% in strings like \texttt{REG\_EXPAND\_SZ}:

```python
>>> ExpandEnvironmentStrings('%%%windir%\')
'C:\\Windows'
```

**winreg.\texttt{FlushKey}(key)**

Writes all the attributes of a key to the registry.

\textit{key} is an already open key, or one of the predefined \texttt{HKEY\_*} constants.

It is not necessary to call \texttt{FlushKey()} to change a key. Registry changes are flushed to disk by the registry using its lazy flusher. Registry changes are also flushed to disk at system shutdown. Unlike \texttt{CloseKey()}, the \texttt{FlushKey()} method returns only when all the data has been written to the registry. An application should only call \texttt{FlushKey()} if it requires absolute certainty that registry changes are on disk.

\textbf{Note:} If you don’t know whether a \texttt{FlushKey()} call is required, it probably isn’t.

**winreg.\texttt{LoadKey}(key, sub_key, file_name)**

Creates a subkey under the specified key and stores registration information from a specified file into that subkey.

\textit{key} is a handle returned by \texttt{ConnectRegistry()} or one of the constants \texttt{HKEY\_USERS} or \texttt{HKEY\_LOCAL\_MACHINE}.
**sub_key** is a string that identifies the subkey to load.

*file_name* is the name of the file to load registry data from. This file must have been created with the `SaveKey()` function. Under the file allocation table (FAT) file system, the filename may not have an extension.

A call to `LoadKey()` fails if the calling process does not have the **SE_RESTORE_PRIVILEGE** privilege. Note that privileges are different from permissions – see the RegLoadKey documentation for more details.

If *key* is a handle returned by `ConnectRegistry()`, then the path specified in *file_name* is relative to the remote computer.

```python
winreg.OpenKey(key, sub_key, reserved=0, access=KEY_READ)
winreg.OpenKeyEx(key, sub_key, reserved=0, access=KEY_READ)
```

Opens the specified key, returning a handle object.

*key* is an already open key, or one of the predefined **HKEY_* constants**.

*sub_key* is a string that identifies the sub_key to open.

*reserved* is a reserved integer, and must be zero. The default is zero.

*access* is an integer that specifies an access mask that describes the desired security access for the key. Default is **KEY_READ**. See **Access Rights** for other allowed values.

The result is a new handle to the specified key.
If the function fails, `OSError` is raised.

*Changed in version 3.2:* Allow the use of named arguments.

*Changed in version 3.3:* See above.

**winreg.**`QueryInfoKey(key)`

Returns information about a key, as a tuple.

`key` is an already open key, or one of the predefined HKEY_* constants.

The result is a tuple of 3 items:

<table>
<thead>
<tr>
<th>Index</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>An integer giving the number of sub keys this key has.</td>
</tr>
<tr>
<td>1</td>
<td>An integer giving the number of values this key has.</td>
</tr>
<tr>
<td>2</td>
<td>An integer giving when the key was last modified (if available) as 100’s of nanoseconds since Jan 1, 1601.</td>
</tr>
</tbody>
</table>

**winreg.**`QueryValue(key, sub_key)`

Retrieves the unnamed value for a key, as a string.

`key` is an already open key, or one of the predefined HKEY_* constants.

`sub_key` is a string that holds the name of the subkey with which the value is associated. If this parameter is None or empty, the function retrieves the value set by the `SetValue()` method for the key identified by `key`.

Values in the registry have name, type, and data components. This method retrieves the data for a key's first value that has a NULL
name. But the underlying API call doesn’t return the type, so always use `QueryValueEx()` if possible.

```python
winreg.QueryValueEx(key, value_name)
```

Retrieves the type and data for a specified value name associated with an open registry key.

- `key` is an already open key, or one of the predefined `HKEY_*` constants.
- `value_name` is a string indicating the value to query.

The result is a tuple of 2 items:

<table>
<thead>
<tr>
<th>Index</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>The value of the registry item.</td>
</tr>
<tr>
<td>1</td>
<td>An integer giving the registry type for this value (see table in docs for <code>SetValueEx()</code>).</td>
</tr>
</tbody>
</table>

```python
winreg.SaveKey(key, file_name)
```

Saves the specified key, and all its subkeys to the specified file.

- `key` is an already open key, or one of the predefined `HKEY_*` constants.
- `file_name` is the name of the file to save registry data to. This file cannot already exist. If this filename includes an extension, it cannot be used on file allocation table (FAT) file systems by the `LoadKey()` method.

If `key` represents a key on a remote computer, the path described by `file_name` is relative to the remote computer. The caller of this method must possess the `SeBackupPrivilege` security...
privilege. Note that privileges are different than permissions – see the Conflicts Between User Rights and Permissions documentation for more details.

This function passes NULL for security_attributes to the API.

```cpp
call winreg.SetValue(key, sub_key, type, value)
```
Associates a value with a specified key.

- **key** is an already open key, or one of the predefined HKEY_* constants.
- **sub_key** is a string that names the subkey with which the value is associated.
- **type** is an integer that specifies the type of the data. Currently this must be REG_SZ, meaning only strings are supported. Use the SetValueEx() function for support for other data types.
- **value** is a string that specifies the new value.

If the key specified by the **sub_key** parameter does not exist, the SetValue function creates it.

Value lengths are limited by available memory. Long values (more than 2048 bytes) should be stored as files with the filenames stored in the configuration registry. This helps the registry perform efficiently.

The key identified by the **key** parameter must have been opened with KEY_SET_VALUE access.

```cpp
call winreg.SetValueEx(key, value_name, reserved, type, value)
```
Stores data in the value field of an open registry key.
**key** is an already open key, or one of the predefined **HKEY_* constants**.

**value_name** is a string that names the subkey with which the value is associated.

**reserved** can be anything – zero is always passed to the API.

**type** is an integer that specifies the type of the data. See **Value Types** for the available types.

**value** is a string that specifies the new value.

This method can also set additional value and type information for the specified key. The key identified by the key parameter must have been opened with **KEY_SET_VALUE** access.

To open the key, use the **CreateKey()** or **OpenKey()** methods.

Value lengths are limited by available memory. Long values (more than 2048 bytes) should be stored as files with the filenames stored in the configuration registry. This helps the registry perform efficiently.

**winreg.DisableReflectionKey(key)**

Disables registry reflection for 32-bit processes running on a 64-bit operating system.

**key** is an already open key, or one of the predefined **HKEY_* constants**.

Will generally raise **NotImplemented** if executed on a 32-bit operating system.
If the key is not on the reflection list, the function succeeds but has no effect. Disabling reflection for a key does not affect reflection of any subkeys.

`winreg.EnableReflectionKey(key)`
Restores registry reflection for the specified disabled key.

`key` is an already open key, or one of the predefined `HKEY_*` constants.

Will generally raise `NotImplemented` if executed on a 32-bit operating system.

Restoring reflection for a key does not affect reflection of any subkeys.

`winreg.QueryReflectionKey(key)`
Determines the reflection state for the specified key.

`key` is an already open key, or one of the predefined `HKEY_*` constants.

Returns True if reflection is disabled.

Will generally raise `NotImplemented` if executed on a 32-bit operating system.
34.3.2. Constants

The following constants are defined for use in many _winreg functions.

34.3.2.1. HKEY_* Constants

winreg.HKEY_CLASSES_ROOT

Registry entries subordinate to this key define types (or classes) of documents and the properties associated with those types. Shell and COM applications use the information stored under this key.

winreg.HKEY_CURRENT_USER

Registry entries subordinate to this key define the preferences of the current user. These preferences include the settings of environment variables, data about program groups, colors, printers, network connections, and application preferences.

winreg.HKEY_LOCAL_MACHINE

Registry entries subordinate to this key define the physical state of the computer, including data about the bus type, system memory, and installed hardware and software.

winreg.HKEY_USERS

Registry entries subordinate to this key define the default user configuration for new users on the local computer and the user configuration for the current user.

winreg.HKEY_PERFORMANCE_DATA

Registry entries subordinate to this key allow you to access performance data. The data is not actually stored in the registry;
the registry functions cause the system to collect the data from its source.

**winreg.HKEY_CURRENT_CONFIG**
Contains information about the current hardware profile of the local computer system.

**winreg.HKEY_DYN_DATA**
This key is not used in versions of Windows after 98.

### 34.3.2.2. Access Rights

For more information, see *Registry Key Security and Access*.

**winreg.KEY_ALL_ACCESS**
Combines the **STANDARD_RIGHTS_REQUIRED**, **KEY_QUERY_VALUE**, **KEY_SET_VALUE**, **KEY_CREATE_SUB_KEY**, **KEY_ENUMERATE_SUB_KEYS**, **KEY_NOTIFY**, and **KEY_CREATE_LINK** access rights.

**winreg.KEY_WRITE**
Combines the **STANDARD_RIGHTS_WRITE**, **KEY_SET_VALUE**, and **KEY_CREATE_SUB_KEY** access rights.

**winreg.KEY_READ**
Combines the **STANDARD_RIGHTS_READ**, **KEY_QUERY_VALUE**, **KEY_ENUMERATE_SUB_KEYS**, and **KEY_NOTIFY** values.

**winreg.KEY_EXECUTE**
Equivalent to **KEY_READ**.

**winreg.KEY_QUERY_VALUE**
Required to query the values of a registry key.

\texttt{winreg.KEY\_SET\_VALUE}

Required to create, delete, or set a registry value.

\texttt{winreg.KEY\_CREATE\_SUB\_KEY}

Required to create a subkey of a registry key.

\texttt{winreg.KEY\_ENUMERATE\_SUB\_KEYS}

Required to enumerate the subkeys of a registry key.

\texttt{winreg.KEY\_NOTIFY}

Required to request change notifications for a registry key or for subkeys of a registry key.

\texttt{winreg.KEY\_CREATE\_LINK}

Reserved for system use.

34.3.2.2.1. 64-bit Specific

For more information, see Accessing an Alternate Registry View.

\texttt{winreg.KEY\_WOW64\_64KEY}

Indicates that an application on 64-bit Windows should operate on the 64-bit registry view.

\texttt{winreg.KEY\_WOW64\_32KEY}

Indicates that an application on 64-bit Windows should operate on the 32-bit registry view.

34.3.2.3. Value Types

For more information, see Registry Value Types.
**winreg.REG_BINARY**
Binary data in any form.

**winreg.REG_DWORD**
32-bit number.

**winreg.REG_DWORD_LITTLE_ENDIAN**
A 32-bit number in little-endian format.

**winreg.REG_DWORD_BIG_ENDIAN**
A 32-bit number in big-endian format.

**winreg.REG_EXPAND_SZ**
Null-terminated string containing references to environment variables (%PATH%).

**winreg.REG_LINK**
A Unicode symbolic link.

**winreg.REG_MULTI_SZ**
A sequence of null-terminated strings, terminated by two null characters. (Python handles this termination automatically.)

**winreg.REG_NONE**
No defined value type.

**winreg.REG_RESOURCE_LIST**
A device-driver resource list.

**winreg.REG_FULL_RESOURCE_DESCRIPTOR**
A hardware setting.

**winreg.REG_RESOURCE_REQUIREMENTS_LIST**
A hardware resource list.
winreg.\texttt{REG\_SZ}

A null-terminated string.
34.3.3. Registry Handle Objects

This object wraps a Windows HKEY object, automatically closing it when the object is destroyed. To guarantee cleanup, you can call either the `Close()` method on the object, or the `CloseKey()` function.

All registry functions in this module return one of these objects.

All registry functions in this module which accept a handle object also accept an integer, however, use of the handle object is encouraged.

Handle objects provide semantics for `__bool__()` – thus

```python
if handle:
    print("Yes")
```

will print Yes if the handle is currently valid (has not been closed or detached).

The object also support comparison semantics, so handle objects will compare true if they both reference the same underlying Windows handle value.

Handle objects can be converted to an integer (e.g., using the built-in `int()` function), in which case the underlying Windows handle value is returned. You can also use the `Detach()` method to return the integer handle, and also disconnect the Windows handle from the handle object.

```python
PyHKEY.Close()

Closes the underlying Windows handle.
```
If the handle is already closed, no error is raised.

**PyHKEY.Detach()**

Detaches the Windows handle from the handle object.

The result is an integer that holds the value of the handle before it is detached. If the handle is already detached or closed, this will return zero.

After calling this function, the handle is effectively invalidated, but the handle is not closed. You would call this function when you need the underlying Win32 handle to exist beyond the lifetime of the handle object.

**PyHKEY.__enter__()**
**PyHKEY.__exit__(*exc_info)**

The HKEY object implements __enter__() and __exit__() and thus supports the context protocol for the with statement:

```python
with OpenKey(HKEY_LOCAL_MACHINE, "foo") as key:
    ...
    # work with key
```

will automatically close key when control leaves the with block.
34.4. **winsound** — Sound-playing interface for Windows

The **winsound** module provides access to the basic sound-playing machinery provided by Windows platforms. It includes functions and several constants.

**winsound.**`Beep(frequency, duration)`

Beep the PC's speaker. The `frequency` parameter specifies frequency, in hertz, of the sound, and must be in the range 37 through 32,767. The `duration` parameter specifies the number of milliseconds the sound should last. If the system is not able to beep the speaker, `RuntimeError` is raised.

**winsound.**`PlaySound(sound, flags)`

Call the underlying `PlaySound()` function from the Platform API. The `sound` parameter may be a filename, audio data as a string, or `None`. Its interpretation depends on the value of `flags`, which can be a bitwise ORed combination of the constants described below. If the `sound` parameter is `None`, any currently playing waveform sound is stopped. If the system indicates an error, `RuntimeError` is raised.

**winsound.**`MessageBeep(type=MB_OK)`

Call the underlying `MessageBeep()` function from the Platform API. This plays a sound as specified in the registry. The `type` argument specifies which sound to play; possible values are `-1, MB_ICONASTERISK, MB_ICONEXCLAMATION, MB_ICONHAND, MB_ICONQUESTION`, and `MB_OK`, all described below. The value
-1 produces a “simple beep”; this is the final fallback if a sound cannot be played otherwise.

**winsound.SND_FILENAME**

The *sound* parameter is the name of a WAV file. Do not use with **SND_ALIAS**.

**winsound.SND_ALIAS**

The *sound* parameter is a sound association name from the registry. If the registry contains no such name, play the system default sound unless **SND_NODEFAULT** is also specified. If no default sound is registered, raise **RuntimeError**. Do not use with **SND_FILENAME**.

All Win32 systems support at least the following; most systems support many more:

<table>
<thead>
<tr>
<th>PlaySound() <em>name</em></th>
<th>Corresponding Control Panel Sound name</th>
</tr>
</thead>
<tbody>
<tr>
<td>'SystemAsterisk'</td>
<td>Asterisk</td>
</tr>
<tr>
<td>'SystemExclamation'</td>
<td>Exclamation</td>
</tr>
<tr>
<td>'SystemExit'</td>
<td>Exit Windows</td>
</tr>
<tr>
<td>'SystemHand'</td>
<td>Critical Stop</td>
</tr>
<tr>
<td>'SystemQuestion'</td>
<td>Question</td>
</tr>
</tbody>
</table>

For example:

```python
import winsound

# Play Windows exit sound.
winsound.PlaySound("SystemExit", winsound.SND_ALIAS)

# Probably play Windows default sound, if any is
```
winsound.**SND_LOOP**

Play the sound repeatedly. The **SND_ASYNC** flag must also be used to avoid blocking. Cannot be used with **SND_MEMORY**.

**winsound.** **SND_MEMORY**

The *sound* parameter to *PlaySound()* is a memory image of a WAV file, as a string.

**Note:** This module does not support playing from a memory image asynchronously, so a combination of this flag and **SND_ASYNC** will raise *RuntimeError*.

**winsound.** **SND_PURGE**

Stop playing all instances of the specified sound.

**Note:** This flag is not supported on modern Windows platforms.

**winsound.** **SND_ASYNC**

Return immediately, allowing sounds to play asynchronously.

**winsound.** **SND_NODEFAULT**

If the specified sound cannot be found, do not play the system default sound.

**winsound.** **SND_NOSTOP**

Do not interrupt sounds currently playing.

**winsound.** **SND_NOWAIT**

Return immediately if the sound driver is busy.
Note: This flag is not supported on modern Windows platforms.

winsound.\texttt{MB\_ICONASTERISK}
Play the SystemDefault sound.

winsound.\texttt{MB\_ICONEXCLAMATION}
Play the SystemExclamation sound.

winsound.\texttt{MB\_ICONHAND}
Play the SystemHand sound.

winsound.\texttt{MB\_ICONQUESTION}
Play the SystemQuestion sound.

winsound.\texttt{MB\_OK}
Play the SystemDefault sound.
35. Unix Specific Services

The modules described in this chapter provide interfaces to features that are unique to the Unix operating system, or in some cases to some or many variants of it. Here's an overview:

- **35.1. posix — The most common POSIX system calls**
  - 35.1.1. Large File Support
  - 35.1.2. Notable Module Contents
- **35.2. pwd — The password database**
- **35.3. spwd — The shadow password database**
- **35.4. grp — The group database**
- **35.5. crypt — Function to check Unix passwords**
  - 35.5.1. Hashing Methods
  - 35.5.2. Module Attributes
  - 35.5.3. Module Functions
  - 35.5.4. Examples
- **35.6. termios — POSIX style tty control**
  - 35.6.1. Example
- **35.7. tty — Terminal control functions**
- **35.8. pty — Pseudo-terminal utilities**
  - 35.8.1. Example
- **35.9. fcntl — The fcntl and ioctl system calls**
- **35.10. pipes — Interface to shell pipelines**
  - 35.10.1. Template Objects
- **35.11. resource — Resource usage information**
  - 35.11.1. Resource Limits
  - 35.11.2. Resource Usage
- **35.12. nis — Interface to Sun’s NIS (Yellow Pages)**
- **35.13. syslog — Unix syslog library routines**
  - 35.13.1. Examples
    - 35.13.1.1. Simple example
35.1. **posix** — The most common POSIX system calls

This module provides access to operating system functionality that is standardized by the C Standard and the POSIX standard (a thinly disguised Unix interface).

**Do not import this module directly.** Instead, import the module `os`, which provides a *portable* version of this interface. On Unix, the `os` module provides a superset of the `posix` interface. On non-Unix operating systems the `posix` module is not available, but a subset is always available through the `os` interface. Once `os` is imported, there is *no* performance penalty in using it instead of `posix`. In addition, `os` provides some additional functionality, such as automatically calling `putenv()` when an entry in `os.environ` is changed.

Errors are reported as exceptions; the usual exceptions are given for type errors, while errors reported by the system calls raise `OSError`. 
35.1.1. Large File Support

Several operating systems (including AIX, HP-UX, Irix and Solaris) provide support for files that are larger than 2 GiB from a C programming model where `int` and `long` are 32-bit values. This is typically accomplished by defining the relevant size and offset types as 64-bit values. Such files are sometimes referred to as *large files*.

Large file support is enabled in Python when the size of an `off_t` is larger than a `long` and the `long long` type is available and is at least as large as an `off_t`. It may be necessary to configure and compile Python with certain compiler flags to enable this mode. For example, it is enabled by default with recent versions of Irix, but with Solaris 2.6 and 2.7 you need to do something like:

```
CFLAGS="\`getconf LFS_CFLAGS`" OPT="-g -O2 $CFLAGS"
./configure
```

On large-file-capable Linux systems, this might work:

```
CFLAGS='\-D_LARGEFILE64_SOURCE \-D_FILE_Offset_BITS=64'
./configure
```
35.1.2. Notable Module Contents

In addition to many functions described in the `os` module documentation, `posix` defines the following data item:

`posix.environ`

A dictionary representing the string environment at the time the interpreter was started. Keys and values are bytes on Unix and `str` on Windows. For example, `environ[b'HOME']` (`environ['HOME']` on Windows) is the pathname of your home directory, equivalent to `getenv("HOME")` in C.

Modifying this dictionary does not affect the string environment passed on by `execv()`, `popen()` or `system()`; if you need to change the environment, pass `environ` to `execve()` or add variable assignments and export statements to the command string for `system()` or `popen()`.

*Changed in version 3.2:* On Unix, keys and values are bytes.

**Note:** The `os` module provides an alternate implementation of `environ` which updates the environment on modification. Note also that updating `os.environ` will render this dictionary obsolete. Use of the `os` module version of this is recommended over direct access to the `posix` module.
35.2. **pwd** — The password database

This module provides access to the Unix user account and password database. It is available on all Unix versions.

Password database entries are reported as a tuple-like object, whose attributes correspond to the members of the passwd structure (Attribute field below, see `<pwd.h>`):

<table>
<thead>
<tr>
<th>Index</th>
<th>Attribute</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>pw_name</td>
<td>Login name</td>
</tr>
<tr>
<td>1</td>
<td>pw_passwd</td>
<td>Optional encrypted password</td>
</tr>
<tr>
<td>2</td>
<td>pw_uid</td>
<td>Numerical user ID</td>
</tr>
<tr>
<td>3</td>
<td>pw_gid</td>
<td>Numerical group ID</td>
</tr>
<tr>
<td>4</td>
<td>pw_gecos</td>
<td>User name or comment field</td>
</tr>
<tr>
<td>5</td>
<td>pw_dir</td>
<td>User home directory</td>
</tr>
<tr>
<td>6</td>
<td>pw_shell</td>
<td>User command interpreter</td>
</tr>
</tbody>
</table>

The uid and gid items are integers, all others are strings. `KeyError` is raised if the entry asked for cannot be found.

**Note:** In traditional Unix the field `pw_passwd` usually contains a password encrypted with a DES derived algorithm (see module `crypt`). However most modern unices use a so-called *shadow password* system. On those unices the `pw_passwd` field only contains an asterisk (`'*'`) or the letter `'x'` where the encrypted password is stored in a file `/etc/shadow` which is not world
Whether the `pw_passwd` field contains anything useful is system-dependent. If available, the `pwd` module should be used where access to the encrypted password is required.

It defines the following items:

```python
pwd.getpwuid(uid)
```

Return the password database entry for the given numeric user ID.

```python
pwd.getpwnam(name)
```

Return the password database entry for the given user name.

```python
pwd.getpwall()
```

Return a list of all available password database entries, in arbitrary order.

**See also:**

- **Module grp**
  
  An interface to the group database, similar to this.

- **Module spwd**
  
  An interface to the shadow password database, similar to this.
35.3. **spwd** — The shadow password database

This module provides access to the Unix shadow password database. It is available on various Unix versions.

You must have enough privileges to access the shadow password database (this usually means you have to be root).

Shadow password database entries are reported as a tuple-like object, whose attributes correspond to the members of the spwd structure (Attribute field below, see `<shadow.h>`):

<table>
<thead>
<tr>
<th>Index</th>
<th>Attribute</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>sp_namp</td>
<td>Login name</td>
</tr>
<tr>
<td>1</td>
<td>sp_pwdp</td>
<td>Encrypted password</td>
</tr>
<tr>
<td>2</td>
<td>sp_lstchg</td>
<td>Date of last change</td>
</tr>
<tr>
<td>3</td>
<td>sp_min</td>
<td>Minimal number of days between changes</td>
</tr>
<tr>
<td>4</td>
<td>sp_max</td>
<td>Maximum number of days between changes</td>
</tr>
<tr>
<td>5</td>
<td>sp_warn</td>
<td>Number of days before password expires to warn user about it</td>
</tr>
<tr>
<td>6</td>
<td>sp_inact</td>
<td>Number of days after password expires until account is disabled</td>
</tr>
<tr>
<td>7</td>
<td>sp_expire</td>
<td>Number of days since 1970-01-01 when account expires</td>
</tr>
<tr>
<td>8</td>
<td>sp_flag</td>
<td>Reserved</td>
</tr>
</tbody>
</table>
The sp_namp and sp_pwdp items are strings, all others are integers. 
`KeyError` is raised if the entry asked for cannot be found.

The following functions are defined:

```python
spwd.getspnam(name)
```

Return the shadow password database entry for the given user name.

```python
spwd.getspall()
```

Return a list of all available shadow password database entries, in arbitrary order.

**See also:**

- **Module grp**
  An interface to the group database, similar to this.

- **Module pwd**
  An interface to the normal password database, similar to this.
35.4. `grp` — The group database

This module provides access to the Unix group database. It is available on all Unix versions.

Group database entries are reported as a tuple-like object, whose attributes correspond to the members of the group structure (Attribute field below, see `<pwd.h>`):

<table>
<thead>
<tr>
<th>Index</th>
<th>Attribute</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>gr_name</td>
<td>the name of the group</td>
</tr>
<tr>
<td>1</td>
<td>gr_passwd</td>
<td>the (encrypted) group password; often empty</td>
</tr>
<tr>
<td>2</td>
<td>gr_gid</td>
<td>the numerical group ID</td>
</tr>
<tr>
<td>3</td>
<td>gr_mem</td>
<td>all the group member’s user names</td>
</tr>
</tbody>
</table>

The gid is an integer, name and password are strings, and the member list is a list of strings. (Note that most users are not explicitly listed as members of the group they are in according to the password database. Check both databases to get complete membership information. Also note that a `gr_name` that starts with a + or - is likely to be a YP/NIS reference and may not be accessible via `getgrnam()` or `getgrgid()`.)

It defines the following items:

`grp.getgrgid(gid)`

Return the group database entry for the given numeric group ID. `KeyError` is raised if the entry asked for cannot be found.
** grp.getgrnam(name) **

Return the group database entry for the given group name.  
`KeyError` is raised if the entry asked for cannot be found.

** grp.getgrall() **

Return a list of all available group entries, in arbitrary order.

---

**See also:**

**Module** `pwd`

An interface to the user database, similar to this.

**Module** `spwd`

An interface to the shadow password database, similar to this.
35.5. **crypt** — Function to check Unix passwords

This module implements an interface to the `crypt(3)` routine, which is a one-way hash function based upon a modified DES algorithm; see the Unix man page for further details. Possible uses include storing hashed passwords so you can check passwords without storing the actual password, or attempting to crack Unix passwords with a dictionary.

Notice that the behavior of this module depends on the actual implementation of the `crypt(3)` routine in the running system. Therefore, any extensions available on the current implementation will also be available on this module.
35.5.1. Hashing Methods

New in version 3.3.

The `crypt` module defines the list of hashing methods (not all methods are available on all platforms):

`crypt.METHOD_SHA512`  
A Modular Crypt Format method with 16 character salt and 86 character hash. This is the strongest method.

`crypt.METHOD_SHA256`  
Another Modular Crypt Format method with 16 character salt and 43 character hash.

`crypt.METHOD_MD5`  
Another Modular Crypt Format method with 8 character salt and 22 character hash.

`crypt.METHOD_CRYPT`  
The traditional method with a 2 character salt and 13 characters of hash. This is the weakest method.
35.5.2. Module Attributes

*New in version 3.3.*

crypt.methods

A list of available password hashing algorithms, as crypt.METHOD_* objects. This list is sorted from strongest to weakest, and is guaranteed to have at least crypt.METHOD_CRYPT.
35.5.3. Module Functions

The `crypt` module defines the following functions:

```python
crypt.crypt(word, salt=None)
```

`word` will usually be a user’s password as typed at a prompt or in a graphical interface. The optional `salt` is either a string as returned from `mksalt()`, one of the `crypt.METHOD_` values (though not all may be available on all platforms), or a full encrypted password including salt, as returned by this function. If `salt` is not provided, the strongest method will be used (as returned by `methods()`).

Checking a password is usually done by passing the plain-text password as `word` and the full results of a previous `crypt()` call, which should be the same as the results of this call.

`salt` (either a random 2 or 16 character string, possibly prefixed with `$digit$` to indicate the method) which will be used to perturb the encryption algorithm. The characters in `salt` must be in the set `[./a-zA-Z0-9]`, with the exception of Modular Crypt Format which prefixes a `$digit$`.

Returns the hashed password as a string, which will be composed of characters from the same alphabet as the salt.

Since a few `crypt(3)` extensions allow different values, with different sizes in the `salt`, it is recommended to use the full crypted password as `salt` when checking for a password.

*Changed in version 3.3:* Accept `crypt.METHOD_` values in addition to strings for `salt`. 
crypt.mksalt(method=None)

Return a randomly generated salt of the specified method. If no method is given, the strongest method available as returned by methods() is used.

The return value is a string either of 2 characters in length for crypt.METHOD_CRYPT, or 19 characters starting with $digit$ and 16 random characters from the set [. /a-zA-Z0-9], suitable for passing as the salt argument to crypt().

New in version 3.3.
35.5.4. Examples

A simple example illustrating typical use (a constant-time comparison operation is needed to limit exposure to timing attacks. hmac.compare_digest() is suitable for this purpose):

```python
import pwd
import crypt
import getpass
from hmac import compare_digest as compare_hash

def login():
    username = input('Python login: ')
    cryptedpasswd = pwd.getpwnam(username)[1]
    if cryptedpasswd:
        if cryptedpasswd == 'x' or cryptedpasswd ==
            raise ValueError('no support for shadow
      cleartext = getpass.getpass()
    return compare_hash(crypt.crypt(cleartext, c
else:
    return True
```

To generate a hash of a password using the strongest available method and check it against the original:

```python
import crypt
from hmac import compare_digest as compare_hash

hashed = crypt.crypt(plaintext)
if not compare_hash(hashed, crypt.crypt(plaintext, h
    raise ValueError('hashed version doesn' t validate
```
35.6. **termios** — POSIX style tty control

This module provides an interface to the POSIX calls for tty I/O control. For a complete description of these calls, see the POSIX or Unix manual pages. It is only available for those Unix versions that support POSIX **termios** style tty I/O control (and then only if configured at installation time).

All functions in this module take a file descriptor *fd* as their first argument. This can be an integer file descriptor, such as returned by `sys.stdin.fileno()`, or a file object, such as `sys.stdin` itself.

This module also defines all the constants needed to work with the functions provided here; these have the same name as their counterparts in C. Please refer to your system documentation for more information on using these terminal control interfaces.

The module defines the following functions:

**termios**.tcgetattr(*fd*)

Return a list containing the tty attributes for file descriptor *fd*, as follows: `[iflag, oflag, cflag, lflag, ispeed, ospeed, cc]` where *cc* is a list of the tty special characters (each a string of length 1, except the items with indices VMIN and VTIME, which are integers when these fields are defined). The interpretation of the flags and the speeds as well as the indexing in the *cc* array must be done using the symbolic constants defined in the **termios** module.
termios.tcsetattr(fd, when, attributes)
Set the tty attributes for file descriptor fd from the attributes, which is a list like the one returned by tcgetattr(). The when argument determines when the attributes are changed: TCSANOW to change immediately, TCSADRAIN to change after transmitting all queued output, or TCSAFLUSH to change after transmitting all queued output and discarding all queued input.

termios.tcsendbreak(fd, duration)
Send a break on file descriptor fd. A zero duration sends a break for 0.25 – 0.5 seconds; a nonzero duration has a system dependent meaning.

termios.tcdrain(fd)
Wait until all output written to file descriptor fd has been transmitted.

termios.tcflush(fd, queue)
Discard queued data on file descriptor fd. The queue selector specifies which queue: TCIFLUSH for the input queue, TCOFLUSH for the output queue, or TCI0FLUSH for both queues.

termios.tcflow(fd, action)
Suspend or resume input or output on file descriptor fd. The action argument can be TCOFF to suspend output, TCOON to restart output, TCI0FF to suspend input, or TCI0N to restart input.

See also:
Module tty
Convenience functions for common terminal control operations.
35.6.1. Example

Here's a function that prompts for a password with echoing turned off. Note the technique using a separate `tcgetattr()` call and a `try ... finally` statement to ensure that the old tty attributes are restored exactly no matter what happens:

```python
def getpass(prompt="Password: "):
    import termios, sys
    fd = sys.stdin.fileno()
    old = termios.tcgetattr(fd)
    new = termios.tcgetattr(fd)
    try:
        termios.tcsetattr(fd, termios.TCSADRAIN, new)
        passwd = input(prompt)
    finally:
        termios.tcsetattr(fd, termios.TCSADRAIN, old)
    return passwd
```
35.7. **tty** — Terminal control functions

The **tty** module defines functions for putting the tty into cbreak and raw modes.

Because it requires the **termios** module, it will work only on Unix.

The **tty** module defines the following functions:

```python
tty.setraw(fd, when=termios.TCSAFLUSH)
```

Change the mode of the file descriptor `fd` to raw. If `when` is omitted, it defaults to `termios.TCSAFLUSH`, and is passed to `termios.tcsetattr()`.

```python
tty.setcbreak(fd, when=termios.TCSAFLUSH)
```

Change the mode of file descriptor `fd` to cbreak. If `when` is omitted, it defaults to `termios.TCSAFLUSH`, and is passed to `termios.tcsetattr()`.

See also:

**Module termios**

Low-level terminal control interface.
35.8. **pty** — Pseudo-terminal utilities

The **pty** module defines operations for handling the pseudo-terminal concept: starting another process and being able to write to and read from its controlling terminal programmatically.

Because pseudo-terminal handling is highly platform dependent, there is code to do it only for Linux. (The Linux code is supposed to work on other platforms, but hasn’t been tested yet.)

The **pty** module defines the following functions:

**pty.fork()**
Fork. Connect the child’s controlling terminal to a pseudo-terminal. Return value is (pid, fd). Note that the child gets **pid** 0, and the **fd** is invalid. The parent’s return value is the **pid** of the child, and **fd** is a file descriptor connected to the child’s controlling terminal (and also to the child’s standard input and output).

**pty.openpty()**
Open a new pseudo-terminal pair, using **os.openpty()** if possible, or emulation code for generic Unix systems. Return a pair of file descriptors (**master**, **slave**), for the master and the slave end, respectively.

**pty.spawn(argv[, master_read[, stdin_read]])**
Spawn a process, and connect its controlling terminal with the current process’s standard io. This is often used to baffle programs which insist on reading from the controlling terminal.
The functions `master_read` and `stdin_read` should be functions which read from a file descriptor. The defaults try to read 1024 bytes each time they are called.

*Changed in version 3.4:* `spawn()` now returns the status value from `os.waitpid()` on the child process.
35.8.1. Example

The following program acts like the Unix command `script(1)`, using a pseudo-terminal to record all input and output of a terminal session in a “typescript”.

```python
import argparse
import os
import pty
import sys
import time

parser = argparse.ArgumentParser()
parser.add_argument('-a', dest='append', action='store_true',
                    help='append to existing script')
parser.add_argument('-p', dest='use_python', action='store_true',
                    help='use Python syntax instead of bash')
parser.add_argument('filename', nargs='?', default='typescript',
                    help='name of file to record to or script to append to')

options = parser.parse_args()

shell = sys.executable if options.use_python else os.execl
filename = options.filename
mode = 'ab' if options.append else 'wb'

with open(filename, mode) as script:
    def read(fd):
        data = os.read(fd, 1024)
        script.write(data)
        return data

    print('Script started, file is', filename)
    script.write(('Script started on %s\n' % time.asctime) %
                 (time.asctime, os.getpid(), sys.executable))
    pty.spawn(shell, read)

    script.write(('Script done on %s\n' % time.asctime) %
                 (time.asctime, os.getpid(), sys.executable))
    print('Script done, file is', filename)
```
35.9. `fcntl` — The `fcntl` and `ioctl` system calls

This module performs file control and I/O control on file descriptors. It is an interface to the `fcntl()` and `ioctl()` Unix routines.

All functions in this module take a file descriptor `fd` as their first argument. This can be an integer file descriptor, such as returned by `sys.stdin.fileno()`, or an `io.IOBase` object, such as `sys.stdin` itself, which provides a `fileno()` that returns a genuine file descriptor.

Changed in version 3.3: Operations in this module used to raise an `IOError` where they now raise an `OSError`.

The module defines the following functions:

`fcntl(fd, cmd, arg=0)`

Perform the operation `cmd` on file descriptor `fd` (file objects providing a `fileno()` method are accepted as well). The values used for `cmd` are operating system dependent, and are available as constants in the `fcntl` module, using the same names as used in the relevant C header files. The argument `arg` can either be an integer value, or a `bytes` object. With an integer value, the return value of this function is the integer return value of the C `fcntl()` call. When the argument is bytes it represents a binary structure, e.g. created by `struct.pack()` The binary data is copied to a buffer whose address is passed to the C `fcntl()` call. The return value after a successful call is the contents of the buffer, converted to a `bytes` object. The length of the returned object will be the
same as the length of the *arg* argument. This is limited to 1024 bytes. If the information returned in the buffer by the operating system is larger than 1024 bytes, this is most likely to result in a segmentation violation or a more subtle data corruption.

If the *fcntl()* fails, an *OSError* is raised.

**:fcntl().ioctl**( *fd*, *request*, *arg=0*, *mutate_flag=True*)

This function is identical to the *fcntl()* function, except that the argument handling is even more complicated.

The *request* parameter is limited to values that can fit in 32-bits. Additional constants of interest for use as the *request* argument can be found in the *termios* module, under the same names as used in the relevant C header files.

The parameter *arg* can be one of an integer, an object supporting the read-only buffer interface (like *bytes*) or an object supporting the read-write buffer interface (like *bytearray*).

In all but the last case, behaviour is as for the *fcntl()* function.

If a mutable buffer is passed, then the behaviour is determined by the value of the *mutate_flag* parameter.

If it is false, the buffer’s mutability is ignored and behaviour is as for a read-only buffer, except that the 1024 byte limit mentioned above is avoided – so long as the buffer you pass is at least as long as what the operating system wants to put there, things should work.

If *mutate_flag* is true (the default), then the buffer is (in effect) passed to the underlying *ioctl()* system call, the latter’s return code is passed back to the calling Python, and the buffer’s new
contents reflect the action of the `ioctl()`. This is a slight simplification, because if the supplied buffer is less than 1024 bytes long it is first copied into a static buffer 1024 bytes long which is then passed to `ioctl()` and copied back into the supplied buffer.

If the `ioctl()` fails, an `IOError` exception is raised.

An example:

```python
>>> import array, fcntl, struct, termios, os
>>> os.getpgrp()
13341
>>> struct.unpack('h', fcntl.ioctl(0, termios.TIOCGPGRP))
13341
>>> buf = array.array('h', [0])
>>> fcntl.ioctl(0, termios.TIOCGPGRP, buf, 1)
0
>>> buf
array('h', [13341])
```

`fcntl.flock(fd, operation)`

Perform the lock operation `operation` on file descriptor `fd` (file objects providing a `fileno()` method are accepted as well). See the Unix manual `flock(2)` for details. (On some systems, this function is emulated using `fcntl()`.)

If the `flock()` fails, an `IOError` exception is raised.

`fcntl.lockf(fd, cmd, len=0, start=0, whence=0)`

This is essentially a wrapper around the `fcntl()` locking calls. `fd` is the file descriptor of the file to lock or unlock, and `cmd` is one of the following values:
- LOCK_UN – unlock
- LOCK_SH – acquire a shared lock
- LOCK_EX – acquire an exclusive lock

When cmd is LOCK_SH or LOCK_EX, it can also be bitwise ORed with LOCK_NB to avoid blocking on lock acquisition. If LOCK_NB is used and the lock cannot be acquired, an OSError will be raised and the exception will have an errno attribute set to EACCES or EAGAIN (depending on the operating system; for portability, check for both values). On at least some systems, LOCK_EX can only be used if the file descriptor refers to a file opened for writing.

len is the number of bytes to lock, start is the byte offset at which the lock starts, relative to whence, and whence is as with io.IOBase.seek(), specifically:

- 0 – relative to the start of the file (os.SEEK_SET)
- 1 – relative to the current buffer position (os.SEEK_CUR)
- 2 – relative to the end of the file (os.SEEK_END)

The default for start is 0, which means to start at the beginning of the file. The default for len is 0 which means to lock to the end of the file. The default for whence is also 0.

Examples (all on a SVR4 compliant system):

```python
import struct, fcntl, os

f = open(...)  
rv = fcntl.fcntl(f, fcntl.F_SETFL, os.O_NDELAY)

lockdata = struct.pack('hhllhh', fcntl.F_WRLCK, 0, 0)  
rv = fcntl.fcntl(f, fcntl.F_SETLK, lockdata)
```
Note that in the first example the return value variable \( rv \) will hold an integer value; in the second example it will hold a \texttt{bytes} object. The structure lay-out for the \texttt{lockdata} variable is system dependent — therefore using the \texttt{flock()} call may be better.

See also:

**Module os**

If the locking flags \texttt{O\_SHLOCK} and \texttt{O\_EXLOCK} are present in the \texttt{os} module (on BSD only), the \texttt{os.open()} function provides an alternative to the \texttt{lockf()} and \texttt{flock()} functions.
35.10. **pipes** — Interface to shell pipelines

**Source code:** `Lib/pipes.py`

The `pipes` module defines a class to abstract the concept of a *pipeline* — a sequence of converters from one file to another.

Because the module uses `/bin/sh` command lines, a POSIX or compatible shell for `os.system()` and `os.popen()` is required.

The `pipes` module defines the following class:

```python
class pipes.Template
    An abstraction of a pipeline.
```

Example:

```python
>>> import pipes
>>> t = pipes.Template()
>>> t.append('tr a-z A-Z', '-
')
>>> f = t.open('pipefile', 'w')
>>> f.write('hello world')
>>> f.close()
>>> open('pipefile').read()
'HELLO WORLD'
```
35.10.1. Template Objects

Template objects following methods:

**Template.reset()**

- Restore a pipeline template to its initial state.

**Template.clone()**

- Return a new, equivalent, pipeline template.

**Template.debug(flag)**

- If flag is true, turn debugging on. Otherwise, turn debugging off. When debugging is on, commands to be executed are printed, and the shell is given set -x command to be more verbose.

**Template.append(cmd, kind)**

- Append a new action at the end. The cmd variable must be a valid bourne shell command. The kind variable consists of two letters.

  - The first letter can be either of '-' (which means the command reads its standard input), 'f' (which means the commands reads a given file on the command line) or '.' (which means the commands reads no input, and hence must be first.)

  - Similarly, the second letter can be either of '-' (which means the command writes to standard output), 'f' (which means the command writes a file on the command line) or '.' (which means the command does not write anything, and hence must be last.)

**Template.prepend(cmd, kind)**

- Add a new action at the beginning. See `append()` for explanations of the arguments.
Template.\texttt{open}(\textit{file}, \textit{mode})

Return a file-like object, open to \textit{file}, but read from or written to by the pipeline. Note that only one of 'r', 'w' may be given.

Template.\texttt{copy}(\textit{infile}, \textit{outfile})

Copy \textit{infile} to \textit{outfile} through the pipe.
35.11. resource — Resource usage information

This module provides basic mechanisms for measuring and controlling system resources utilized by a program.

Symbolic constants are used to specify particular system resources and to request usage information about either the current process or its children.

An OSError is raised on syscall failure.

except resource.error
    A deprecated alias of OSError.

    Changed in version 3.3: Following PEP 3151, this class was made an alias of OSError.
35.11.1. Resource Limits

Resources usage can be limited using the setrlimit() function described below. Each resource is controlled by a pair of limits: a soft limit and a hard limit. The soft limit is the current limit, and may be lowered or raised by a process over time. The soft limit can never exceed the hard limit. The hard limit can be lowered to any value greater than the soft limit, but not raised. (Only processes with the effective UID of the super-user can raise a hard limit.)

The specific resources that can be limited are system dependent. They are described in the getrlimit(2) man page. The resources listed below are supported when the underlying operating system supports them; resources which cannot be checked or controlled by the operating system are not defined in this module for those platforms.

resource.RLIM_INFINITY

Constant used to represent the limit for an unlimited resource.

resource.getrlimit(resource)

Returns a tuple (soft, hard) with the current soft and hard limits of resource. Raises ValueError if an invalid resource is specified, or error if the underlying system call fails unexpectedly.

resource.setrlimit(resource, limits)

Sets new limits of consumption of resource. The limits argument must be a tuple (soft, hard) of two integers describing the new limits. A value of RLIM_INFINITY can be used to request a limit that is unlimited.

Raises ValueError if an invalid resource is specified, if the new
soft limit exceeds the hard limit, or if a process tries to raise its hard limit. Specifying a limit of \texttt{RLIM\_INFINITY} when the hard or system limit for that resource is not unlimited will result in a \texttt{ValueError}. A process with the effective UID of super-user can request any valid limit value, including unlimited, but \texttt{ValueError} will still be raised if the requested limit exceeds the system imposed limit.

\texttt{setrlimit} may also raise \texttt{error} if the underlying system call fails.

\texttt{resource.prlimit}(\texttt{pid}, \texttt{resource}[, \texttt{limits}])

Combines \texttt{setrlimit()} and \texttt{getrlimit()} in one function and supports to get and set the resources limits of an arbitrary process. If \texttt{pid} is 0, then the call applies to the current process. \texttt{resource} and \texttt{limits} have the same meaning as in \texttt{setrlimit()}, except that \texttt{limits} is optional.

When \texttt{limits} is not given the function returns the \texttt{resource} limit of the process \texttt{pid}. When \texttt{limits} is given the \texttt{resource} limit of the process is set and the former resource limit is returned.

Raises \texttt{ProcessLookupError} when \texttt{pid} can’t be found and \texttt{PermissionError} when the user doesn’t have \texttt{CAP\_SYS\_RESOURCE} for the process.

Availability: Linux 2.6.36 or later with glibc 2.13 or later

\textit{New in version 3.4.}

These symbols define resources whose consumption can be controlled using the \texttt{setrlimit()} and \texttt{getrlimit()} functions described below. The values of these symbols are exactly the
constants used by C programs.

The Unix man page for `getrlimit(2)` lists the available resources. Note that not all systems use the same symbol or same value to denote the same resource. This module does not attempt to mask platform differences — symbols not defined for a platform will not be available from this module on that platform.

**resource.**\texttt{RLIMIT\_CORE}

The maximum size (in bytes) of a core file that the current process can create. This may result in the creation of a partial core file if a larger core would be required to contain the entire process image.

**resource.**\texttt{RLIMIT\_CPU}

The maximum amount of processor time (in seconds) that a process can use. If this limit is exceeded, a SIGXCPU signal is sent to the process. (See the `signal` module documentation for information about how to catch this signal and do something useful, e.g. flush open files to disk.)

**resource.**\texttt{RLIMIT\_FSIZE}

The maximum size of a file which the process may create. This only affects the stack of the main thread in a multi-threaded process.

**resource.**\texttt{RLIMIT\_DATA}

The maximum size (in bytes) of the process's heap.

**resource.**\texttt{RLIMIT\_STACK}

The maximum size (in bytes) of the call stack for the current process.

**resource.**\texttt{RLIMIT\_RSS}
The maximum resident set size that should be made available to the process.

**resource.RLIMIT_NPROC**

The maximum number of processes the current process may create.

**resource.RLIMIT_NOFILE**

The maximum number of open file descriptors for the current process.

**resource.RLIMIT_OFILE**

The BSD name for `RLIMIT_NOFILE`.

**resource.RLIMIT_MEMLOCK**

The maximum address space which may be locked in memory.

**resource.RLIMIT_VMEM**

The largest area of mapped memory which the process may occupy.

**resource.RLIMIT_AS**

The maximum area (in bytes) of address space which may be taken by the process.

**resource.RLIMIT_MSGQUEUE**

The number of bytes that can be allocated for POSIX message queues.

*Availability:* Linux 2.6.8 or later.

*New in version 3.4.*

**resource.RLIMIT_NICE**
The ceiling for the process's nice level (calculated as 20 - rlim_cur).

Availability: Linux 2.6.12 or later.

New in version 3.4.

resource RLIMIT_RTPRIO
The ceiling of the real-time priority.

Availability: Linux 2.6.12 or later.

New in version 3.4.

resource RLIMIT_RTTIME
The time limit (in microseconds) on CPU time that a process can spend under real-time scheduling without making a blocking syscall.

Availability: Linux 2.6.25 or later.

New in version 3.4.

resource RLIMIT_SIGPENDING
The number of signals which the process may queue.

Availability: Linux 2.6.8 or later.

New in version 3.4.

resource RLIMIT_SBSIZE
The maximum size (in bytes) of socket buffer usage for this user. This limits the amount of network memory, and hence the amount of mbufs, that this user may hold at any time.

Availability: FreeBSD 9 or later.
New in version 3.4.

resource `RLIMIT_SWAP`

The maximum size (in bytes) of the swap space that may be reserved or used by all of this user id's processes. This limit is enforced only if bit 1 of the `vm.overcommit` sysctl is set. Please see `tuning(7)` for a complete description of this sysctl.

Availability: FreeBSD 9 or later.

New in version 3.4.

resource `RLIMIT_NPTS`

The maximum number of pseudo-terminals created by this user id.

Availability: FreeBSD 9 or later.

New in version 3.4.
35.11.2. Resource Usage

These functions are used to retrieve resource usage information:

resource.getrusage(who)

This function returns an object that describes the resources consumed by either the current process or its children, as specified by the who parameter. The who parameter should be specified using one of the RUSAGE_* constants described below.

The fields of the return value each describe how a particular system resource has been used, e.g. amount of time spent running is user mode or number of times the process was swapped out of main memory. Some values are dependent on the clock tick internal, e.g. the amount of memory the process is using.

For backward compatibility, the return value is also accessible as a tuple of 16 elements.

The fields ru_utime and ru_stime of the return value are floating point values representing the amount of time spent executing in user mode and the amount of time spent executing in system mode, respectively. The remaining values are integers. Consult the getrusage(2) man page for detailed information about these values. A brief summary is presented here:

<table>
<thead>
<tr>
<th>Index</th>
<th>Field</th>
<th>Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>ru_utime</td>
<td>time in user mode (float)</td>
</tr>
<tr>
<td>1</td>
<td>ru_stime</td>
<td>time in system mode (float)</td>
</tr>
<tr>
<td>2</td>
<td>ru_maxrss</td>
<td>maximum resident set size</td>
</tr>
<tr>
<td>3</td>
<td>ru_ixrss</td>
<td>shared memory size</td>
</tr>
<tr>
<td></td>
<td>Field</td>
<td>Description</td>
</tr>
<tr>
<td>---</td>
<td>-------------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td>4</td>
<td>ru_idrss</td>
<td>unshared memory size</td>
</tr>
<tr>
<td>5</td>
<td>ru_isrss</td>
<td>unshared stack size</td>
</tr>
<tr>
<td>6</td>
<td>ru_minflt</td>
<td>page faults not requiring I/O</td>
</tr>
<tr>
<td>7</td>
<td>ru_majflt</td>
<td>page faults requiring I/O</td>
</tr>
<tr>
<td>8</td>
<td>ru_nswap</td>
<td>number of swap outs</td>
</tr>
<tr>
<td>9</td>
<td>ru_inblock</td>
<td>block input operations</td>
</tr>
<tr>
<td>10</td>
<td>ru_oublock</td>
<td>block output operations</td>
</tr>
<tr>
<td>11</td>
<td>ru_msgsnd</td>
<td>messages sent</td>
</tr>
<tr>
<td>12</td>
<td>ru_msgrcv</td>
<td>messages received</td>
</tr>
<tr>
<td>13</td>
<td>ru_nsignals</td>
<td>signals received</td>
</tr>
<tr>
<td>14</td>
<td>ru_nvcsw</td>
<td>voluntary context switches</td>
</tr>
<tr>
<td>15</td>
<td>ru_nivcsw</td>
<td>involuntary context switches</td>
</tr>
</tbody>
</table>

This function will raise a `ValueError` if an invalid `who` parameter is specified. It may also raise `error` exception in unusual circumstances.

**resource.getpagesize()**

Returns the number of bytes in a system page. (This need not be the same as the hardware page size.)

The following RUSAGE_* symbols are passed to the `getrusage()` function to specify which processes information should be provided for.

**resource.RUSAGE_SELF**

Pass to `getrusage()` to request resources consumed by the calling process, which is the sum of resources used by all threads in the process.

**resource.RUSAGE_CHILDREN**
Pass to `getusage()` to request resources consumed by child processes of the calling process which have been terminated and waited for.

**resource.**RUSAGE_BOTH

Pass to `getusage()` to request resources consumed by both the current process and child processes. May not be available on all systems.

**resource.**RUSAGE_THREAD

Pass to `getusage()` to request resources consumed by the current thread. May not be available on all systems.

*New in version 3.2.*
35.12. **nis** — Interface to Sun’s NIS (Yellow Pages)

The **nis** module gives a thin wrapper around the NIS library, useful for central administration of several hosts.

Because NIS exists only on Unix systems, this module is only available for Unix.

The **nis** module defines the following functions:

```python
nis.match(key, mapname, domain=default_domain)
```

Return the match for `key` in map `mapname`, or raise an error (**nis.error**) if there is none. Both should be strings, `key` is 8-bit clean. Return value is an arbitrary array of bytes (may contain NULL and other joys).

Note that `mapname` is first checked if it is an alias to another name.

The `domain` argument allows to override the NIS domain used for the lookup. If unspecified, lookup is in the default NIS domain.

```python
nis.cat(mapname, domain=default_domain)
```

Return a dictionary mapping `key` to `value` such that `match(key, mapname) == value`. Note that both keys and values of the dictionary are arbitrary arrays of bytes.

Note that `mapname` is first checked if it is an alias to another name.

The `domain` argument allows to override the NIS domain used for the lookup. If unspecified, lookup is in the default NIS domain.
nis.maps(domain=default_domain)

Return a list of all valid maps.

The domain argument allows to override the NIS domain used for the lookup. If unspecified, lookup is in the default NIS domain.

nis.get_default_domain()

Return the system default NIS domain.

The nis module defines the following exception:

exception nis.error

An error raised when a NIS function returns an error code.

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Last updated on Dec 06, 2015. Found a bug?
Created using Sphinx 1.3.1.
35.13. **syslog** — Unix syslog library routines

This module provides an interface to the Unix syslog library routines. Refer to the Unix manual pages for a detailed description of the syslog facility.

This module wraps the system syslog family of routines. A pure Python library that can speak to a syslog server is available in the `logging.handlers` module as `SysLogHandler`.

The module defines the following functions:

```python
syslog.syslog(message)
```

```python
syslog.syslog(priority, message)
```

Send the string `message` to the system logger. A trailing newline is added if necessary. Each message is tagged with a priority composed of a `facility` and a `level`. The optional `priority` argument, which defaults to `LOG_INFO`, determines the message priority. If the facility is not encoded in `priority` using logical-or (LOG_INFO | LOG_USER), the value given in the `openlog()` call is used.

If `openlog()` has not been called prior to the call to `syslog()`, `openlog()` will be called with no arguments.

```python
syslog.openlog([ident[, logoption[, facility]]])
```

Logging options of subsequent `syslog()` calls can be set by calling `openlog()`. `syslog()` will call `openlog()` with no arguments if the log is not currently open.
The optional `ident` keyword argument is a string which is prepended to every message, and defaults to `sys.argv[0]` with leading path components stripped. The optional `logoption` keyword argument (default is 0) is a bit field – see below for possible values to combine. The optional `facility` keyword argument (default is `LOG_USER`) sets the default facility for messages which do not have a facility explicitly encoded.

*Changed in version 3.2:* In previous versions, keyword arguments were not allowed, and `ident` was required. The default for `ident` was dependent on the system libraries, and often was `python` instead of the name of the python program file.

**syslog.closelog()**

Reset the syslog module values and call the system library `closelog()`.

This causes the module to behave as it does when initially imported. For example, `openlog()` will be called on the first `syslog()` call (if `openlog()` hasn’t already been called), and `ident` and other `openlog()` parameters are reset to defaults.

**syslog.setlogmask(maskpri)**

Set the priority mask to `maskpri` and return the previous mask value. Calls to `syslog()` with a priority level not set in `maskpri` are ignored. The default is to log all priorities. The function `LOG_MASK(pri)` calculates the mask for the individual priority `pri`. The function `LOG_UPTO(pri)` calculates the mask for all priorities up to and including `pri`.

The module defines the following constants:

Priority levels (high to low):
LOG_EMERG, LOG_ALERT, LOG_CRIT, LOG_ERR, LOG_WARNING, LOG_NOTICE, LOG_INFO, LOG_DEBUG.

Facilities:
LOG_KERN, LOG_USER, LOG_MAIL, LOG_DAEMON, LOG_AUTH, LOG_LPR, LOG_NEWS, LOG_UUCP, LOG_CRON, LOG_SYSLOG, LOG_LOCAL0 to LOG_LOCAL7, and, if defined in `<syslog.h>`, LOG_AUTHPRIV.

Log options:
LOG_PID, LOG_CONS, LOG_NDELAY, and, if defined in `<syslog.h>`, LOG_ODELAY, LOG_NOWAIT, and LOG_PERROR.
35.13.1. Examples

35.13.1.1. Simple example

A simple set of examples:

```python
import syslog

syslog.syslog('Processing started')
if error:
    syslog.syslog(syslog.LOG_ERR, 'Processing started')

An example of setting some log options, these would include the process ID in logged messages, and write the messages to the destination facility used for mail logging:

```python
syslog.openlog(logoption=syslog.LOG_PID, facility=syslog.FSMTP)
syslog.syslog('E-mail processing initiated...')
```
36. Superseded Modules

The modules described in this chapter are deprecated and only kept for backwards compatibility. They have been superseded by other modules.

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    - 36.1.1.1. Terminology
    - 36.1.1.2. What are options for?
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    - 36.1.2.1. Understanding option actions
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36.2. imp — Access the import internals

36.2.1. Examples
36.1. `optparse` — Parser for command line options

*Deprecated since version 3.2:* The `optparse` module is deprecated and will not be developed further; development will continue with the `argparse` module.

**Source code:** Lib/optparse.py

`optparse` is a more convenient, flexible, and powerful library for parsing command-line options than the old `getopt` module. `optparse` uses a more declarative style of command-line parsing: you create an instance of `OptionParser`, populate it with options, and parse the command line. `optparse` allows users to specify options in the conventional GNU/POSIX syntax, and additionally generates usage and help messages for you.

Here's an example of using `optparse` in a simple script:

```python
from optparse import OptionParser

parser = OptionParser()
parser.add_option("-f", "--file", dest="filename",
help="write report to FILE", metavar="filename")
parser.add_option("-q", "--quiet",
action="store_false", dest="verbose",
help="don't print status messages")

(options, args) = parser.parse_args()
```
With these few lines of code, users of your script can now do the “usual thing” on the command-line, for example:

```bash
<yourscript> --file=outfile -q
```

As it parses the command line, `optparse` sets attributes of the options object returned by `parse_args()` based on user-supplied command-line values. When `parse_args()` returns from parsing this command line, `options.filename` will be "outfile" and `options.verbose` will be False. `optparse` supports both long and short options, allows short options to be merged together, and allows options to be associated with their arguments in a variety of ways. Thus, the following command lines are all equivalent to the above example:

```bash
<yourscript> -f outfile --quiet
<yourscript> --quiet --file outfile
<yourscript> -q -f outfile
<yourscript> -qf outfile
```

Additionally, users can run one of

```bash
<yourscript> -h
<yourscript> --help
```

and `optparse` will print out a brief summary of your script's options:

```
Usage: <yourscript> [options]

Options:
  -h, --help    show this help message and exit
  -f FILE, --file=FILE  write report to FILE
  -q, --quiet  don't print status messages
```
where the value of *yourscript* is determined at runtime (normally from `sys.argv[0]`).
36.1.1. Background

optparse was explicitly designed to encourage the creation of programs with straightforward, conventional command-line interfaces. To that end, it supports only the most common command-line syntax and semantics conventionally used under Unix. If you are unfamiliar with these conventions, read this section to acquaint yourself with them.

36.1.1.1. Terminology

argument

a string entered on the command-line, and passed by the shell to `exec1()` or `execv()`. In Python, arguments are elements of `sys.argv[1:]` (`sys.argv[0]` is the name of the program being executed). Unix shells also use the term “word”.

It is occasionally desirable to substitute an argument list other than `sys.argv[1:]`, so you should read “argument” as “an element of `sys.argv[1:]`, or of some other list provided as a substitute for `sys.argv[1:]`”.

option

an argument used to supply extra information to guide or customize the execution of a program. There are many different syntaxes for options; the traditional Unix syntax is a hyphen ("-") followed by a single letter, e.g. `-x` or `-F`. Also, traditional Unix syntax allows multiple options to be merged into a single argument, e.g. `-x` `-F` is equivalent to `-xF`. The GNU project introduced -- followed by a series of hyphen-separated words, e.g. --file or --dry-run. These are the only two option syntaxes provided by
Some other option syntaxes that the world has seen include:

- a hyphen followed by a few letters, e.g. -pf (this is not the same as multiple options merged into a single argument)
- a hyphen followed by a whole word, e.g. -file (this is technically equivalent to the previous syntax, but they aren’t usually seen in the same program)
- a plus sign followed by a single letter, or a few letters, or a word, e.g. +f, +rgb
- a slash followed by a letter, or a few letters, or a word, e.g. /f, /file

These option syntaxes are not supported by `optparse`, and they never will be. This is deliberate: the first three are non-standard on any environment, and the last only makes sense if you’re exclusively targeting VMS, MS-DOS, and/or Windows.

**option argument**

an argument that follows an option, is closely associated with that option, and is consumed from the argument list when that option is. With `optparse`, option arguments may either be in a separate argument from their option:

```
-f foo
--file foo
```

or included in the same argument:

```
-ffoo
--file=foo
```

Typically, a given option either takes an argument or it doesn’t. Lots
of people want an “optional option arguments” feature, meaning that some options will take an argument if they see it, and won’t if they don’t. This is somewhat controversial, because it makes parsing ambiguous: if -a takes an optional argument and -b is another option entirely, how do we interpret -ab? Because of this ambiguity, optparse does not support this feature.

Positional argument
something leftover in the argument list after options have been parsed, i.e. after options and their arguments have been parsed and removed from the argument list.

Required option
an option that must be supplied on the command-line; note that the phrase “required option” is self-contradictory in English. optparse doesn’t prevent you from implementing required options, but doesn’t give you much help at it either.

For example, consider this hypothetical command-line:

```
prog -v --report report.txt foo bar
```

-v and --report are both options. Assuming that --report takes one argument, report.txt is an option argument. foo and bar are positional arguments.

36.1.1.2. What are options for?

Options are used to provide extra information to tune or customize the execution of a program. In case it wasn’t clear, options are usually optional. A program should be able to run just fine with no options whatsoever. (Pick a random program from the Unix or GNU toolsets. Can it run without any options at all and still make sense? The main
exceptions are find, tar, and dd—all of which are mutant oddballs that have been rightly criticized for their non-standard syntax and confusing interfaces.)

Lots of people want their programs to have “required options”. Think about it. If it's required, then it's not optional! If there is a piece of information that your program absolutely requires in order to run successfully, that's what positional arguments are for.

As an example of good command-line interface design, consider the humble cp utility, for copying files. It doesn’t make much sense to try to copy files without supplying a destination and at least one source. Hence, cp fails if you run it with no arguments. However, it has a flexible, useful syntax that does not require any options at all:

```
cp SOURCE DEST
cp SOURCE ... DEST-DIR
```

You can get pretty far with just that. Most cp implementations provide a bunch of options to tweak exactly how the files are copied: you can preserve mode and modification time, avoid following symlinks, ask before clobbering existing files, etc. But none of this distracts from the core mission of cp, which is to copy either one file to another, or several files to another directory.

36.1.1.3. What are positional arguments for?

Positional arguments are for those pieces of information that your program absolutely, positively requires to run.

A good user interface should have as few absolute requirements as possible. If your program requires 17 distinct pieces of information in
order to run successfully, it doesn't much matter how you get that information from the user—most people will give up and walk away before they successfully run the program. This applies whether the user interface is a command-line, a configuration file, or a GUI: if you make that many demands on your users, most of them will simply give up.

In short, try to minimize the amount of information that users are absolutely required to supply—use sensible defaults whenever possible. Of course, you also want to make your programs reasonably flexible. That's what options are for. Again, it doesn't matter if they are entries in a config file, widgets in the “Preferences” dialog of a GUI, or command-line options—the more options you implement, the more flexible your program is, and the more complicated its implementation becomes. Too much flexibility has drawbacks as well, of course; too many options can overwhelm users and make your code much harder to maintain.
36.1.2. Tutorial

While `optparse` is quite flexible and powerful, it's also straightforward to use in most cases. This section covers the code patterns that are common to any `optparse`-based program.

First, you need to import the OptionParser class; then, early in the main program, create an OptionParser instance:

```python
from optparse import OptionParser

parser = OptionParser()
```

Then you can start defining options. The basic syntax is:

```python
parser.add_option(opt_str, ..., 
                  attr=value, ...)
```

Each option has one or more option strings, such as `-f` or `--file`, and several option attributes that tell `optparse` what to expect and what to do when it encounters that option on the command line.

Typically, each option will have one short option string and one long option string, e.g.:

```python
parser.add_option("-f", "--file", ...)
```

You're free to define as many short option strings and as many long option strings as you like (including zero), as long as there is at least one option string overall.

The option strings passed to `OptionParser.add_option()` are effectively labels for the option defined by that call. For brevity, we will
frequently refer to *encountering an option* on the command line; in reality, *optparse* encounters *option strings* and looks up options from them.

Once all of your options are defined, instruct *optparse* to parse your program's command line:

```
(options, args) = parser.parse_args()
```

(If you like, you can pass a custom argument list to `parse_args()`, but that's rarely necessary: by default it uses `sys.argv[1:]`.)

`parse_args()` returns two values:

- `options`, an object containing values for all of your options—e.g. if `--file` takes a single string argument, then `options.file` will be the filename supplied by the user, or `None` if the user did not supply that option
- `args`, the list of positional arguments leftover after parsing options

This tutorial section only covers the four most important option attributes: *action*, *type*, *dest* (destination), and *help*. Of these, *action* is the most fundamental.

### 36.1.2.1. Understanding option actions

Actions tell *optparse* what to do when it encounters an option on the command line. There is a fixed set of actions hard-coded into *optparse*; adding new actions is an advanced topic covered in section *Extending optparse*. Most actions tell *optparse* to store a value in some variable—for example, take a string from the command
line and store it in an attribute of options.

If you don’t specify an option action, `optparse` defaults to store.

### 36.1.2.2. The store action

The most common option action is `store`, which tells `optparse` to take the next argument (or the remainder of the current argument), ensure that it is of the correct type, and store it to your chosen destination.

For example:

```python
def add_option(arg, action='store', type='string', dest=None):
    options.addArgument(arg, action=action, type=type, dest=dest)
```

Now let's make up a fake command line and ask `optparse` to parse it:

```python
args = ['-f', 'foo.txt']
(options, args) = parser.parse_args(args)
```

When `optparse` sees the option string `-f`, it consumes the next argument, `foo.txt`, and stores it in `options.filename`. So, after this call to `parse_args()`, `options.filename` is "foo.txt".

Some other option types supported by `optparse` are `int` and `float`. Here's an option that expects an integer argument:

```python
parser.add_option('-n', type='int', dest='num')
```

Note that this option has no long option string, which is perfectly
acceptable. Also, there's no explicit action, since the default is store.

Let's parse another fake command-line. This time, we'll jam the option argument right up against the option: since -n42 (one argument) is equivalent to -n 42 (two arguments), the code

```python
(options, args) = parser.parse_args(['-n42'])
print(options.num)
```

will print 42.

If you don't specify a type, `optparse` assumes string. Combined with the fact that the default action is store, that means our first example can be a lot shorter:

```python
parser.add_option('-f', '--file', dest='filename')
```

If you don't supply a destination, `optparse` figures out a sensible default from the option strings: if the first long option string is --foo-bar, then the default destination is foo_bar. If there are no long option strings, `optparse` looks at the first short option string: the default destination for -f is f.

`optparse` also includes the built-in complex type. Adding types is covered in section Extending optparse.

36.1.2.3. Handling boolean (flag) options

Flag options—set a variable to true or false when a particular option is seen—are quite common. `optparse` supports them with two separate actions, store_true and store_false. For example, you might have a verbose flag that is turned on with -v and off with -q:
Here we have two different options with the same destination, which is perfectly OK. (It just means you have to be a bit careful when setting default values— see below.)

When `optparse` encounters `-v` on the command line, it sets `options.verbose` to `True`; when it encounters `-q`, `options.verbose` is set to `False`.

### 36.1.2.4. Other actions

Some other actions supported by `optparse` are:

"store_const"

store a constant value

"append"

append this option's argument to a list

"count"

increment a counter by one

"callback"

call a specified function

These are covered in section [Reference Guide](#), [Reference Guide](#) and section [Option Callbacks](#).

### 36.1.2.5. Default values

All of the above examples involve setting some variable (the “destination”) when certain command-line options are seen. What
happens if those options are never seen? Since we didn’t supply any defaults, they are all set to None. This is usually fine, but sometimes you want more control. `optparse` lets you supply a default value for each destination, which is assigned before the command line is parsed.

First, consider the verbose/quiet example. If we want `optparse` to set verbose to `True` unless `-q` is seen, then we can do this:

```python
parser.add_option("-v", action="store_true", dest="verbose")
parser.add_option("-q", action="store_false", dest="verbose")
```

Since default values apply to the *destination* rather than to any particular option, and these two options happen to have the same destination, this is exactly equivalent:

```python
parser.add_option("-v", action="store_true", dest="verbose")
parser.add_option("-q", action="store_false", dest="verbose")
```

Consider this:

```python
parser.add_option("-v", action="store_true", dest="verbose")
parser.add_option("-q", action="store_false", dest="verbose")
```

Again, the default value for verbose will be `True`: the last default value supplied for any particular destination is the one that counts.

A clearer way to specify default values is the `set_defaults()` method of `OptionParser`, which you can call at any time before calling `parse_args()`:

```python
parser.set_defaults(verbos=True)
```
As before, the last value specified for a given option destination is the one that counts. For clarity, try to use one method or the other of setting default values, not both.

### 36.1.2.6. Generating help

`optparse`'s ability to generate help and usage text automatically is useful for creating user-friendly command-line interfaces. All you have to do is supply a help value for each option, and optionally a short usage message for your whole program. Here's an OptionParser populated with user-friendly (documented) options:

```python
usage = "%prog [options] arg1 arg2"
parser = OptionParser(usage=usage)
parser.add_option("-v", "--verbose",
    action="store_true", dest="verbose",
    help="make lots of noise [default]
parser.add_option("-q", "--quiet",
    action="store_false", dest="verbose",
    help="be vewwy quiet (I'm hunting
parser.add_option("-f", "--filename",
    metavar="FILE", help="write output
parser.add_option("-m", "--mode",
    default="intermediate",
    help="interaction mode: novice, in
" or expert [default: %default
```

If `optparse` encounters either -h or --help on the command-line, or if you just call `parser.print_help()`, it prints the following to standard output:
Usage: <yourscript> [options] arg1 arg2

Options:
- h, --help                     show this help message and exit
- v, --verbose                 make lots of noise [default]
- q, --quiet                   be vewwy quiet (I'm hunting)
- f FILE, --filename=FILE      write output to FILE
- m MODE, --mode=MODE          interaction mode: novice, intermediate, expert [default: intermediate]

(If the help output is triggered by a help option, optparse exits after printing the help text.)

There's a lot going on here to help optparse generate the best possible help message:

- the script defines its own usage message:

  usage = "usage: %prog [options] arg1 arg2"

  optparse expands %prog in the usage string to the name of the current program, i.e. os.path.basename(sys.argv[0]). The expanded string is then printed before the detailed option help.

  If you don't supply a usage string, optparse uses a bland but sensible default: "Usage: %prog [options]", which is fine if your script doesn't take any positional arguments.

- every option defines a help string, and doesn't worry about line-wrapping— optparse takes care of wrapping lines and making the help output look good.

- options that take a value indicate this fact in their automatically-
generated help message, e.g. for the “mode” option:

```
-m MODE, --mode=MODE
```

Here, “MODE” is called the meta-variable: it stands for the argument that the user is expected to supply to -m/-mode. By default, `optparse` converts the destination variable name to uppercase and uses that for the meta-variable. Sometimes, that’s not what you want—for example, the --filename option explicitly sets metavar="FILE", resulting in this automatically-generated option description:

```
-f FILE, --filename=FILE
```

This is important for more than just saving space, though: the manually written help text uses the meta-variable FILE to clue the user in that there’s a connection between the semi-formal syntax -f FILE and the informal semantic description “write output to FILE”. This is a simple but effective way to make your help text a lot clearer and more useful for end users.

- options that have a default value can include %default in the help string—`optparse` will replace it with `str()` of the option’s default value. If an option has no default value (or the default value is None), %default expands to `none`.

36.1.2.6.1. Grouping Options

When dealing with many options, it is convenient to group these options for better help output. An `OptionParser` can contain several option groups, each of which can contain several options.
An option group is obtained using the class `OptionGroup`:

```python
class optparse.OptionGroup(parser, title, description=None)
```

where

- parser is the `OptionParser` instance the group will be inserted in to
- title is the group title
- description, optional, is a long description of the group

`OptionGroup` inherits from `OptionContainer` (like `OptionParser`) and so the `add_option()` method can be used to add an option to the group.

Once all the options are declared, using the `OptionParser` method `add_option_group()` the group is added to the previously defined parser.

Continuing with the parser defined in the previous section, adding an `OptionGroup` to a parser is easy:

```python
group = OptionGroup(parser, "Dangerous Options",
                   "Caution: use these options at your own risk. It is believed that some of them bite.
"
group.add_option("-g", action="store_true", help="Group option.
"
parsers.add_option_group(group)
```

This would result in the following help output:

```
Usage: <yourscript> [options] arg1 arg2

Options:
  -h, --help             show this help message and exit
  -v, --verbose          make lots of noise [default]
```
-q, --quiet be vewwy quiet (I'm hunting
-f FILE, --filename=FILE write output to FILE
-m MODE, --mode=MODE interaction mode: novice, inter:
expert [default: intermediate]

Dangerous Options:
Caution: use these options at your own risk. It
of them bite.
-g Group option.

A bit more complete example might involve using more than one

| group = OptionGroup(parser, "Dangerous Options",
| "Caution: use these options at your own risk. It is believed that some of them bite."
| group.add_option("-g", action="store_true", help="Group option."
| parser.add_option_group(group)

| group = OptionGroup(parser, "Debug Options")
| group.add_option("-d", "--debug", action="store_true",
| help="Print debug information")
| group.add_option("-s", "--sql", action="store_true",
| help="Print all SQL statements executed")
| group.add_option("-e", action="store_true", help="Print
done")
| parser.add_option_group(group)

that results in the following output:

Usage: <yourscript> [options] arg1 arg2

Options:
-h, --help show this help message and e
-v, --verbose       make lots of noise [default]
-q, --quiet         be vewwy quiet (I'm hunting
-f FILE, --filename=FILE write output to FILE
-m MODE, --mode=MODE interaction mode: novice, int
            [default: intermediate]

Dangerous Options:
    Caution: use these options at your own risk. It of them bite.

-g                  Group option.

Debug Options:
    -d, --debug        Print debug information
    -s, --sql          Print all SQL statements exec
    -e                Print every action done

Another interesting method, in particular when working programmatically with option groups is:

OptionParser.get_option_group(opt_str)
    Return the OptionGroup to which the short or long option string
    opt_str (e.g. '-o' or '--option') belongs. If there's no such
    OptionGroup, return None.

36.1.2.7. Printing a version string

Similar to the brief usage string, optparse can also print a version string for your program. You have to supply the string as the version argument to OptionParser:

parser = OptionParser(usage="%prog [-f] [-q]", version="..."
%prog is expanded just like it is in usage. Apart from that, version can contain anything you like. When you supply it, optparse automatically adds a --version option to your parser. If it encounters this option on the command line, it expands your version string (by replacing %prog), prints it to stdout, and exits.

For example, if your script is called /usr/bin/foo:

```
$ /usr/bin/foo --version
foo 1.0
```

The following two methods can be used to print and get the version string:

**OptionParser.print_version(file=None)**

Print the version message for the current program (self.version) to file (default stdout). As with print_usage(), any occurrence of %prog in self.version is replaced with the name of the current program. Does nothing if self.version is empty or undefined.

**OptionParser.get_version()**

Same as print_version() but returns the version string instead of printing it.

### 36.1.2.8. How optparse handles errors

There are two broad classes of errors that optparse has to worry about: programmer errors and user errors. Programmer errors are usually erroneous calls to OptionParser.add_option(), e.g. invalid option strings, unknown option attributes, missing option
attributes, etc. These are dealt with in the usual way: raise an exception (either optparse.OptionError or TypeError) and let the program crash.

Handling user errors is much more important, since they are guaranteed to happen no matter how stable your code is. optparse can automatically detect some user errors, such as bad option arguments (passing \texttt{-n 4x} where \texttt{-n} takes an integer argument), missing arguments (\texttt{-n} at the end of the command line, where \texttt{-n} takes an argument of any type). Also, you can call OptionParser.error() to signal an application-defined error condition:

\begin{verbatim}
(options, args) = parser.parse_args()
[...]
if options.a and options.b:
    parser.error("options -a and -b are mutually exclusive")
\end{verbatim}

In either case, optparse handles the error the same way: it prints the program's usage message and an error message to standard error and exits with error status 2.

Consider the first example above, where the user passes \texttt{4x} to an option that takes an integer:

\begin{verbatim}
$ /usr/bin/foo -n 4x
Usage: foo [options]

foo: error: option -n: invalid integer value: '4x'
\end{verbatim}

Or, where the user fails to pass a value at all:

\begin{verbatim}
$ /usr/bin/foo -n
\end{verbatim}
Usage: foo [options]

foo: error: -n option requires an argument

*optparse*-generated error messages take care always to mention the option involved in the error; be sure to do the same when calling OptionParser.error() from your application code.

If *optparse*'s default error-handling behaviour does not suit your needs, you'll need to subclass OptionParser and override its exit() and/or error() methods.

36.1.2.9. Putting it all together

Here’s what *optparse*-based scripts usually look like:

```python
from optparse import OptionParser

def main():
    usage = "usage: %prog [options] arg"
    parser = OptionParser(usage)
    parser.add_option("-f", "--file", dest="filename",
                     help="read data from FILENAME"
    parser.add_option("-v", "--verbose",
                     action="store_true", dest="verbose"
    parser.add_option("-q", "--quiet",
                     action="store_false", dest="verbose"
    
    (options, args) = parser.parse_args()
    if len(args) != 1:
        parser.error("incorrect number of arguments")
    if options.verbose:
        print("reading %s..." % options.filename)
```

if __name__ == "__main__":
    main()
36.1.3. Reference Guide

36.1.3.1. Creating the parser

The first step in using `optparse` is to create an OptionParser instance.

```python
class optparse.OptionParser(...)
```

The OptionParser constructor has no required arguments, but a number of optional keyword arguments. You should always pass them as keyword arguments, i.e. do not rely on the order in which the arguments are declared.

```python
usage (default: "%prog [options]")
```

The usage summary to print when your program is run incorrectly or with a help option. When `optparse` prints the usage string, it expands `%prog` to `os.path.basename(sys.argv[0])` (or to `prog` if you passed that keyword argument). To suppress a usage message, pass the special value `optparse.SUPPRESS_USAGE`.

```python
option_list (default: [])
```

A list of Option objects to populate the parser with. The options in `option_list` are added after any options in `standard_option_list` (a class attribute that may be set by OptionParser subclasses), but before any version or help options. Deprecated; use `add_option()` after creating the parser instead.

```python
option_class (default: optparse.Option)
```

Class to use when adding options to the parser in `add_option()`.
version (default: None)
    A version string to print when the user supplies a version option. If you supply a true value for version, `optparse` automatically adds a version option with the single option string `--version`. The substring `%prog` is expanded the same as for usage.

conflict_handler (default: "error")
    Specifies what to do when options with conflicting option strings are added to the parser; see section Conflicts between options.

description (default: None)
    A paragraph of text giving a brief overview of your program. `optparse` reformats this paragraph to fit the current terminal width and prints it when the user requests help (after usage, but before the list of options).

formatter (default: a new IndentedHelpFormatter)
    An instance of `optparse.HelpFormatter` that will be used for printing help text. `optparse` provides two concrete classes for this purpose: `IndentedHelpFormatter` and `TitledHelpFormatter`.

add_help_option (default: True)
    If true, `optparse` will add a help option (with option strings -h and --help) to the parser.

prog
    The string to use when expanding `%prog` in usage and version instead of `os.path.basename(sys.argv[0])`.

epilog (default: None)
    A paragraph of help text to print after the option help.

36.1.3.2. Populating the parser
There are several ways to populate the parser with options. The preferred way is by using `OptionParser.add_option()`, as shown in section `Tutorial`. `add_option()` can be called in one of two ways:

- pass it an Option instance (as returned by `make_option()`)
- pass it any combination of positional and keyword arguments that are acceptable to `make_option()` (i.e., to the Option constructor), and it will create the Option instance for you

The other alternative is to pass a list of pre-constructed Option instances to the OptionParser constructor, as in:

```python
option_list = [
    make_option("-f", "--filename",
                action="store", type="string", dest=
    make_option("-q", "--quiet",
                action="store_false", dest="verbose"
]
parser = OptionParser(option_list=option_list)
```

`make_option()` is a factory function for creating Option instances; currently it is an alias for the Option constructor. A future version of `optparse` may split Option into several classes, and `make_option()` will pick the right class to instantiate. Do not instantiate Option directly.)

36.1.3.3. Defining options

Each Option instance represents a set of synonymous command-line option strings, e.g. `-f` and `--file`. You can specify any number of short or long option strings, but you must specify at least one overall option string.
The canonical way to create an Option instance is with the add_option() method of OptionParser.

OptionParser.add_option(option)
OptionParser.add_option(*opt_str, attr=value, ...)

To define an option with only a short option string:

```python
parser.add_option("-f", attr=value, ...)
```

And to define an option with only a long option string:

```python
parser.add_option("--foo", attr=value, ...)
```

The keyword arguments define attributes of the new Option object. The most important option attribute is action, and it largely determines which other attributes are relevant or required. If you pass irrelevant option attributes, or fail to pass required ones, optparse raises an OptionError exception explaining your mistake.

An option’s action determines what optparse does when it encounters this option on the command-line. The standard option actions hard-coded into optparse are:

"store"
    store this option’s argument (default)
"store_const"
    store a constant value
"store_true"
    store a true value
"store_false"
    store a false value
"append"
  append this option's argument to a list
"append_const"
  append a constant value to a list
"count"
  increment a counter by one
"callback"
  call a specified function
"help"
  print a usage message including all options and the documentation for them

(If you don't supply an action, the default is "store". For this action, you may also supply type and dest option attributes; see Standard option actions.)

As you can see, most actions involve storing or updating a value somewhere. optparse always creates a special object for this, conventionally called options (it happens to be an instance of optparse.Values). Option arguments (and various other values) are stored as attributes of this object, according to the dest (destination) option attribute.

For example, when you call

```
parser.parse_args()
```

one of the first things optparse does is create the options object:

```
options = Values()
```

If one of the options in this parser is defined with
parser.add_option("-f", "--file", action="store", type="string")

and the command-line being parsed includes any of the following:

-ffoo
-f foo
--file=foo
--file foo

then optparse, on seeing this option, will do the equivalent of

options.filename = "foo"

The type and dest option attributes are almost as important as action, but action is the only one that makes sense for all options.

36.1.3.4. Option attributes

The following option attributes may be passed as keyword arguments to OptionParser.add_option(). If you pass an option attribute that is not relevant to a particular option, or fail to pass a required option attribute, optparse raises OptionError.

Option.action
  (default: "store")

  Determines optparse's behaviour when this option is seen on the command line; the available options are documented here.

Option.type
  (default: "string")
The argument type expected by this option (e.g., "string" or "int"); the available option types are documented here.

Option `dest`
(default: derived from option strings)

If the option’s action implies writing or modifying a value somewhere, this tells `optparse` where to write it: `dest` names an attribute of the options object that `optparse` builds as it parses the command line.

Option `default`

The value to use for this option's destination if the option is not seen on the command line. See also `OptionParser.set_defaults()`.

Option `nargs`
(default: 1)

How many arguments of type `type` should be consumed when this option is seen. If > 1, `optparse` will store a tuple of values to `dest`.

Option `const`

For actions that store a constant value, the constant value to store.

Option `choices`

For options of type "choice", the list of strings the user may choose from.

Option `callback`

For options with action "callback", the callable to call when this option is seen. See section `Option Callbacks` for detail on the
arguments passed to the callable.

Option **callback_args**
Option **callback_kwargs**

Additional positional and keyword arguments to pass to callback after the four standard callback arguments.

Option **help**

Help text to print for this option when listing all available options after the user supplies a help option (such as --help). If no help text is supplied, the option will be listed without help text. To hide this option, use the special value optparse.SUPPRESS_HELP.

Option **metavar**

(default: derived from option strings)

Stand-in for the option argument(s) to use when printing help text. See section Tutorial for an example.

### 36.1.3.5. Standard option actions

The various option actions all have slightly different requirements and effects. Most actions have several relevant option attributes which you may specify to guide optparse's behaviour; a few have required attributes, which you must specify for any option using that action.

- "store" [relevant: type, dest, nargs, choices]

  The option must be followed by an argument, which is converted to a value according to type and stored in dest. If nargs > 1, multiple arguments will be consumed from the command line; all will be converted according to type and stored to dest as a
tuple. See the **Standard option types** section.

If `choices` is supplied (a list or tuple of strings), the type defaults to "choice".

If `type` is not supplied, it defaults to "string".

If `dest` is not supplied, `optparse` derives a destination from the first long option string (e.g., `--foo-bar` implies `foo_bar`). If there are no long option strings, `optparse` derives a destination from the first short option string (e.g., `-f` implies `f`).

Example:

```python
parser.add_option("-f")
parser.add_option("-p", type="float", nargs=3, dest="point")
```

As it parses the command line

```
-f foo.txt -p 1 -3.5 4 -fbar.txt
```

`optparse` will set

```python
options.f = "foo.txt"
options.point = (1.0, -3.5, 4.0)
options.f = "bar.txt"
```

- "store_const" [required: `const`; relevant: `dest`]

  The value `const` is stored in `dest`.

  Example:

  ```python
  parser.add_option("-q", "--quiet",
  ```
If --noisy is seen, `optparse` will set

```python
options.verbose = 2
```

- **"store_true"** [relevant: `dest`]

  A special case of "store_const" that stores a true value to `dest`.

- **"store_false"** [relevant: `dest`]

  Like "store_true", but stores a false value.

  Example:

  ```python
  parser.add_option("--clobber", action="store_true")
  parser.add_option("--no-clobber", action="store_true")
  ```

- **"append"** [relevant: `type`, `dest`, `nargs`, `choices`]

  The option must be followed by an argument, which is appended to the list in `dest`. If no default value for `dest` is supplied, an empty list is automatically created when `optparse` first encounters this option on the command-line. If `nargs > 1`, multiple arguments are consumed, and a tuple of length `nargs` is appended to `dest`. 
The defaults for type and dest are the same as for the "store" action.

Example:

```python
parser.add_option("-t", "--tracks", action="append")
```

If -t3 is seen on the command-line, optparse does the equivalent of:

```python
options.tracks = []
options.tracks.append(int("3"))
```

If, a little later on, --tracks=4 is seen, it does:

```python
options.tracks.append(int("4"))
```

The append action calls the append method on the current value of the option. This means that any default value specified must have an append method. It also means that if the default value is non-empty, the default elements will be present in the parsed value for the option, with any values from the command line appended after those default values:

```python
>>> parser.add_option("--files", action="append")
>>> opts, args = parser.parse_args(["--files", 
'~/mypkg/defaults', 'overrides.mypkg'])
```

- "append_const" [required: const; relevant: dest]

  Like "store_const", but the value const is appended to dest;
as with "append", dest defaults to None, and an empty list is automatically created the first time the option is encountered.

- "count" [relevant: dest]

Increment the integer stored at dest. If no default value is supplied, dest is set to zero before being incremented the first time.

Example:

```python
parser.add_option("-v", action="count", dest="verbosity")
```

The first time -v is seen on the command line, optparse does the equivalent of:

```python
options.verbosity = 0
options.verbosity += 1
```

Every subsequent occurrence of -v results in

```python
options.verbosity += 1
```

- "callback" [required: callback; relevant: type, nargs, callback_args, callback_kwargs]

Call the function specified by callback, which is called as

```python
func(option, opt_str, value, parser, *args, **kwargs)
```

See section Option Callbacks for more detail.

- "help"
Prints a complete help message for all the options in the current option parser. The help message is constructed from the usage string passed to OptionParser's constructor and the help string passed to every option.

If no help string is supplied for an option, it will still be listed in the help message. To omit an option entirely, use the special value optparse.SUPPRESS_HELP.

optparse automatically adds a help option to all OptionParsers, so you do not normally need to create one.

Example:

```python
from optparse import OptionParser, SUPPRESS_HELP

# usually, a help option is added automatically, # be suppressed using the add_help_option argument
parser = OptionParser(add_help_option=False)

parser.add_option("-h", "--help", action="help")
parser.add_option("-v", action="store_true", dest="help",
help="Be moderately verbose")
parser.add_option("--file", dest="filename",
help="Input file to read data")
parser.add_option("--secret", help=SUPPRESS_HELP)
```

If optparse sees either -h or --help on the command line, it will print something like the following help message to stdout (assuming sys.argv[0] is "foo.py"):

```
Usage: foo.py [options]
```
Options:
- **-h, --help**  Show this help message and exit
- **-v**  Be moderately verbose
- **--file=FILENAME**  Input file to read data from

After printing the help message, **optparse** terminates your process with `sys.exit(0)`.

- **"version"**

  Prints the version number supplied to the OptionParser to stdout and exits. The version number is actually formatted and printed by the `print_version()` method of OptionParser. Generally only relevant if the version argument is supplied to the OptionParser constructor. As with **help** options, you will rarely create version options, since **optparse** automatically adds them when needed.

### 36.1.3.6. Standard option types

**optparse** has five built-in option types: "string", "int", "choice", "float" and "complex". If you need to add new option types, see section **Extending optparse**.

Arguments to string options are not checked or converted in any way: the text on the command line is stored in the destination (or passed to the callback) as-is.

Integer arguments (type "int") are parsed as follows:

- if the number starts with 0x, it is parsed as a hexadecimal number
- if the number starts with 0, it is parsed as an octal number
- if the number starts with 0b, it is parsed as a binary number
otherwise, the number is parsed as a decimal number

The conversion is done by calling `int()` with the appropriate base (2, 8, 10, or 16). If this fails, so will `optparse`, although with a more useful error message.

"float" and "complex" option arguments are converted directly with `float()` and `complex()`, with similar error-handling.

"choice" options are a subtype of "string" options. The `choices` option attribute (a sequence of strings) defines the set of allowed option arguments. `optparse.check_choice()` compares user-supplied option arguments against this master list and raises `OptionValueError` if an invalid string is given.

36.1.3.7. Parsing arguments

The whole point of creating and populating an OptionParser is to call its `parse_args()` method:

```python
(options, args) = parser.parse_args(args=None, values=None)
```

where the input parameters are

**args**

the list of arguments to process (default: `sys.argv[1:]`)

**values**

an `optparse.Values` object to store option arguments in (default: a new instance of `Values`) – if you give an existing object, the option defaults will not be initialized on it

and the return values are
options
   the same object that was passed in as values, or the optparse.Values instance created by optparse

args
   the leftover positional arguments after all options have been processed

The most common usage is to supply neither keyword argument. If you supply values, it will be modified with repeated setattr() calls (roughly one for every option argument stored to an option destination) and returned by parse_args().

If parse_args() encounters any errors in the argument list, it calls the OptionParser's error() method with an appropriate end-user error message. This ultimately terminates your process with an exit status of 2 (the traditional Unix exit status for command-line errors).

36.1.3.8. Querying and manipulating your option parser

The default behavior of the option parser can be customized slightly, and you can also poke around your option parser and see what's there. OptionParser provides several methods to help you out:

OptionParser.**disable_interspersed_args**()
   Set parsing to stop on the first non-option. For example, if -a and -b are both simple options that take no arguments, optparse normally accepts this syntax:

   **prog -a arg1 -b arg2**

   and treats it as equivalent to
To disable this feature, call `disable_interspersed_args()`. This restores traditional Unix syntax, where option parsing stops with the first non-option argument.

Use this if you have a command processor which runs another command which has options of its own and you want to make sure these options don’t get confused. For example, each command might have a different set of options.

**OptionParser.enable_interspersed_args()**
Set parsing to not stop on the first non-option, allowing interspersing switches with command arguments. This is the default behavior.

**OptionParser.get_option(opt_str)**
Returns the Option instance with the option string `opt_str`, or None if no options have that option string.

**OptionParser.has_option(opt_str)**
Return true if the OptionParser has an option with option string `opt_str` (e.g., `-q` or `--verbose`).

**OptionParser.remove_option(opt_str)**
If the OptionParser has an option corresponding to `opt_str`, that option is removed. If that option provided any other option strings, all of those option strings become invalid. If `opt_str` does not occur in any option belonging to this OptionParser, raises ValueError.

36.1.3.9. Conflicts between options
If you’re not careful, it’s easy to define options with conflicting option strings:

```python
parser.add_option("-n", "--dry-run", ...)  
[...]  
parser.add_option("-n", "--noisy", ...)  
```

(This is particularly true if you’ve defined your own OptionParser subclass with some standard options.)

Every time you add an option, optparse checks for conflicts with existing options. If it finds any, it invokes the current conflict-handling mechanism. You can set the conflict-handling mechanism either in the constructor:

```python
parser = OptionParser(..., conflict_handler=handler)  
```

or with a separate call:

```python
parser.set_conflict_handler(handler)  
```

The available conflict handlers are:

- "error" (default)
  - assume option conflicts are a programming error and raise OptionConflictError
- "resolve"
  - resolve option conflicts intelligently (see below)

As an example, let’s define an OptionParser that resolves conflicts intelligently and add conflicting options to it:

```python
parser = OptionParser(conflict_handler="resolve")  
```
At this point, `optparse` detects that a previously-added option is already using the `-n` option string. Since `conflict_handler` is "resolve", it resolves the situation by removing `-n` from the earlier option’s list of option strings. Now `--dry-run` is the only way for the user to activate that option. If the user asks for help, the help message will reflect that:

```
Options:
    --dry-run     do no harm
[...]
    -n, --noisy   be noisy
```

It’s possible to whittle away the option strings for a previously-added option until there are none left, and the user has no way of invoking that option from the command-line. In that case, `optparse` removes that option completely, so it doesn’t show up in help text or anywhere else. Carrying on with our existing OptionParser:

```
parser.add_option("--dry-run", ..., help="new dry-run option")
```

At this point, the original `-n/--dry-run` option is no longer accessible, so `optparse` removes it, leaving this help text:

```
Options:
    [...]  
    -n, --noisy   be noisy
    --dry-run     new dry-run option
```

36.1.3.10. Cleanup
OptionParser instances have several cyclic references. This should not be a problem for Python’s garbage collector, but you may wish to break the cyclic references explicitly by calling `destroy()` on your OptionParser once you are done with it. This is particularly useful in long-running applications where large object graphs are reachable from your OptionParser.

### 36.1.3.11. Other methods

OptionParser supports several other public methods:

**OptionParser.set_usage(usage)**

Set the usage string according to the rules described above for the usage constructor keyword argument. Passing None sets the default usage string; use `optparse.SUPPRESS_USAGE` to suppress a usage message.

**OptionParser.print_usage(file=None)**

Print the usage message for the current program (`self.usage`) to `file` (default stdout). Any occurrence of the string `%prog` in `self.usage` is replaced with the name of the current program. Does nothing if `self.usage` is empty or not defined.

**OptionParser.get_usage()**

Same as `print_usage()` but returns the usage string instead of printing it.

**OptionParser.set_defaults(dest=value,...)**

Set default values for several option destinations at once. Using `set_defaults()` is the preferred way to set default values for
options, since multiple options can share the same destination. For example, if several “mode” options all set the same destination, any one of them can set the default, and the last one wins:

```python
parser.add_option("--advanced", action="store_const",
                 dest="mode", const="advanced",
                 default="novice")  # overridden

parser.add_option("--novice", action="store_const",
                 dest="mode", const="novice",
                 default="advanced")  # overrides above setting
```

To avoid this confusion, use `set_defaults()`:

```python
parser.set_defaults(mode="advanced")
parser.add_option("--advanced", action="store_const",
                 dest="mode", const="advanced")
parser.add_option("--novice", action="store_const",
                 dest="mode", const="novice")
```
36.1.4. Option Callbacks

When `optparse`'s built-in actions and types aren’t quite enough for your needs, you have two choices: extend `optparse` or define a callback option. Extending `optparse` is more general, but overkill for a lot of simple cases. Quite often a simple callback is all you need.

There are two steps to defining a callback option:

- define the option itself using the "callback" action
- write the callback; this is a function (or method) that takes at least four arguments, as described below

36.1.4.1. Defining a callback option

As always, the easiest way to define a callback option is by using the `OptionParser.add_option()` method. Apart from `action`, the only option attribute you must specify is `callback`, the function to call:

```python
parser.add_option("-c", action="callback", callback=callback)
```

callback is a function (or other callable object), so you must have already defined `my_callback()` when you create this callback option. In this simple case, `optparse` doesn't even know if `-c` takes any arguments, which usually means that the option takes no arguments—the mere presence of `-c` on the command-line is all it needs to know. In some circumstances, though, you might want your callback to consume an arbitrary number of command-line arguments. This is where writing callbacks gets tricky; it's covered later in this
section.

`optparse` always passes four particular arguments to your callback, and it will only pass additional arguments if you specify them via `callback_args` and `callback_kwargs`. Thus, the minimal callback function signature is:

```python
def my_callback(option, opt, value, parser):
```

The four arguments to a callback are described below.

There are several other option attributes that you can supply when you define a callback option:

**type**
- has its usual meaning: as with the "store" or "append" actions, it instructs `optparse` to consume one argument and convert it to *type*. Rather than storing the converted value(s) anywhere, though, `optparse` passes it to your callback function.

**nargs**
- also has its usual meaning: if it is supplied and > 1, `optparse` will consume `nargs` arguments, each of which must be convertible to *type*. It then passes a tuple of converted values to your callback.

**callback_args**
- a tuple of extra positional arguments to pass to the callback

**callback_kwargs**
- a dictionary of extra keyword arguments to pass to the callback

### 36.1.4.2. How callbacks are called

All callbacks are called as follows:
func(option, opt_str, value, parser, *args, **kwargs)

where

option
  is the Option instance that’s calling the callback

opt_str
  is the option string seen on the command-line that’s triggering the callback. (If an abbreviated long option was used, opt_str will be the full, canonical option string—e.g. if the user puts --foo on the command-line as an abbreviation for --foobar, then opt_str will be "--foobar".)

value
  is the argument to this option seen on the command-line. optparse will only expect an argument if type is set; the type of value will be the type implied by the option’s type. If type for this option is None (no argument expected), then value will be None. If nargs > 1, value will be a tuple of values of the appropriate type.

parser
  is the OptionParser instance driving the whole thing, mainly useful because you can access some other interesting data through its instance attributes:

  parser.largs
    the current list of leftover arguments, ie. arguments that have been consumed but are neither options nor option arguments. Feel free to modify parser.largs, e.g. by adding more arguments to it. (This list will become args, the second return value of parse_args().)

  parser.rargs
the current list of remaining arguments, i.e. with `opt_str` and value (if applicable) removed, and only the arguments following them still there. Feel free to modify `parser.rargs`, e.g. by consuming more arguments.

`parser.values`

the object where option values are by default stored (an instance of `optparse.OptionValues`). This lets callbacks use the same mechanism as the rest of `optparse` for storing option values; you don’t need to mess around with globals or closures. You can also access or modify the value(s) of any options already encountered on the command-line.

`args`

is a tuple of arbitrary positional arguments supplied via the `callback_args` option attribute.

`kwargs`

is a dictionary of arbitrary keyword arguments supplied via `callback_kwargs`.

36.1.4.3. Raising errors in a callback

The callback function should raise `OptionValueError` if there are any problems with the option or its argument(s). `optparse` catches this and terminates the program, printing the error message you supply to stderr. Your message should be clear, concise, accurate, and mention the option at fault. Otherwise, the user will have a hard time figuring out what he did wrong.

36.1.4.4. Callback example 1: trivial callback

Here’s an example of a callback option that takes no arguments, and simply records that the option was seen:
```
def record_foo_seen(option, opt_str, value, parser):
    parser.values.saw_foo = True

parser.add_option("--foo", action="callback", callback=...
```

Of course, you could do that with the "store_true" action.

### 36.1.4.5. Callback example 2: check option order

Here’s a slightly more interesting example: record the fact that `-a` is seen, but blow up if it comes after `-b` in the command-line.

```
def check_order(option, opt_str, value, parser):
    if parser.values.b:
        raise OptionValueError("can't use -a after -b")
    parser.values.a = 1

parser.add_option("-a", action="callback", callback=...
```

### 36.1.4.6. Callback example 3: check option order (generalized)

If you want to re-use this callback for several similar options (set a flag, but blow up if `-b` has already been seen), it needs a bit of work: the error message and the flag that it sets must be generalized.

```
def check_order(option, opt_str, value, parser):
    if parser.values.b:
        raise OptionValueError("can't use %s after -b")
    setattr(parser.values, option.dest, 1)
```
36.1.4.7. Callback example 4: check arbitrary condition

Of course, you could put any condition in there—you’re not limited to checking the values of already-defined options. For example, if you have options that should not be called when the moon is full, all you have to do is this:

```python
def check_moon(option, opt_str, value, parser):
    if is_moon_full():
        raise OptionValueError("%s option invalid when the moon is full\n" % opt_str)
    setattr(parser.values, option.dest, 1)
```

(The definition of is_moon_full() is left as an exercise for the reader.)

36.1.4.8. Callback example 5: fixed arguments

Things get slightly more interesting when you define callback options that take a fixed number of arguments. Specifying that a callback option takes arguments is similar to defining a "store" or "append" option: if you define type, then the option takes one argument that must be convertible to that type; if you further define nargs, then the
option takes `nargs` arguments.

Here's an example that just emulates the standard "store" action:

```python
def store_value(option, opt_str, value, parser):
    setattr(parser.values, option.dest, value)

parser.add_option("--foo",
    action="callback",
    callback=store_value,
    type="int",
    nargs=3,
    dest="foo")
```

Note that `optparse` takes care of consuming 3 arguments and converting them to integers for you; all you have to do is store them. (Or whatever; obviously you don't need a callback for this example.)

### 36.1.4.9. Callback example 6: variable arguments

Things get hairy when you want an option to take a variable number of arguments. For this case, you must write a callback, as `optparse` doesn't provide any built-in capabilities for it. And you have to deal with certain intricacies of conventional Unix command-line parsing that `optparse` normally handles for you. In particular, callbacks should implement the conventional rules for bare `--` and `-` arguments:

- either `--` or `-` can be option arguments
- bare `--` (if not the argument to some option): halt command-line processing and discard the `--`
- bare `-` (if not the argument to some option): halt command-line processing but keep the `-` (append it to `parser.largs`)

If you want an option that takes a variable number of arguments, there are several subtle, tricky issues to worry about. The exact
implementation you choose will be based on which trade-offs you're willing to make for your application (which is why `optparse` doesn't support this sort of thing directly).

Nevertheless, here's a stab at a callback for an option with variable arguments:

```python
def vararg_callback(option, opt_str, value, parser):
    assert value is None
    value = []

def floatable(str):
    try:
        float(str)
        return True
    except ValueError:
        return False

for arg in parser.rargs:
    # stop on --foo like options
    if arg[:2] == "--" and len(arg) > 2:
        break
    # stop on -a, but not on -3 or -3.0
    if arg[:1] == "-" and len(arg) > 1 and not
        break
    value.append(arg)

del parser.rargs[:len(value)]
setattr(parser.values, option.dest, value)

[...]
parsed.add_option("-c", "--callback", dest="vararg_attr",
                  action="callback", callback=vararg_callback)
```
36.1.5. Extending optparse

Since the two major controlling factors in how optparse interprets command-line options are the action and type of each option, the most likely direction of extension is to add new actions and new types.

36.1.5.1. Adding new types

To add new types, you need to define your own subclass of optparse's Option class. This class has a couple of attributes that define optparse's types: TYPES and TYPE_CHECKER.

Option. TYPES

A tuple of type names; in your subclass, simply define a new tuple TYPES that builds on the standard one.

Option. TYPE_CHECKER

A dictionary mapping type names to type-checking functions. A type-checking function has the following signature:

```python
def check_mytype(option, opt, value)
```

where option is an Option instance, opt is an option string (e.g., -f), and value is the string from the command line that must be checked and converted to your desired type. check_mytype() should return an object of the hypothetical type mytype. The value returned by a type-checking function will wind up in the OptionValues instance returned by OptionParser.parse_args(), or be passed to a callback as the value parameter.
Your type-checking function should raise `OptionValueError` if it encounters any problems. `OptionValueError` takes a single string argument, which is passed as-is to `OptionParser`'s `error()` method, which in turn prepends the program name and the string "error:" and prints everything to stderr before terminating the process.

Here's a silly example that demonstrates adding a "complex" option type to parse Python-style complex numbers on the command line. (This is even sillier than it used to be, because `optparse` 1.3 added built-in support for complex numbers, but never mind.)

First, the necessary imports:

```python
from copy import copy
from optparse import Option, OptionValueError
```

You need to define your type-checker first, since it's referred to later (in the `TYPE_CHECKER` class attribute of your Option subclass):

```python
def check_complex(option, opt, value):
    try:
        return complex(value)
    except ValueError:
        raise OptionValueError("option %s: invalid complex value: %r" %

Finally, the Option subclass:

```python
class MyOption (Option):
    TYPES = Option.TYPES + ("complex",)
    TYPE_CHECKER = copy(Option.TYPE_CHECKER)
    TYPE_CHECKER['complex'] = check_complex
```
(If we didn't make a copy() of Option.TYPE_CHECKER, we would end up modifying the TYPE_CHECKER attribute of optparse's Option class. This being Python, nothing stops you from doing that except good manners and common sense.)

That's it! Now you can write a script that uses the new option type just like any other optparse-based script, except you have to instruct your OptionParser to use MyOption instead of Option:

```python
parser = OptionParser(option_class=MyOption)
parser.add_option("-c", type="complex")
```

Alternately, you can build your own option list and pass it to OptionParser; if you don't use add_option() in the above way, you don't need to tell OptionParser which option class to use:

```python
option_list = [MyOption("-c", action="store", type='complex')]
parser = OptionParser(option_list=option_list)
```

36.1.5.2. Adding new actions

Adding new actions is a bit trickier, because you have to understand that optparse has a couple of classifications for actions:

“store” actions

actions that result in optparse storing a value to an attribute of the current OptionValues instance; these options require a dest attribute to be supplied to the Option constructor.

“typed” actions

actions that take a value from the command line and expect it to be of a certain type; or rather, a string that can be converted to a certain type. These options require a type attribute to the Option
constructor.

These are overlapping sets: some default “store” actions are "store", "store_const", "append", and "count", while the default “typed” actions are "store", "append", and "callback".

When you add an action, you need to categorize it by listing it in at least one of the following class attributes of Option (all are lists of strings):

Option.**ACTIONS**
   All actions must be listed in ACTIONS.

Option.**STORE_ACTIONS**
   “store” actions are additionally listed here.

Option.**TYPED_ACTIONS**
   “typed” actions are additionally listed here.

Option.**ALWAYS_TYPED_ACTIONS**
   Actions that always take a type (i.e. whose options always take a value) are additionally listed here. The only effect of this is that **optparse** assigns the default type, "string", to options with no explicit type whose action is listed in **ALWAYS_TYPED_ACTIONS**.

In order to actually implement your new action, you must override Option's `take_action()` method and add a case that recognizes your action.

For example, let's add an "extend" action. This is similar to the standard "append" action, but instead of taking a single value from the command-line and appending it to an existing list, "extend" will take multiple values in a single comma-delimited string, and extend an
existing list with them. That is, if `--names` is an "extend" option of type "string", the command line

```
--names=foo,bar --names blah --names ding,dong
```

would result in a list

```
["foo", "bar", "blah", "ding", "dong"]
```

Again we define a subclass of Option:

```python
class MyOption(Option):
    ACTIONS = Option.ACTIONS + ("extend",)
    STORE_ACTIONS = Option.STORE_ACTIONS + ("extend")
    TYPED_ACTIONS = Option.TYPED_ACTIONS + ("extend")
    ALWAYS_TYPED_ACTIONS = Option.ALWAYS_TYPED_ACTIONS

    def take_action(self, action, dest, opt, value,
                        if action == "extend":
                            lvalue = value.split("","")
                            values.ensure_value(dest, []).extend(lvalue)
                        else:
                            Option.take_action(self, action, dest, opt, value, value)
```

Features of note:

- "extend" both expects a value on the command-line and stores that value somewhere, so it goes in both `STORE_ACTIONS` and `TYPED_ACTIONS`.

- to ensure that `optparse` assigns the default type of "string" to "extend" actions, we put the "extend" action in
**ALWAYS_TYPED_ACTIONS** as well.

- MyOption.take_action() implements just this one new action, and passes control back to Option.take_action() for the standard `optparse` actions.

- values is an instance of the `optparse` Values class, which provides the very useful `ensure_value()` method. `ensure_value()` is essentially `getattr()` with a safety valve; it is called as

```python
values.ensure_value(attr, value)
```

If the `attr` attribute of `values` doesn’t exist or is `None`, then `ensure_value()` first sets it to `value`, and then returns `value`. This is very handy for actions like "extend", "append", and "count", all of which accumulate data in a variable and expect that variable to be of a certain type (a list for the first two, an integer for the latter). Using `ensure_value()` means that scripts using your action don’t have to worry about setting a default value for the option destinations in question; they can just leave the default as `None` and `ensure_value()` will take care of getting it right when it’s needed.
36.2. **imp** — Access the **import** internals

*Deprecated since version 3.4:* The **imp** package is pending deprecation in favor of **importlib**.

This module provides an interface to the mechanisms used to implement the **import** statement. It defines the following constants and functions:

**imp.get_magic()**

Return the magic string value used to recognize byte-compiled code files (.pyc files). (This value may be different for each Python version.)

*Deprecated since version 3.4:* Use **importlib.util.MAGIC_NUMBER** instead.

**imp.get_suffixes()**

Return a list of 3-element tuples, each describing a particular type of module. Each triple has the form (suffix, mode, type), where suffix is a string to be appended to the module name to form the filename to search for, mode is the mode string to pass to the built-in open() function to open the file (this can be 'r' for text files or 'rb' for binary files), and type is the file type, which has one of the values **PY_SOURCE**, **PY_COMPILED**, or **C_EXTENSION**, described below.

*Deprecated since version 3.3:* Use the constants defined on **importlib.machinery** instead.
imp.\texttt{find\_module}(name[, path])

Try to find the module \textit{name}. If \textit{path} is omitted or None, the list of directory names given by \texttt{sys.path} is searched, but first a few special places are searched: the function tries to find a built-in module with the given name (\texttt{C\_BUILTIN}), then a frozen module (\texttt{PY\_FROZEN}), and on some systems some other places are looked in as well (on Windows, it looks in the registry which may point to a specific file).

Otherwise, \textit{path} must be a list of directory names; each directory is searched for files with any of the suffixes returned by \texttt{get\_suffixes()} above. Invalid names in the list are silently ignored (but all list items must be strings).

If search is successful, the return value is a 3-element tuple (\textit{file}, \textit{pathname}, \textit{description}):

\textit{file} is an open \texttt{file object} positioned at the beginning, \textit{pathname} is the pathname of the file found, and \textit{description} is a 3-element tuple as contained in the list returned by \texttt{get\_suffixes()} describing the kind of module found.

If the module does not live in a file, the returned \textit{file} is None, \textit{pathname} is the empty string, and the \textit{description} tuple contains empty strings for its suffix and mode; the module type is indicated as given in parentheses above. If the search is unsuccessful, \texttt{ImportError} is raised. Other exceptions indicate problems with the arguments or environment.

If the module is a package, \textit{file} is None, \textit{pathname} is the package path and the last item in the \textit{description} tuple is \texttt{PKG\_DIRECTORY}. 
This function does not handle hierarchical module names (names containing dots). In order to find $P.M$, that is, submodule $M$ of package $P$, use `find_module()` and `load_module()` to find and load package $P$, and then use `find_module()` with the `path` argument set to $P.__path__$. When $P$ itself has a dotted name, apply this recipe recursively.

*Deprecated since version 3.3:* Use `importlib.util.find_spec()` instead unless Python 3.3 compatibility is required, in which case use `importlib.find_loader()`.

```
imp.load_module(name, file, pathname, description)
```

Load a module that was previously found by `find_module()` (or by an otherwise conducted search yielding compatible results). This function does more than importing the module: if the module was already imported, it will reload the module! The `name` argument indicates the full module name (including the package name, if this is a submodule of a package). The `file` argument is an open file, and `pathname` is the corresponding file name; these can be None and '', respectively, when the module is a package or not being loaded from a file. The `description` argument is a tuple, as would be returned by `get_suffixes()`, describing what kind of module must be loaded.

If the load is successful, the return value is the module object; otherwise, an exception (usually `ImportError`) is raised.

**Important:** the caller is responsible for closing the `file` argument, if it was not None, even when an exception is raised. This is best done using a `try ... finally` statement.
Deprecated since version 3.3: If previously used in conjunction with `imp.find_module()` then consider using `importlib.import_module()`, otherwise use the loader returned by the replacement you chose for `imp.find_module()`.
If you called `imp.load_module()` and related functions directly then use the classes in `importlib.machinery`, e.g. `importlib.machinery.SourceFileLoader(name, path).load_module()`.

```python
imp.new_module(name)
```

Return a new empty module object called `name`. This object is not inserted in `sys.modules`.

*Deprecated since version 3.4:* Use `types.ModuleType` instead.

```python
imp.reload(module)
```

Reload a previously imported `module`. The argument must be a module object, so it must have been successfully imported before. This is useful if you have edited the module source file using an external editor and want to try out the new version without leaving the Python interpreter. The return value is the module object (the same as the `module` argument).

When `reload(module)` is executed:

- Python modules' code is recompiled and the module-level code reexecuted, defining a new set of objects which are bound to names in the module's dictionary. The `init` function of extension modules is not called a second time.
- As with all other objects in Python the old objects are only reclaimed after their reference counts drop to zero.
- The names in the module namespace are updated to point to any new or changed objects.
- Other references to the old objects (such as names external to the module) are not rebound to refer to the new objects and must be updated in each namespace where they occur if that is desired.

There are a number of other caveats:

When a module is reloaded, its dictionary (containing the module’s global variables) is retained. Redefinitions of names will override the old definitions, so this is generally not a problem. If the new version of a module does not define a name that was defined by the old version, the old definition remains. This feature can be used to the module’s advantage if it maintains a global table or cache of objects — with a `try` statement it can test for the table’s presence and skip its initialization if desired:

```python
try:
    cache
except NameError:
    cache = {}  
```

It is legal though generally not very useful to reload built-in or dynamically loaded modules, except for `sys`, `__main__` and `builtins`. In many cases, however, extension modules are not designed to be initialized more than once, and may fail in arbitrary ways when reloaded.

If a module imports objects from another module using `from ... import ...`, calling `reload()` for the other module does not redefine the objects imported from it — one way around this is to re-execute the `from` statement, another is to use `import` and qualified names (`module.*name*`) instead.

If a module instantiates instances of a class, reloading the module
that defines the class does not affect the method definitions of the instances — they continue to use the old class definition. The same is true for derived classes.

*Changed in version 3.3:* Relies on both `__name__` and `__loader__` being defined on the module being reloaded instead of just `__name__`.

*Deprecated since version 3.4:* Use `importlib.reload()` instead.

The following functions are conveniences for handling PEP 3147 byte-compiled file paths.

*New in version 3.2.*

```python
imp.cache_from_source(path, debug_override=None)
```

Return the PEP 3147 path to the byte-compiled file associated with the source `path`. For example, if `path` is `/foo/bar/baz.py` the return value would be `/foo/bar/__pycache__/baz.cpython-32.pyc` for Python 3.2. The cpython-32 string comes from the current magic tag (see `get_tag()`; if `sys.implementation.cache_tag` is not defined then `NotImplementedError` will be raised). By passing in True or False for `debug_override` you can override the system's value for `__debug__`, leading to optimized bytecode.

`path` need not exist.

*Changed in version 3.3:* If `sys.implementation.cache_tag` is None, then `NotImplementedError` is raised.

*Deprecated since version 3.4:* Use
importlib.util.cache_from_source() instead.

*Changed in version 3.5:* The `debug_override` parameter no longer creates a .pyo file.

```
imp.source_from_cache(path)
```

Given the `path` to a [PEP 3147](https://www.python.org/dev/peps/pep-0314/) file name, return the associated source code file path. For example, if `path` is `/foo/bar/__pycache__/baz.cpython-32.pyc` the returned path would be `/foo/bar/baz.py`. `path` need not exist, however if it does not conform to [PEP 3147](https://www.python.org/dev/peps/pep-0314/) format, a `ValueError` is raised. If `sys.implementation.cache_tag` is not defined, `NotImplementedError` is raised.

*Changed in version 3.3:* Raise `NotImplementedError` when `sys.implementation.cache_tag` is not defined.

```
DeprecationWarning: Since version 3.4: Use importlib.util.source_from_cache() instead.
```

```
imp.get_tag()
```

Return the [PEP 3147](https://www.python.org/dev/peps/pep-0314/) magic tag string matching this version of Python’s magic number, as returned by `get_magic()`.

```
DeprecationWarning: Since version 3.4: Use sys.implementation.cache_tag directly starting in Python 3.3.
```

The following functions help interact with the import system’s internal locking mechanism. Locking semantics of imports are an implementation detail which may vary from release to release. However, Python ensures that circular imports work without any deadlocks.
**imp.lock_held()**

Return True if the global import lock is currently held, else False. On platforms without threads, always return False.

On platforms with threads, a thread executing an import first holds a global import lock, then sets up a per-module lock for the rest of the import. This blocks other threads from importing the same module until the original import completes, preventing other threads from seeing incomplete module objects constructed by the original thread. An exception is made for circular imports, which by construction have to expose an incomplete module object at some point.

*Changed in version 3.3:* The locking scheme has changed to per-module locks for the most part. A global import lock is kept for some critical tasks, such as initializing the per-module locks.

*Deprecated since version 3.4.*

**imp.acquire_lock()**

Acquire the interpreter’s global import lock for the current thread. This lock should be used by import hooks to ensure thread-safety when importing modules.

Once a thread has acquired the import lock, the same thread may acquire it again without blocking; the thread must release it once for each time it has acquired it.

On platforms without threads, this function does nothing.

*Changed in version 3.3:* The locking scheme has changed to per-module locks for the most part. A global import lock is kept for some critical tasks, such as initializing the per-module locks.
Deprecation warnings:

**Deprecated since version 3.4.**

**imp.release_lock()**
Release the interpreter’s global import lock. On platforms without threads, this function does nothing.

*Changed in version 3.3:* The locking scheme has changed to per-module locks for the most part. A global import lock is kept for some critical tasks, such as initializing the per-module locks.

**Deprecation warnings:**

The following constants with integer values, defined in this module, are used to indicate the search result of `find_module()`.

**imp.PY_SOURCE**
The module was found as a source file.

*Deprecation since version 3.3.*

**imp.PY_COMPILED**
The module was found as a compiled code object file.

*Deprecation since version 3.3.*

**imp.C_EXTENSION**
The module was found as dynamically loadable shared library.

*Deprecation since version 3.3.*

**imp.PKG_DIRECTORY**
The module was found as a package directory.

*Deprecation since version 3.3.*
imp.C_BUILTIN
The module was found as a built-in module.

*Deprecated since version 3.3.*

imp.PY_FROZEN
The module was found as a frozen module.

*Deprecated since version 3.3.*

class imp.NullImporter(path_string)
The NullImporter type is a PEP 302 import hook that handles non-directory path strings by failing to find any modules. Calling this type with an existing directory or empty string raises `ImportError`. Otherwise, a NullImporter instance is returned.

Instances have only one method:

**find_module**(fullname[, path])
This method always returns None, indicating that the requested module could not be found.

*Changed in version 3.3*: None is inserted into `sys.path_importer_cache` instead of an instance of NullImporter.

*Deprecated since version 3.4*: Insert None into `sys.path_importer_cache` instead.
36.2.1. Examples

The following function emulates what was the standard import statement up to Python 1.4 (no hierarchical module names). (This implementation wouldn’t work in that version, since `find_module()` has been extended and `load_module()` has been added in 1.4.)

```python
import imp
import sys

def __import__(name, globals=None, locals=None, fromlist=[]):
    # Fast path: see if the module has already been imported.
    try:
        return sys.modules[name]
    except KeyError:
        pass

    # If any of the following calls raises an exception,
    # there's a problem we can't handle -- let the caller handle it.
    fp, pathname, description = imp.find_module(name, fromlist=[])

    try:
        return imp.load_module(name, fp, pathname, description)
    finally:
        # Since we may exit via an exception, close the file.
        if fp:
            fp.close()
```

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37. Undocumented Modules

Here’s a quick listing of modules that are currently undocumented, but that should be documented. Feel free to contribute documentation for them! (Send via email to docs@python.org.)

The idea and original contents for this chapter were taken from a posting by Fredrik Lundh; the specific contents of this chapter have been substantially revised.
37.1. Platform specific modules

These modules are used to implement the `os.path` module, and are not documented beyond this mention. There’s little need to document these.

`ntpath`
- Implementation of `os.path` on Win32, Win64, and WinCE platforms.

`posixpath`
- Implementation of `os.path` on POSIX.
1. Extending Python with C or C++

It is quite easy to add new built-in modules to Python, if you know how to program in C. Such extension modules can do two things that can’t be done directly in Python: they can implement new built-in object types, and they can call C library functions and system calls.

To support extensions, the Python API (Application Programmers Interface) defines a set of functions, macros and variables that provide access to most aspects of the Python run-time system. The Python API is incorporated in a C source file by including the header "Python.h".

The compilation of an extension module depends on its intended use as well as on your system setup; details are given in later chapters.

**Note:** The C extension interface is specific to CPython, and extension modules do not work on other Python implementations. In many cases, it is possible to avoid writing C extensions and preserve portability to other implementations. For example, if your use case is calling C library functions or system calls, you should consider using the `ctypes` module or the `cffi` library rather than writing custom C code. These modules let you write Python code to interface with C code and are more portable between implementations of Python than writing and compiling a C extension module.
1.1. A Simple Example

Let's create an extension module called spam (the favorite food of Monty Python fans...) and let's say we want to create a Python interface to the C library function system(). [1] This function takes a null-terminated character string as argument and returns an integer. We want this function to be callable from Python as follows:

```python
>>> import spam
>>> status = spam.system("ls -l")
```

Begin by creating a file spammodule.c. (Historically, if a module is called spam, the C file containing its implementation is called spammodule.c; if the module name is very long, like spammify, the module name can be just spammify.c.)

The first line of our file can be:

```c
#include <Python.h>
```

which pulls in the Python API (you can add a comment describing the purpose of the module and a copyright notice if you like).

**Note:** Since Python may define some preprocessor definitions which affect the standard headers on some systems, you must include Python.h before any standard headers are included.

All user-visible symbols defined by Python.h have a prefix of Py or PY, except those defined in standard header files. For convenience, and since they are used extensively by the Python interpreter, "Python.h" includes a few standard header files: <stdio.h>,
<string.h>, <errno.h>, and <stdlib.h>. If the latter header file does not exist on your system, it declares the functions malloc(), free() and realloc() directly.

The next thing we add to our module file is the C function that will be called when the Python expression spam.system(string) is evaluated (we'll see shortly how it ends up being called):

```c
static PyObject *
spam_system(PyObject *self, PyObject *args)
{
    const char *command;
    int sts;

    if (!PyArg_ParseTuple(args, "s", &command))
        return NULL;
    sts = system(command);
    return PyLong_FromLong(sts);
}
```

There is a straightforward translation from the argument list in Python (for example, the single expression "ls -l") to the arguments passed to the C function. The C function always has two arguments, conventionally named `self` and `args`.

The `self` argument points to the module object for module-level functions; for a method it would point to the object instance.

The `args` argument will be a pointer to a Python tuple object containing the arguments. Each item of the tuple corresponds to an argument in the call's argument list. The arguments are Python objects — in order to do anything with them in our C function we have to convert them to C values. The function `PyArg_ParseTuple()` in the Python API checks the argument types and converts them to C values. It uses a
template string to determine the required types of the arguments as well as the types of the C variables into which to store the converted values. More about this later.

`PyArg_ParseTuple()` returns true (nonzero) if all arguments have the right type and its components have been stored in the variables whose addresses are passed. It returns false (zero) if an invalid argument list was passed. In the latter case it also raises an appropriate exception so the calling function can return `NULL` immediately (as we saw in the example).
1.2. Intermezzo: Errors and Exceptions

An important convention throughout the Python interpreter is the following: when a function fails, it should set an exception condition and return an error value (usually a NULL pointer). Exceptions are stored in a static global variable inside the interpreter; if this variable is NULL no exception has occurred. A second global variable stores the “associated value” of the exception (the second argument to `raise`). A third variable contains the stack traceback in case the error originated in Python code. These three variables are the C equivalents of the result in Python of `sys.exc_info()` (see the section on module `sys` in the Python Library Reference). It is important to know about them to understand how errors are passed around.

The Python API defines a number of functions to set various types of exceptions.

The most common one is `PyErr_SetString()`. Its arguments are an exception object and a C string. The exception object is usually a predefined object like `PyExc_ZeroDivisionError`. The C string indicates the cause of the error and is converted to a Python string object and stored as the “associated value” of the exception.

Another useful function is `PyErr_SetFromErrno()`, which only takes an exception argument and constructs the associated value by inspection of the global variable `errno`. The most general function is `PyErr_SetObject()`, which takes two object arguments, the exception and its associated value. You don’t need to `Py_INCREF()` the objects passed to any of these functions.

You can test non-destructively whether an exception has been set with
**PyErr_Occurred()**. This returns the current exception object, or **NULL** if no exception has occurred. You normally don't need to call **PyErr_Occurred()** to see whether an error occurred in a function call, since you should be able to tell from the return value.

When a function \( f \) that calls another function \( g \) detects that the latter fails, \( f \) should itself return an error value (usually **NULL** or -1). It should not call one of the **PyErr_***( ) functions — one has already been called by \( g \). \( f \)'s caller is then supposed to also return an error indication to its caller, again without calling **PyErr_***( ), and so on — the most detailed cause of the error was already reported by the function that first detected it. Once the error reaches the Python interpreter’s main loop, this aborts the currently executing Python code and tries to find an exception handler specified by the Python programmer.

(There are situations where a module can actually give a more detailed error message by calling another **PyErr_***( ) function, and in such cases it is fine to do so. As a general rule, however, this is not necessary, and can cause information about the cause of the error to be lost: most operations can fail for a variety of reasons.)

To ignore an exception set by a function call that failed, the exception condition must be cleared explicitly by calling **PyErr_Clear()**. The only time C code should call **PyErr_Clear()** is if it doesn't want to pass the error on to the interpreter but wants to handle it completely by itself (possibly by trying something else, or pretending nothing went wrong).

Every failing **malloc()** call must be turned into an exception — the direct caller of **malloc()** (or **realloc()**) must call **PyErr_NoMemory()** and return a failure indicator itself. All the object-
creating functions (for example, `PyLong_FromLong()`) already do this, so this note is only relevant to those who call `malloc()` directly.

Also note that, with the important exception of `PyArg_ParseTuple()` and friends, functions that return an integer status usually return a positive value or zero for success and `-1` for failure, like Unix system calls.

Finally, be careful to clean up garbage (by making `Py_XDECREF()` or `Py_DECREF()` calls for objects you have already created) when you return an error indicator!

The choice of which exception to raise is entirely yours. There are predeclared C objects corresponding to all built-in Python exceptions, such as `PyExc_ZeroDivisionError`, which you can use directly. Of course, you should choose exceptions wisely — don’t use `PyExc_TypeError` to mean that a file couldn’t be opened (that should probably be `PyExc_IOError`). If something’s wrong with the argument list, the `PyArg_ParseTuple()` function usually raises `PyExc_TypeError`. If you have an argument whose value must be in a particular range or must satisfy other conditions, `PyExc_ValueError` is appropriate.

You can also define a new exception that is unique to your module. For this, you usually declare a static object variable at the beginning of your file:

```c
static PyObject *SpamError;
```

and initialize it in your module’s initialization function (`PyInit_spam()`) with an exception object (leaving out the error checking for now):
PyMODINIT_FUNC
PyInit_spam(void)
{
    PyObject *m;

    m = PyModule_Create(&spammodule);
    if (m == NULL)
        return NULL;

    SpamError = PyErr_NewException("spam.error", NULL);
    Py_INCREF(SpamError);
    PyModule_AddObject(m, "error", SpamError);
    return m;
}

Note that the Python name for the exception object is spam.error. The PyErr_NewException() function may create a class with the base class being Exception (unless another class is passed in instead of NULL), described in Built-in Exceptions.

Note also that the SpamError variable retains a reference to the newly created exception class; this is intentional! Since the exception could be removed from the module by external code, an owned reference to the class is needed to ensure that it will not be discarded, causing SpamError to become a dangling pointer. Should it become a dangling pointer, C code which raises the exception could cause a core dump or other unintended side effects.

We discuss the use of PyMODINIT_FUNC as a function return type later in this sample.

The spam.error exception can be raised in your extension module using a call to PyErr_SetString() as shown below:
static PyObject *
spam_system(PyObject *self, PyObject *args)
{
    const char *command;
    int sts;

    if (!PyArg_ParseTuple(args, "s", &command))
        return NULL;
    sts = system(command);
    if (sts < 0) {
        PyErr_SetString(SpamError, "System command failed");
        return NULL;
    }
    return PyLong_FromLong(sts);
}
1.3. Back to the Example

Going back to our example function, you should now be able to understand this statement:

```c
if (!PyArg_ParseTuple(args, "s", &command))
    return NULL;
```

It returns `NULL` (the error indicator for functions returning object pointers) if an error is detected in the argument list, relying on the exception set by `PyArg_ParseTuple()`. Otherwise the string value of the argument has been copied to the local variable `command`. This is a pointer assignment and you are not supposed to modify the string to which it points (so in Standard C, the variable `command` should properly be declared as `const char *command`).

The next statement is a call to the Unix function `system()`, passing it the string we just got from `PyArg_ParseTuple()`:

```c
sts = system(command);
```

Our `spam.system()` function must return the value of `sts` as a Python object. This is done using the function `PyLong_FromLong()`.

```c
return PyLong_FromLong(sts);
```

In this case, it will return an integer object. (Yes, even integers are objects on the heap in Python!)

If you have a C function that returns no useful argument (a function returning `void`), the corresponding Python function must return `None`. You need this idiom to do so (which is implemented by the
Py_RETURN_NONE macro):

```c
Py_INCREF(Py_None);
return Py_None;
```

*Py_None* is the C name for the special Python object None. It is a genuine Python object rather than a *NULL* pointer, which means “error” in most contexts, as we have seen.
1.4. The Module’s Method Table and Initialization Function

I promised to show how spam_system() is called from Python programs. First, we need to list its name and address in a “method table”:

```c
static PyMethodDef SpamMethods[] = {
    ...
    {"system", spam_system, METH_VARARGS,
        "Execute a shell command."},
    ...
    {NULL, NULL, 0, NULL} /* Sentinel */
};
```

Note the third entry (METH_VARARGS). This is a flag telling the interpreter the calling convention to be used for the C function. It should normally always be METH_VARARGS or METH_VARARGS | METH_KEYWORDS; a value of 0 means that an obsolete variant of PyArg_ParseTuple() is used.

When using only METH_VARARGS, the function should expect the Python-level parameters to be passed in as a tuple acceptable for parsing via PyArg_ParseTuple(); more information on this function is provided below.

The METH_KEYWORDS bit may be set in the third field if keyword arguments should be passed to the function. In this case, the C function should accept a third PyObject * parameter which will be a dictionary of keywords. Use PyArg_ParseTupleAndKeywords() to parse the arguments to such a function.
The method table must be referenced in the module definition structure:

```c
static struct PyModuleDef spammodule = {
    PyModuleDef_HEAD_INIT,
    "spam",    /* name of module */
    spam_doc, /* module documentation, may be NULL */
    -1,    /* size of per-interpreter state of the
            or -1 if the module keeps state in global
    SpamMethods
};
```

This structure, in turn, must be passed to the interpreter in the module's initialization function. The initialization function must be named `PyInit_name()`, where `name` is the name of the module, and should be the only non-static item defined in the module file:

```c
PyMODINIT_FUNC
PyInit_spam(void)
{
    return PyModule_Create(&spammodule);
}
```

Note that `PyMODINIT_FUNC` declares the function as `PyObject *` return type, declares any special linkage declarations required by the platform, and for C++ declares the function as `extern "C"`.

When the Python program imports module `spam` for the first time, `PyInit_spam()` is called. (See below for comments about embedding Python.) It calls `PyModule_Create()`, which returns a module object, and inserts built-in function objects into the newly created module based upon the table (an array of `PyMethodDef` structures) found in the module definition. `PyModule_Create()`
returns a pointer to the module object that it creates. It may abort with a fatal error for certain errors, or return NULL if the module could not be initialized satisfactorily. The init function must return the module object to its caller, so that it then gets inserted into sys.modules.

When embedding Python, the PyInit_spam() function is not called automatically unless there's an entry in the PyImport_Inittab table. To add the module to the initialization table, use PyImport_AppendInittab(), optionally followed by an import of the module:

```c
int main(int argc, char *argv[]) {
    wchar_t *program = Py_DecodeLocale(argv[0], NULL);
    if (program == NULL) {
        fprintf(stderr, "Fatal error: cannot decode argv[0]"
                exit(1);
    }

    /* Add a built-in module, before Py_Initialize */
    PyImport_AppendInittab("spam", PyInit_spam);

    /* Pass argv[0] to the Python interpreter */
    Py_SetProgramName(program);

    /* Initialize the Python interpreter. Required. */
    Py_Initialize();

    /* Optionally import the module; alternatively, import can be deferred until the embedded script imports it. */
    PyImport_ImportModule("spam");

    ...
```
PyMem_RawFree(program);
return 0;
}

Note: Removing entries from sys.modules or importing compiled modules into multiple interpreters within a process (or following a fork() without an intervening exec()) can create problems for some extension modules. Extension module authors should exercise caution when initializing internal data structures.

A more substantial example module is included in the Python source distribution as Modules/xxmodule.c. This file may be used as a template or simply read as an example.

Note: Unlike our spam example, xxmodule uses multi-phase initialization (new in Python 3.5), where a PyModuleDef structure is returned from PyInit_spam, and creation of the module is left to the import machinery. For details on multi-phase initialization, see PEP 489.
1.5. Compilation and Linkage

There are two more things to do before you can use your new extension: compiling and linking it with the Python system. If you use dynamic loading, the details may depend on the style of dynamic loading your system uses; see the chapters about building extension modules (chapter Building C and C++ Extensions) and additional information that pertains only to building on Windows (chapter Building C and C++ Extensions on Windows) for more information about this.

If you can't use dynamic loading, or if you want to make your module a permanent part of the Python interpreter, you will have to change the configuration setup and rebuild the interpreter. Luckily, this is very simple on Unix: just place your file (spammodule.c for example) in the Modules/ directory of an unpacked source distribution, add a line to the file Modules/Setup.local describing your file:

```
spam spammodule.o
```

and rebuild the interpreter by running `make` in the toplevel directory. You can also run `make` in the Modules/ subdirectory, but then you must first rebuild Makefile there by running 'make Makefile'. (This is necessary each time you change the Setup file.)

If your module requires additional libraries to link with, these can be listed on the line in the configuration file as well, for instance:

```
spam spammodule.o -lX11
```
1.6. Calling Python Functions from C

So far we have concentrated on making C functions callable from Python. The reverse is also useful: calling Python functions from C. This is especially the case for libraries that support so-called “callback” functions. If a C interface makes use of callbacks, the equivalent Python often needs to provide a callback mechanism to the Python programmer; the implementation will require calling the Python callback functions from a C callback. Other uses are also imaginable.

Fortunately, the Python interpreter is easily called recursively, and there is a standard interface to call a Python function. (I won’t dwell on how to call the Python parser with a particular string as input — if you’re interested, have a look at the implementation of the -c command line option in Modules/main.c from the Python source code.)

Calling a Python function is easy. First, the Python program must somehow pass you the Python function object. You should provide a function (or some other interface) to do this. When this function is called, save a pointer to the Python function object (be careful to `Py_INCREF()` it!) in a global variable — or wherever you see fit. For example, the following function might be part of a module definition:

```c
static PyObject *my_callback = NULL;

static PyObject *
my_set_callback(PyObject *dummy, PyObject *args)
{
    PyObject *result = NULL;
    PyObject *temp;

    if (PyArg_ParseTuple(args, "O:set_callback", &te
```
if (!PyCallable_Check(temp)) {
    PyErr_SetString(PyExc_TypeError, "parameter must be callable"),
    return NULL;
}
Py_INCREF(temp);  /* Add a reference to new callback */
Py_XDECREF(my_callback);  /* Dispose of previous callback */
my_callback = temp;  /* Remember new callback */
/* Boilerplate to return "None" */
Py_INCREF(Py_None);
result = Py_None;
}
return result;

This function must be registered with the interpreter using the METH_VARARGS flag; this is described in section The Module's Method Table and Initialization Function. The PyArg_ParseTuple() function and its arguments are documented in section Extracting Parameters in Extension Functions.

The macros Py_INCREF() and Py_XDECREF() increment/decrement the reference count of an object and are safe in the presence of NULL pointers (but note that temp will not be NULL in this context). More info on them in section Reference Counts.

Later, when it is time to call the function, you call the C function PyObject_CallObject(). This function has two arguments, both pointers to arbitrary Python objects: the Python function, and the argument list. The argument list must always be a tuple object, whose length is the number of arguments. To call the Python function with no arguments, pass in NULL, or an empty tuple; to call it with one argument, pass a singleton tuple. Py_BuildValue() returns a tuple when its format string consists of zero or more format codes between
parentheses. For example:

```c
int arg;
PyObject *arglist;
PyObject *result;
...
arg = 123;
...
/* Time to call the callback */
arglist = Py_BuildValue("(i)", arg);
result = PyObject_CallObject(my_callback, arglist);
Py_DECREF(arglist);
```

`PyObject_CallObject()` returns a Python object pointer: this is the return value of the Python function. `PyObject_CallObject()` is “reference-count-neutral” with respect to its arguments. In the example a new tuple was created to serve as the argument list, which is `Py_DECREF()`-ed immediately after the `PyObject_CallObject()` call.

The return value of `PyObject_CallObject()` is “new”: either it is a brand new object, or it is an existing object whose reference count has been incremented. So, unless you want to save it in a global variable, you should somehow `Py_DECREF()` the result, even (especially!) if you are not interested in its value.

Before you do this, however, it is important to check that the return value isn’t `NULL`. If it is, the Python function terminated by raising an exception. If the C code that called `PyObject_CallObject()` is called from Python, it should now return an error indication to its Python caller, so the interpreter can print a stack trace, or the calling Python code can handle the exception. If this is not possible or desirable, the exception should be cleared by calling
PyErr_Clear(). For example:

```python
if (result == NULL)
    return NULL; /* Pass error back */
...
use result...
Py_DecREF(result);
```

Depending on the desired interface to the Python callback function, you may also have to provide an argument list to `PyObject_CallObject()`. In some cases the argument list is also provided by the Python program, through the same interface that specified the callback function. It can then be saved and used in the same manner as the function object. In other cases, you may have to construct a new tuple to pass as the argument list. The simplest way to do this is to call `Py_BuildValue()`. For example, if you want to pass an integral event code, you might use the following code:

```python
PyObject *arglist;
...
arglist = Py_BuildValue("(l)", eventcode);
result = PyObject_CallObject(my_callback, arglist);
Py_DecREF(arglist);
if (result == NULL)
    return NULL; /* Pass error back */
/* Here maybe use the result */
Py_DecREF(result);
```

Note the placement of `Py_DecREF(arglist)` immediately after the call, before the error check! Also note that strictly speaking this code is not complete: `Py_BuildValue()` may run out of memory, and this should be checked.

You may also call a function with keyword arguments by using `PyObject_Call()`, which supports arguments and keyword
Arguments. As in the above example, we use `Py_BuildValue()` to construct the dictionary.

```c
PyObject *dict;
...
dict = Py_BuildValue("{s:i}", "name", val);
result = PyObject_Call(my_callback, NULL, dict);
Py_DECREF(dict);
if (result == NULL)
    return NULL; /* Pass error back */
/* Here maybe use the result */
Py_DECREF(result);
```
1.7. Extracting Parameters in Extension Functions

The `Py Arg_ParseTuple()` function is declared as follows:

```
int PyArg_ParseTuple(PyObject *arg, const char *format)
```

The `arg` argument must be a tuple object containing an argument list passed from Python to a C function. The `format` argument must be a format string, whose syntax is explained in Parsing arguments and building values in the Python/C API Reference Manual. The remaining arguments must be addresses of variables whose type is determined by the format string.

Note that while `PyArg_ParseTuple()` checks that the Python arguments have the required types, it cannot check the validity of the addresses of C variables passed to the call: if you make mistakes there, your code will probably crash or at least overwrite random bits in memory. So be careful!

Note that any Python object references which are provided to the caller are borrowed references; do not decrement their reference count!

Some example calls:

```
#define PY_SSIZE_T_CLEAN /* Make "s#" use Py_ssize_t */
#include <Python.h>

int ok;
int i, j;
```
long k, l;
const char *s;
Py_ssize_t size;

ok = PyArg_ParseTuple(args, ""); /* No arguments */
    /* Python call: f() */

ok = PyArg_ParseTuple(args, "s", &s); /* A string */
    /* Possible Python call: f('whoops!') */

ok = PyArg_ParseTuple(args, "lls", &k, &l, &s); /* Two longs and a string */
    /* Possible Python call: f(1, 2, 'three') */

ok = PyArg_ParseTuple(args, "(ii)s#", &i, &j, &s, &size);
    /* A pair of ints and a string, whose size is also returned */
    /* Possible Python call: f((1, 2), 'three') */

{ const char *file;
  const char *mode = "r";
  int bufsize = 0;
  ok = PyArg_ParseTuple(args, "s|si", &file, &mode);
  /* A string, and optionally another string and an integer */
  /* Possible Python calls: */
  f('spam')
  f('spam', 'w')
  f('spam', 'wb', 100000) */
}

{ int left, top, right, bottom, h, v;
  ok = PyArg_ParseTuple(args, "(((ii))(ii))(ii)",
                        &left, &top, &right, &bottom, &h, &v);
/* A rectangle and a point */
/* Possible Python call:
f(((0, 0), (400, 300)), (10, 10)) */

{
    Py_complex c;
    ok = PyArg_ParseTuple(args, "D:myfunction", &c);
    /* a complex, also providing a function name for */
    /* Possible Python call: myfunction(1+2j) */
}
1.8. Keyword Parameters for Extension Functions

The `PyArg_ParseTupleAndKeywords()` function is declared as follows:

```
int PyArg_ParseTupleAndKeywords(PyObject *arg, PyObject const char *format,
                                 const PyObject *kwdict, const char *kwlist)
```

The `arg` and `format` parameters are identical to those of the `PyArg_ParseTuple()` function. The `kwdict` parameter is the dictionary of keywords received as the third parameter from the Python runtime. The `kwlist` parameter is a `NULL`-terminated list of strings which identify the parameters; the names are matched with the type information from `format` from left to right. On success, `PyArg_ParseTupleAndKeywords()` returns true, otherwise it returns false and raises an appropriate exception.

**Note:** Nested tuples cannot be parsed when using keyword arguments! Keyword parameters passed in which are not present in the `kwlist` will cause `TypeError` to be raised.

Here is an example module which uses keywords, based on an example by Geoff Philbrick (philbrick@hks.com):

```
#include "Python.h"

static PyObject *
keywdarg_parrot(PyObject *self, PyObject *args, PyObject *kwds)
{
    int voltage;
```
char *state = "a stiff";
char *action = "voom";
char *type = "Norwegian Blue";

static char *kwlist[] = {"voltage", "state", "action"};

if (!PyArg_ParseTupleAndKeywords(args, keywds, "i|sss", &voltage, &state, &action))
    return NULL;

printf("-- This parrot wouldn't %s if you put %i Volts through it.
        "action, voltage);
printf("-- Lovely plumage, the %s -- It's %s!\n");
return PyModule_Create(&keywdargmodule);
1.9. Building Arbitrary Values

This function is the counterpart to `PyArg_ParseTuple()`. It is declared as follows:

```c
PyObject *Py_BuildValue(const char *format, ...);
```

It recognizes a set of format units similar to the ones recognized by `PyArg_ParseTuple()`, but the arguments (which are input to the function, not output) must not be pointers, just values. It returns a new Python object, suitable for returning from a C function called from Python.

One difference with `PyArg_ParseTuple()`: while the latter requires its first argument to be a tuple (since Python argument lists are always represented as tuples internally), `Py_BuildValue()` does not always build a tuple. It builds a tuple only if its format string contains two or more format units. If the format string is empty, it returns None; if it contains exactly one format unit, it returns whatever object is described by that format unit. To force it to return a tuple of size 0 or one, parenthesize the format string.

Examples (to the left the call, to the right the resulting Python value):

```c
Py_BuildValue(""")                    None
Py_BuildValue("i", 123)              123
Py_BuildValue("iii", 123, 456, 789)  (123, 456, 789)
Py_BuildValue("s", "hello")         'hello'
Py_BuildValue("y", "hello")         b'hello'
Py_BuildValue("ss", "hello", "world") ('hello', 'world')
Py_BuildValue("s#", "hello", 4)     'hell'
Py_BuildValue("y#", "hello", 4)     b'hell'
Py_BuildValue("()")                   ()
```
Py_BuildValue("(i)", 123) (123,)
Py_BuildValue("(ii)", 123, 456) (123, 456)
Py_BuildValue("(i,i)", 123, 456) (123, 456)
Py_BuildValue("[i,i]", 123, 456) [123, 456]
Py_BuildValue("{s:i,s:i}",
   "abc", 123, "def", 456) {'abc': 123
Py_BuildValue("((ii)(ii)) (ii)",
  1, 2, 3, 4, 5, 6) (((1, 2), (3, 4)), (5, 6))
1.10. Reference Counts

In languages like C or C++, the programmer is responsible for dynamic allocation and deallocation of memory on the heap. In C, this is done using the functions malloc() and free(). In C++, the operators new and delete are used with essentially the same meaning and we'll restrict the following discussion to the C case.

Every block of memory allocated with malloc() should eventually be returned to the pool of available memory by exactly one call to free(). It is important to call free() at the right time. If a block's address is forgotten but free() is not called for it, the memory it occupies cannot be reused until the program terminates. This is called a memory leak. On the other hand, if a program calls free() for a block and then continues to use the block, it creates a conflict with re-use of the block through another malloc() call. This is called using freed memory. It has the same bad consequences as referencing uninitialized data — core dumps, wrong results, mysterious crashes.

Common causes of memory leaks are unusual paths through the code. For instance, a function may allocate a block of memory, do some calculation, and then free the block again. Now a change in the requirements for the function may add a test to the calculation that detects an error condition and can return prematurely from the function. It's easy to forget to free the allocated memory block when taking this premature exit, especially when it is added later to the code. Such leaks, once introduced, often go undetected for a long time: the error exit is taken only in a small fraction of all calls, and most modern machines have plenty of virtual memory, so the leak only becomes apparent in a long-running process that uses the leaking function frequently. Therefore, it's important to prevent leaks from
happening by having a coding convention or strategy that minimizes this kind of errors.

Since Python makes heavy use of malloc() and free(), it needs a strategy to avoid memory leaks as well as the use of freed memory. The chosen method is called reference counting. The principle is simple: every object contains a counter, which is incremented when a reference to the object is stored somewhere, and which is decremented when a reference to it is deleted. When the counter reaches zero, the last reference to the object has been deleted and the object is freed.

An alternative strategy is called automatic garbage collection. (Sometimes, reference counting is also referred to as a garbage collection strategy, hence my use of “automatic” to distinguish the two.) The big advantage of automatic garbage collection is that the user doesn’t need to call free() explicitly. (Another claimed advantage is an improvement in speed or memory usage — this is no hard fact however.) The disadvantage is that for C, there is no truly portable automatic garbage collector, while reference counting can be implemented portably (as long as the functions malloc() and free() are available — which the C Standard guarantees). Maybe some day a sufficiently portable automatic garbage collector will be available for C. Until then, we’ll have to live with reference counts.

While Python uses the traditional reference counting implementation, it also offers a cycle detector that works to detect reference cycles. This allows applications to not worry about creating direct or indirect circular references; these are the weakness of garbage collection implemented using only reference counting. Reference cycles consist of objects which contain (possibly indirect) references to themselves, so that each object in the cycle has a reference count which is non-
zero. Typical reference counting implementations are not able to reclaim the memory belonging to any objects in a reference cycle, or referenced from the objects in the cycle, even though there are no further references to the cycle itself.

The cycle detector is able to detect garbage cycles and can reclaim them. The gc module exposes a way to run the detector (the \texttt{collect()} function), as well as configuration interfaces and the ability to disable the detector at runtime. The cycle detector is considered an optional component; though it is included by default, it can be disabled at build time using the \texttt{--without-cycle-gc} option to the \texttt{configure} script on Unix platforms (including Mac OS X). If the cycle detector is disabled in this way, the gc module will not be available.

\subsection*{1.10.1. Reference Counting in Python}

There are two macros, \texttt{Py_INCREF(x)} and \texttt{Py_DECREF(x)}, which handle the incrementing and decrementing of the reference count. \texttt{Py_DECREF()} also frees the object when the count reaches zero. For flexibility, it doesn’t call \texttt{free()} directly — rather, it makes a call through a function pointer in the object’s \texttt{type object}. For this purpose (and others), every object also contains a pointer to its type object.

The big question now remains: when to use \texttt{Py_INCREF(x)} and \texttt{Py_DECREF(x)}? Let’s first introduce some terms. Nobody “owns” an object; however, you can \textit{own a reference} to an object. An object’s reference count is now defined as the number of owned references to it. The owner of a reference is responsible for calling \texttt{Py_DECREF()} when the reference is no longer needed. Ownership of a reference can be transferred. There are three ways to dispose of an owned
reference: pass it on, store it, or call `Py_DECREF()`. Forgetting to dispose of an owned reference creates a memory leak.

It is also possible to *borrow* [2] a reference to an object. The borrower of a reference should not call `Py_DECREF()`. The borrower must not hold on to the object longer than the owner from which it was borrowed. Using a borrowed reference after the owner has disposed of it risks using freed memory and should be avoided completely. [3]

The advantage of borrowing over owning a reference is that you don’t need to take care of disposing of the reference on all possible paths through the code — in other words, with a borrowed reference you don’t run the risk of leaking when a premature exit is taken. The disadvantage of borrowing over owning is that there are some subtle situations where in seemingly correct code a borrowed reference can be used after the owner from which it was borrowed has in fact disposed of it.

A borrowed reference can be changed into an owned reference by calling `Py_INCREF()`. This does not affect the status of the owner from which the reference was borrowed — it creates a new owned reference, and gives full owner responsibilities (the new owner must dispose of the reference properly, as well as the previous owner).

### 1.10.2. Ownership Rules

Whenever an object reference is passed into or out of a function, it is part of the function’s interface specification whether ownership is transferred with the reference or not.

Most functions that return a reference to an object pass on ownership with the reference. In particular, all functions whose function it is to
create a new object, such as `PyLong_FromLong()` and `Py_BuildValue()`, pass ownership to the receiver. Even if the object is not actually new, you still receive ownership of a new reference to that object. For instance, `PyLong_FromLong()` maintains a cache of popular values and can return a reference to a cached item.

Many functions that extract objects from other objects also transfer ownership with the reference, for instance `PyObject_GetAttrString()`. The picture is less clear, here, however, since a few common routines are exceptions: `PyTuple_GetItem()`, `PyList_GetItem()`, `PyDict_GetItem()`, and `PyDict_GetItemString()` all return references that you borrow from the tuple, list or dictionary.

The function `PyImport_AddModule()` also returns a borrowed reference, even though it may actually create the object it returns: this is possible because an owned reference to the object is stored in `sys.modules`.

When you pass an object reference into another function, in general, the function borrows the reference from you — if it needs to store it, it will use `Py_INCREF()` to become an independent owner. There are exactly two important exceptions to this rule: `PyTuple_SetItem()` and `PyList_SetItem()`. These functions take over ownership of the item passed to them — even if they fail! (Note that `PyDict_SetItem()` and friends don’t take over ownership — they are “normal.”)

When a C function is called from Python, it borrows references to its arguments from the caller. The caller owns a reference to the object, so the borrowed reference’s lifetime is guaranteed until the function returns. Only when such a borrowed reference must be stored or
passed on, it must be turned into an owned reference by calling `Py_INCREF()`.

The object reference returned from a C function that is called from Python must be an owned reference — ownership is transferred from the function to its caller.

### 1.10.3. Thin Ice

There are a few situations where seemingly harmless use of a borrowed reference can lead to problems. These all have to do with implicit invocations of the interpreter, which can cause the owner of a reference to dispose of it.

The first and most important case to know about is using `Py_DECREF()` on an unrelated object while borrowing a reference to a list item. For instance:

```c
void
bug(PyObject *list)
{
    PyObject *item = PyList_GetItem(list, 0);

    PyList_SetItem(list, 1, PyLong_FromLong(0L));
    PyObject_Print(item, stdout, 0); /* BUG! */
}
```

This function first borrows a reference to `list[0]`, then replaces `list[1]` with the value 0, and finally prints the borrowed reference. Looks harmless, right? But it’s not!

Let’s follow the control flow into `PyList_SetItem()`. The list owns references to all its items, so when item 1 is replaced, it has to dispose
of the original item 1. Now let's suppose the original item 1 was an instance of a user-defined class, and let's further suppose that the class defined a \_\_del\_\_() method. If this class instance has a reference count of 1, disposing of it will call its \_\_del\_\_() method.

Since it is written in Python, the \_\_del\_\_() method can execute arbitrary Python code. Could it perhaps do something to invalidate the reference to item in bug()? You bet! Assuming that the list passed into bug() is accessible to the \_\_del\_\_() method, it could execute a statement to the effect of del list[0], and assuming this was the last reference to that object, it would free the memory associated with it, thereby invalidating item.

The solution, once you know the source of the problem, is easy: temporarily increment the reference count. The correct version of the function reads:

```c
void no_bug(PyObject *list)
{
    PyObject *item = PyList_GetItem(list, 0);

    Py_INCREF(item);
    PyList_SetItem(list, 1, PyLong_FromLong(0L));
    PyObject_Print(item, stdout, 0);
    Py_DECREF(item);
}
```

This is a true story. An older version of Python contained variants of this bug and someone spent a considerable amount of time in a C debugger to figure out why his \_\_del\_\_() methods would fail...

The second case of problems with a borrowed reference is a variant involving threads. Normally, multiple threads in the Python interpreter
can't get in each other's way, because there is a global lock protecting Python's entire object space. However, it is possible to temporarily release this lock using the macro `Py_BEGIN_ALLOW_THREADS`, and to re-acquire it using `Py_END_ALLOW_THREADS`. This is common around blocking I/O calls, to let other threads use the processor while waiting for the I/O to complete. Obviously, the following function has the same problem as the previous one:

```c
void
bug(PyObject *list)
{
    PyObject *item = PyList_GetItem(list, 0);
    Py_BEGIN_ALLOW_THREADS
    ...some blocking I/O call...
    Py_END_ALLOW_THREADS
    PyObject_Print(item, stdout, 0); /* BUG! */
}
```

1.10.4. NULL Pointers

In general, functions that take object references as arguments do not expect you to pass them `NULL` pointers, and will dump core (or cause later core dumps) if you do so. Functions that return object references generally return `NULL` only to indicate that an exception occurred. The reason for not testing for `NULL` arguments is that functions often pass the objects they receive on to other function — if each function were to test for `NULL`, there would be a lot of redundant tests and the code would run more slowly.

It is better to test for `NULL` only at the “source:” when a pointer that may be `NULL` is received, for example, from `malloc()` or from a function that may raise an exception.
The macros `Py_INCREF()` and `Py_DECREF()` do not check for `NULL` pointers — however, their variants `Py_XINCREF()` and `Py_XDECREF()` do.

The macros for checking for a particular object type (`PyObject_TypeCheck()`) don’t check for `NULL` pointers — again, there is much code that calls several of these in a row to test an object against various different expected types, and this would generate redundant tests. There are no variants with `NULL` checking.

The C function calling mechanism guarantees that the argument list passed to C functions (`args` in the examples) is never `NULL` — in fact it guarantees that it is always a tuple. [4]

It is a severe error to ever let a `NULL` pointer “escape” to the Python user.
1.11. Writing Extensions in C++

It is possible to write extension modules in C++. Some restrictions apply. If the main program (the Python interpreter) is compiled and linked by the C compiler, global or static objects with constructors cannot be used. This is not a problem if the main program is linked by the C++ compiler. Functions that will be called by the Python interpreter (in particular, module initialization functions) have to be declared using extern "C". It is unnecessary to enclose the Python header files in extern "C" {...} — they use this form already if the symbol __cplusplus is defined (all recent C++ compilers define this symbol).
1.12. Providing a C API for an Extension Module

Many extension modules just provide new functions and types to be used from Python, but sometimes the code in an extension module can be useful for other extension modules. For example, an extension module could implement a type “collection” which works like lists without order. Just like the standard Python list type has a C API which permits extension modules to create and manipulate lists, this new collection type should have a set of C functions for direct manipulation from other extension modules.

At first sight this seems easy: just write the functions (without declaring them static, of course), provide an appropriate header file, and document the C API. And in fact this would work if all extension modules were always linked statically with the Python interpreter. When modules are used as shared libraries, however, the symbols defined in one module may not be visible to another module. The details of visibility depend on the operating system; some systems use one global namespace for the Python interpreter and all extension modules (Windows, for example), whereas others require an explicit list of imported symbols at module link time (AIX is one example), or offer a choice of different strategies (most Unices). And even if symbols are globally visible, the module whose functions one wishes to call might not have been loaded yet!

Portability therefore requires not to make any assumptions about symbol visibility. This means that all symbols in extension modules should be declared static, except for the module’s initialization function, in order to avoid name clashes with other extension modules (as discussed in section The Module’s Method Table and Initialization
Function). And it means that symbols that *should* be accessible from other extension modules must be exported in a different way.

Python provides a special mechanism to pass C-level information (pointers) from one extension module to another one: Capsules. A Capsule is a Python data type which stores a pointer (void *). Capsules can only be created and accessed via their C API, but they can be passed around like any other Python object. In particular, they can be assigned to a name in an extension module’s namespace. Other extension modules can then import this module, retrieve the value of this name, and then retrieve the pointer from the Capsule.

There are many ways in which Capsules can be used to export the C API of an extension module. Each function could get its own Capsule, or all C API pointers could be stored in an array whose address is published in a Capsule. And the various tasks of storing and retrieving the pointers can be distributed in different ways between the module providing the code and the client modules.

Whichever method you choose, it’s important to name your Capsules properly. The function *PyCapsule_New()* takes a name parameter (const char *); you’re permitted to pass in a *NULL* name, but we strongly encourage you to specify a name. Properly named Capsules provide a degree of runtime type-safety; there is no feasible way to tell one unnamed Capsule from another.

In particular, Capsules used to expose C APIs should be given a name following this convention:

```
modulename.attributename
```

The convenience function *PyCapsule_Import()* makes it easy to load a C API provided via a Capsule, but only if the Capsule’s name
matches this convention. This behavior gives C API users a high degree of certainty that the Capsule they load contains the correct C API.

The following example demonstrates an approach that puts most of the burden on the writer of the exporting module, which is appropriate for commonly used library modules. It stores all C API pointers (just one in the example!) in an array of void pointers which becomes the value of a Capsule. The header file corresponding to the module provides a macro that takes care of importing the module and retrieving its C API pointers; client modules only have to call this macro before accessing the C API.

The exporting module is a modification of the spam module from section A Simple Example. The function spam.system() does not call the C library function system() directly, but a function PySpam_System(), which would of course do something more complicated in reality (such as adding “spam” to every command). This function PySpam_System() is also exported to other extension modules.

The function PySpam_System() is a plain C function, declared static like everything else:

```c
static int
PySpam_System(const char *command)
{
    return system(command);
}
```

The function spam_system() is modified in a trivial way:

```c
static PyObject *
```
**spam_system**(PyObject *self, PyObject *args)
{
    const char *command;
    int sts;

    if (!PyArg_ParseTuple(args, "s", &command))
        return NULL;
    sts = PySpam_System(command);
    return PyLong_FromLong(sts);
}

In the beginning of the module, right after the line

```c
#include "Python.h"
```

two more lines must be added:

```c
#define SPAM_MODULE
#include "spammodule.h"
```

The `#define` is used to tell the header file that it is being included in the exporting module, not a client module. Finally, the module’s initialization function must take care of initializing the C API pointer array:

```c
PyMODINIT_FUNC
PyInit_spam(void)
{
    PyObject *m;
    static void *PySpam_API[PySpam_API_pointers];
    PyObject *c_api_object;

    m = PyModule_Create(&spammodule);
    if (m == NULL)
        return NULL;
```
/* Initialize the C API pointer array */
PySpam_API[PySpam_System_NUM] = (void *)PySpam_System;

/* Create a Capsule containing the API pointer array */
c_api_object = PyCapsule_New((void *)PySpam_API, NULL);
if (c_api_object != NULL)
    PyModule_AddObject(m, "_C_API", c_api_object);
return m;

Note that PySpam_API is declared static; otherwise the pointer array would disappear when PyInit_spam() terminates!

The bulk of the work is in the header file spammodule.h, which looks like this:

```c
#ifndef Py_SPAMMODULE_H
#define Py_SPAMMODULE_H
#ifdef __cplusplus
extern "C" {
#endif

/* Header file for spammodule */

/* C API functions */
#define PySpam_System_NUM 0
#define PySpam_System_RETURN int
#define PySpam_SystemPROTO (const char *command)

/* Total number of C API pointers */
#define PySpam_API_pointers 1
#endif
```
All that a client module must do in order to have access to the function
PySpam_System() is to call the function (or rather macro)
import_spam() in its initialization function:
```
PyInit_client(void)
{
    PyObject *m;

    m = PyModule_Create(&clientmodule);
    if (m == NULL)
        return NULL;
    if (import_spam() < 0)
        return NULL;
    /* additional initialization can happen here */
    return m;
}
```

The main disadvantage of this approach is that the file spammodule.h is rather complicated. However, the basic structure is the same for each function that is exported, so it has to be learned only once.

Finally it should be mentioned that Capsules offer additional functionality, which is especially useful for memory allocation and deallocation of the pointer stored in a Capsule. The details are described in the Python/C API Reference Manual in the section Capsules and in the implementation of Capsules (files Include/pycapsule.h and Objects/pycapsule.c in the Python source code distribution).

**Footnotes**

[1] An interface for this function already exists in the standard module os — it was chosen as a simple and straightforward example.

[2] The metaphor of “borrowing” a reference is not completely correct: the owner still has a copy of the reference.
Checking that the reference count is at least 1 does not work — the reference count itself could be in freed memory and may thus be reused for another object!

These guarantees don’t hold when you use the “old” style calling convention — this is still found in much existing code.
Extending and Embedding the Python Interpreter
2. Defining New Types

As mentioned in the last chapter, Python allows the writer of an extension module to define new types that can be manipulated from Python code, much like strings and lists in core Python.

This is not hard; the code for all extension types follows a pattern, but there are some details that you need to understand before you can get started.
2.1. The Basics

The Python runtime sees all Python objects as variables of type `PyObject*`, which serves as a “base type" for all Python objects. `PyObject` itself only contains the refcount and a pointer to the object’s “type object”. This is where the action is; the type object determines which (C) functions get called when, for instance, an attribute gets looked up on an object or it is multiplied by another object. These C functions are called “type methods”.

So, if you want to define a new object type, you need to create a new type object.

This sort of thing can only be explained by example, so here's a minimal, but complete, module that defines a new type:

```c
#include <Python.h>

typedef struct {
    PyObject_HEAD
    /* Type-specific fields go here. */
} noddy_NoddyObject;

static PyTypeObject noddy_NoddyType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    "noddy.Noddy", /* tp_name */
    sizeof(noddy_NoddyObject), /* tp_basicsize */
    0, /* tp_itemsize */
    0, /* tp_dealloc */
    0, /* tp_print */
    0, /* tp_getattr */
    0, /* tp_setattr */
    0, /* tp_reserved */
    0, /* tp_repr */
};
```
Py_TPFLAGS_DEFAULT,
"Noddy objects",
/* tp_flags */
/* tp_doc */
};

static PyModuleDef noddymodule = {
    PyModuleDef_HEAD_INIT,
    "noddy",
    "Example module that creates an extension type."
-1,
    NULL, NULL, NULL, NULL, NULL
};

PyMODINIT_FUNC
PyInit_noddy(void)
{
    PyObject* m;

    noddy_NoddyType.tp_new = PyType_GenericNew;
    if (PyType_Ready(&noddy_NoddyType) < 0)
        return NULL;

    m = PyModule_Create(&noddymodule);
    if (m == NULL)
        return NULL;

    Py_INCREF(&noddy_NoddyType);
    PyModule_AddObject(m, "Noddy", (PyObject *)&noddy_NoddyType);
    return m;
Now that's quite a bit to take in at once, but hopefully bits will seem familiar from the last chapter.

The first bit that will be new is:

```c
typedef struct {
    PyObject_HEAD
} noddy_NoddyObject;
```

This is what a Noddy object will contain—in this case, nothing more than what every Python object contains—a refcount and a pointer to a type object. These are the fields the `PyObject_HEAD` macro brings in. The reason for the macro is to standardize the layout and to enable special debugging fields in debug builds. Note that there is no semicolon after the `PyObject_HEAD` macro; one is included in the macro definition. Be wary of adding one by accident; it’s easy to do from habit, and your compiler might not complain, but someone else’s probably will! (On Windows, MSVC is known to call this an error and refuse to compile the code.)

For contrast, let’s take a look at the corresponding definition for standard Python floats:

```c
typedef struct {
    PyObject_HEAD
    double ob_fval;
} PyFloatObject;
```

Moving on, we come to the crunch — the type object.

```c
static PyTypeObject noddy_NoddyType = {
```
Now if you go and look up the definition of `PyTypeObject` in `object.h` you'll see that it has many more fields that the definition above. The remaining fields will be filled with zeros by the C compiler, and it's common practice to not specify them explicitly unless you need them.

This is so important that we're going to pick the top of it apart still further:

```c
PyVarObject_HEAD_INIT(NULL, 0)
"noddy.Noddy",
/* tp_name */
sizeof(noddy_NoddyObject), /* tp_basicsize */
0, /* tp_itemsize */
0, /* tp_dealloc */
0, /* tp_print */
0, /* tp_getattr */
0, /* tp_setattr */
0, /* tp_as_async */
0, /* tp_repr */
0, /* tp_as_number */
0, /* tp_as_sequence */
0, /* tp_as_mapping */
0, /* tp_hash */
0, /* tp_call */
0, /* tp_str */
0, /* tp_getattro */
0, /* tp_setattro */
0, /* tp_as_buffer */
Py_TPFLAGS_DEFAULT, /* tp_flags */
"Noddy objects",
/* tp_doc */
};
```

This line is a bit of a wart; what we'd like to write is:
as the type of a type object is “type”, but this isn't strictly conforming C and some compilers complain. Fortunately, this member will be filled in for us by PyType_Ready().

"noddy.Noddy", /* tp_name */

The name of our type. This will appear in the default textual representation of our objects and in some error messages, for example:

```python
>>> "" + noddy.new_noddy()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: cannot add type "noddy.Noddy" to string
```

Note that the name is a dotted name that includes both the module name and the name of the type within the module. The module in this case is noddy and the type is Noddy, so we set the type name to noddy.Noddy.

sizeof(noddy_NoddyObject), /* tp_basicsize */

This is so that Python knows how much memory to allocate when you call PyObject_New().

**Note:** If you want your type to be subclassable from Python, and your type has the same tp_basicsize as its base type, you may have problems with multiple inheritance. A Python subclass of your type will have to list your type first in its __bases__, or else it will not be able to call your type’s __new__() method without getting an error. You can avoid this problem by ensuring that your type has a
larger value for \texttt{tp\_basicsize} than its base type does. Most of the
time, this will be true anyway, because either your base type will be
\texttt{object}, or else you will be adding data members to your base type,
and therefore increasing its size.

0, \quad \text{\texttt{/* tp\_itemsize */}}

This has to do with variable length objects like lists and strings. Ignore
this for now.

Skipping a number of type methods that we don't provide, we set the
class flags to \texttt{Py\_TPFLAGS\_DEFAULT}.

\texttt{Py\_TPFLAGS\_DEFAULT, \quad \texttt{/* tp\_flags */}}

All types should include this constant in their flags. It enables all of the
members defined until at least Python 3.3. If you need further
members, you will need to OR the corresponding flags.

We provide a doc string for the type in \texttt{tp\_doc}.

\texttt{"Noddy objects", \quad \texttt{/* tp\_doc */}}

Now we get into the type methods, the things that make your objects
different from the others. We aren't going to implement any of these in
this version of the module. We'll expand this example later to have
more interesting behavior.

For now, all we want to be able to do is to create new Noddy objects.
To enable object creation, we have to provide a \texttt{tp\_new}
implementation. In this case, we can just use the default
implementation provided by the API function \texttt{PyType\_GenericNew()}. We'd like to just assign this to the \texttt{tp\_new}
slot, but we can’t, for portability sake, On some platforms or compilers, we can’t statically initialize a structure member with a function defined in another C module, so, instead, we’ll assign the \texttt{tp\_new} slot in the module initialization function just before calling \texttt{PyType\_Ready()}:

\begin{verbatim}
noddy_NoddyType.tp_new = PyType_GenericNew;
if (PyType_Ready(&noddy_NoddyType) < 0)
    return;
\end{verbatim}

All the other type methods are \texttt{NULL}, so we’ll go over them later — that’s for a later section!

Everything else in the file should be familiar, except for some code in \texttt{PyInit_noddy()}:

\begin{verbatim}
if (PyType_Ready(&noddy_NoddyType) < 0)
    return;
\end{verbatim}

This initializes the Noddy type, filing in a number of members, including \texttt{ob\_type} that we initially set to \texttt{NULL}.

\begin{verbatim}
PyModule_AddObject(m, "Noddy", (PyObject *)&noddy_NoddyType);
\end{verbatim}

This adds the type to the module dictionary. This allows us to create Noddy instances by calling the Noddy class:

\begin{verbatim}
>>> import noddy
>>> mynoddy = noddy.Noddy()
\end{verbatim}

That’s it! All that remains is to build it; put the above code in a file called \texttt{noddy.c} and

\begin{verbatim}
from distutils.core import setup, Extension
\end{verbatim}
setup(name="noddy", version="1.0",
     ext_modules=[Extension("noddy", ["noddy.c"])])

in a file called setup.py; then typing

```
$ python setup.py build
```

at a shell should produce a file noddy.so in a subdirectory; move to
that directory and fire up Python — you should be able to import
noddy and play around with Noddy objects.

That wasn’t so hard, was it?

Of course, the current Noddy type is pretty uninteresting. It has no
data and doesn’t do anything. It can’t even be subclassed.

### 2.1.1. Adding data and methods to the Basic example

Let’s extend the basic example to add some data and methods. Let’s
also make the type usable as a base class. We’ll create a new module,
noddy2 that adds these capabilities:

```c
#include <Python.h>
#include "structmember.h"

typedef struct {
    PyObject_HEAD
    PyObject *first; /* first name */
    PyObject *last; /* last name */
    int number;
} Noddy;
```
static void
Noddy_dealloc(Noddy* self) {
    Py_XDECREF(self->first);
    Py_XDECREF(self->last);
    Py_TYPE(self)->tp_free((PyObject*)self);
}

static PyObject *
Noddy_new(PyTypeObject *type, PyObject *args, PyObject *kwds) {
    Noddy *self;

    self = (Noddy *)type->tp_alloc(type, 0);
    if (self != NULL) {
        self->first = PyUnicode_FromString("""");
        if (self->first == NULL) {
            Py_DECREF(self);
            return NULL;
        }
    }
    self->last = PyUnicode_FromString("""");
    if (self->last == NULL) {
        Py_DECREF(self);
        return NULL;
    }
    self->number = 0;
}

    return (PyObject *)self;
}

static int
Noddy_init(Noddy *self, PyObject *args, PyObject *kw) {
    PyObject *first=NULL, *last=NULL, *tmp;
static char *kwlist[] = {"first", "last", "number"};

if (! PyArg_ParseTupleAndKeywords(args, kwds, "|OOi", &first, &last, &self->number))
    return -1;

if (first) {
    tmp = self->first;
    Py_INCREF(first);
    self->first = first;
    Py_XDECREF(tmp);
}

if (last) {
    tmp = self->last;
    Py_INCREF(last);
    self->last = last;
    Py_XDECREF(tmp);
}

return 0;
}

static PyMemberDef Noddy_members[] = {
    {"first", T_OBJECT_EX, offsetof(Noddy, first), 0, "first name"},
    {"last", T_OBJECT_EX, offsetof(Noddy, last), 0, "last name"},
    {"number", T_INT, offsetof(Noddy, number), 0, "noddy number"},
    {NULL} /* Sentinel */
};

static PyObject *
Noddy_name(Noddy* self)
{
    if (self->first == NULL) {
        PyErr_SetString(PyExc_AttributeError, "first")
        return NULL;
    }

    if (self->last == NULL) {
        PyErr_SetString(PyExc_AttributeError, "last")
        return NULL;
    }

    return PyUnicode_FromFormat("%S %S", self->first);
}

static PyMethodDef Noddy_methods[] = {
    {"name", (PyCFunction)Noddy_name, METH_NOARGS,
     "Return the name, combining the first and last"},
    {NULL} /* Sentinel */
};

static PyTypeObject NoddyType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    "noddy.Noddy", /* tp_name */
    offsetof(Noddy), /* tp_basicsize */
    0, /* tp_itemsize */
    (destructor)Noddy_dealloc, /* tp_dealloc */
    0, /* tp_print */
    0, /* tp_getattr */
    0, /* tp_setattr */
    0, /* tp_reserved */
    0, /* tp_repr */
    0, /* tp_as_number */
    0, /* tp_as_sequence */
    0, /* tp_as_mapping */
    0, /* tp_hash */
};
Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE,
"Noddy objects",
Noddy_methods,
Noddy_members,
Noddy_new,};

static PyModuleDef noddy2module = {
PyModuleDef_HEAD_INIT,
"noddy2",
"Example module that creates an extension type."
-1,
NULL, NULL, NULL, NULL, NULL
};

PyMODINIT_FUNC
PyInit_noddy2(void)
This version of the module has a number of changes.

We’ve added an extra include:

```
#include <structmember.h>
```

This include provides declarations that we use to handle attributes, as described a bit later.

The name of the Noddy object structure has been shortened to Noddy. The type object name has been shortened to NoddyType.

The Noddy type now has three data attributes, `first`, `last`, and `number`. The `first` and `last` variables are Python strings containing first and last names. The `number` attribute is an integer.

The object structure is updated accordingly:

```
typedef struct {
  PyObject_HEAD
```
Because we now have data to manage, we have to be more careful about object allocation and deallocation. At a minimum, we need a deallocation method:

```c
static void Noddy_dealloc(Noddy* self) {
    Py_XDECREF(self->first);
    Py_XDECREF(self->last);
    Py_TYPE(self)->tp_free((PyObject*)self);
}
```

which is assigned to the `tp_dealloc` member:

```c
(destructor)Noddy_dealloc, /*tp_dealloc*/
```

This method decrements the reference counts of the two Python attributes. We use `Py_XDECREF()` here because the first and last members could be `NULL`. It then calls the `tp_free` member of the object's type to free the object's memory. Note that the object's type might not be NoddyType, because the object may be an instance of a subclass.

We want to make sure that the first and last names are initialized to empty strings, so we provide a new method:

```c
static PyObject * Noddy_new(PyTypeObject *type, PyObject *args, PyObject *kwargs) {
    return;
}
```
Noddy *self;

self = (Noddy *)type->tp_alloc(type, 0);
if (self != NULL) {
    self->first = PyUnicode_FromString(""');
    if (self->first == NULL) {
        Py_DECREF(self);
        return NULL;
    }

    self->last = PyUnicode_FromString(""');
    if (self->last == NULL) {
        Py_DECREF(self);
        return NULL;
    }

    self->number = 0;
}

return (PyObject *)self;

and install it in the tp_new member:

Noddy_new,    /* tp_new */

The new member is responsible for creating (as opposed to initializing) objects of the type. It is exposed in Python as the __new__() method. See the paper titled “Unifying types and classes in Python” for a detailed discussion of the __new__() method. One reason to implement a new method is to assure the initial values of instance variables. In this case, we use the new method to make sure that the initial values of the members first and last are not NULL. If we didn’t care whether the initial values were NULL, we could have used
`PyType_GenericNew()` as our new method, as we did before. `PyType_GenericNew()` initializes all of the instance variable members to `NULL`.

The new method is a static method that is passed the type being instantiated and any arguments passed when the type was called, and that returns the new object created. New methods always accept positional and keyword arguments, but they often ignore the arguments, leaving the argument handling to initializer methods. Note that if the type supports subclassing, the type passed may not be the type being defined. The new method calls the `tp_alloc` slot to allocate memory. We don’t fill the `tp_alloc` slot ourselves. Rather `PyType_Ready()` fills it for us by inheriting it from our base class, which is `object` by default. Most types use the default allocation.

**Note:** If you are creating a co-operative `tp_new` (one that calls a base type’s `tp_new` or `__new__()`), you must **not** try to determine what method to call using method resolution order at runtime. Always statically determine what type you are going to call, and call its `tp_new` directly, or via `type->tp_base->tp_new`. If you do not do this, Python subclasses of your type that also inherit from other Python-defined classes may not work correctly. (Specifically, you may not be able to create instances of such subclasses without getting a `TypeError`.)

We provide an initialization function:

```c
static int Noddy_init(Noddy *self, PyObject *args, PyObject *kw)
{
    PyObject *first=NULL, *last=NULL, *tmp;
```
static char *kwlist[] = {"first", "last", "number"};

if (!PyArg_ParseTupleAndKeywords(args, kwds, "|OOi", &first, &last, &self->number))
    return -1;

if (first) {
    tmp = self->first;
    Py_INCREF(first);
    self->first = first;
    Py_XDECREF(tmp);
}

if (last) {
    tmp = self->last;
    Py_INCREF(last);
    self->last = last;
    Py_XDECREF(tmp);
}

return 0;
}

by filling the tp_init slot.

(initproc)Noddy_init,    /* tp_init */

The tp_init slot is exposed in Python as the __init__() method. It is used to initialize an object after it's created. Unlike the new method, we can't guarantee that the initializer is called. The initializer isn't called when unpickling objects and it can be overridden. Our initializer accepts arguments to provide initial values for our instance. Initializers always accept positional and keyword arguments. Initializers should return either 0 on success or -1 on error.
Initializers can be called multiple times. Anyone can call the \_\_init\_\_() method on our objects. For this reason, we have to be extra careful when assigning the new values. We might be tempted, for example to assign the first member like this:

```python
if (first) {
    Py_XDECREF(self->first);
    Py_INCREF(first);
    self->first = first;
}
```

But this would be risky. Our type doesn’t restrict the type of the first member, so it could be any kind of object. It could have a destructor that causes code to be executed that tries to access the first member. To be paranoid and protect ourselves against this possibility, we almost always reassign members before decrementing their reference counts. When don’t we have to do this?

- when we absolutely know that the reference count is greater than 1
- when we know that deallocation of the object \[1\] will not cause any calls back into our type’s code
- when decrementing a reference count in a \_\_dealloc\_\_ handler when garbage-collections is not supported \[2\]

We want to expose our instance variables as attributes. There are a number of ways to do that. The simplest way is to define member definitions:

```c
static PyMemberDef Noddy_members[] = {
    {"first", T_OBJECT_EX, offsetof(Noddy, first), 0,
     "first name"},
    {
"last", T_OBJECT_EX, offsetof(Noddy, last), 0,
"last name"},
```
and put the definitions in the `tp_members` slot:

```c
Noddy_members,  /* tp_members */
```

Each member definition has a member name, type, offset, access flags and documentation string. See the Generic Attribute Management section below for details.

A disadvantage of this approach is that it doesn’t provide a way to restrict the types of objects that can be assigned to the Python attributes. We expect the first and last names to be strings, but any Python objects can be assigned. Further, the attributes can be deleted, setting the C pointers to `NULL`. Even though we can make sure the members are initialized to non-`NULL` values, the members can be set to `NULL` if the attributes are deleted.

We define a single method, `name()`, that outputs the objects name as the concatenation of the first and last names.

```c
static PyObject *
Noddy_name(Noddy* self)
{
    if (self->first == NULL) {
        PyErr_SetString(PyExc_AttributeError, "first
        return NULL;
    }

    if (self->last == NULL) {
        PyErr_SetString(PyExc_AttributeError, "last"
The method is implemented as a C function that takes a Noddy (or Noddy subclass) instance as the first argument. Methods always take an instance as the first argument. Methods often take positional and keyword arguments as well, but in this case we don’t take any and don’t need to accept a positional argument tuple or keyword argument dictionary. This method is equivalent to the Python method:

```python
def name(self):
    return "%s %s" % (self.first, self.last)
```

Note that we have to check for the possibility that our first and last members are `NULL`. This is because they can be deleted, in which case they are set to `NULL`. It would be better to prevent deletion of these attributes and to restrict the attribute values to be strings. We'll see how to do that in the next section.

Now that we've defined the method, we need to create an array of method definitions:

```python
static PyMethodDef Noddy_methods[] = {
    {"name", (PyCFunction)Noddy_name, METH_NOARGS,
        "Return the name, combining the first and last"},
    {NULL} /* Sentinel */
};
```

and assign them to the `tp_methods` slot:
Note that we used the METH_NOARGS flag to indicate that the method is passed no arguments.

Finally, we'll make our type usable as a base class. We've written our methods carefully so far so that they don't make any assumptions about the type of the object being created or used, so all we need to do is to add the Py_TPFLAGS_BASETYPE to our class flag definition:

We rename PyInit_noddy() to PyInit_noddy2() and update the module name in the PyModuleDef struct.

Finally, we update our setup.py file to build the new module:

2.1.2. Providing finer control over data attributes

In this section, we'll provide finer control over how the first and last attributes are set in the Noddy example. In the previous version of our module, the instance variables first and last could be set to non-string values or even deleted. We want to make sure that these attributes always contain strings.
```c
#include <Python.h>
#include "structmember.h"

typedef struct {
    PyObject_HEAD
    PyObject *first;
    PyObject *last;
    int number;
} Noddy;

static void
Noddy_dealloc(Noddy* self)
{
    Py_XDECREF(self->first);
    Py_XDECREF(self->last);
    Py_TYPE(self)->tp_free((PyObject*)self);
}

static PyObject *
Noddy_new(PyTypeObject *type, PyObject *args, PyObject *)
{
    Noddy *self;

    self = (Noddy *)type->tp_alloc(type, 0);
    if (self != NULL) {
        self->first = PyUnicode_FromString("");  
        if (self->first == NULL) { 
            Py_DECREF(self); 
            return NULL;
        }

        self->last = PyUnicode_FromString("");  
        if (self->last == NULL) { 
            Py_DECREF(self); 
            return NULL;
        }
    }

    return self;
}
```
self->number = 0;
}

return (PyObject *)self;
}

static int Noddy_init(Noddy *self, PyObject *args, PyObject *kwds) {
    PyObject *first=NULL, *last=NULL, *tmp;
    static char *kwlist[] = {"first", "last", "number"};

    if (! PyArg_ParseTupleAndKeywords(args, kwds, "|SSi", &first, &last, &self->number))
        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_DECREF(tmp);
    }

    if (last) {
        tmp = self->last;
        Py_INCREF(last);
        self->last = last;
        Py_DECREF(tmp);
    }

    return 0;
}

static PyMemberDef Noddy_members[] = {
    {"number", T_INT, offsetof(Noddy, number), 0,
"noddy number"},
  {NULL} /* Sentinel */
};

static PyObject *
Noddy_getfirst(Noddy *self, void *closure)
{
    Py_INCREF(self->first);
    return self->first;
}

static int
Noddy_setfirst(Noddy *self, PyObject *value, void *closure)
{
    if (value == NULL) {
        PyErr_SetString(PyExc_TypeError, "Cannot delete first attribute");
        return -1;
    }

    if (!PyUnicode_Check(value)) {
        PyErr_SetString(PyExc_TypeError, "The first attribute value must be a string");
        return -1;
    }

    Py_DECREF(self->first);
    Py_INCREF(value);
    self->first = value;

    return 0;
}

static PyObject *
Noddy_getlast(Noddy *self, void *closure)
{
    Py_INCREF(self->last);
    return self->last;
}
static int Noddy_setlast(Noddy *self, PyObject *value, void *closure)
{
    if (value == NULL) {
        PyErr_SetString(PyExc_TypeError, "Cannot delete the last attribute");
        return -1;
    }

    if (!PyUnicode_Check(value)) {
        PyErr_SetString(PyExc_TypeError, "The last attribute value must be a string");
        return -1;
    }

    Py_DECREF(self->last);
    Py_INCREF(value);
    self->last = value;

    return 0;
}

static PyGetSetDef Noddy_getseters[] = {
    {"first",
     (getter)Noddy_getfirst, (setter)Noddy_setfirst,
     "first name",
     NULL},
    {"last",
     (getter)Noddy_getlast, (setter)Noddy_setlast,
     "last name",
     NULL},
    {NULL} /* Sentinel */
};

static PyObject *
Noddy_name(Noddy* self)
```c
{  
    return PyUnicode_FromFormat("%S %S", self->first
}

static PyMethodDef Noddy_methods[] = {
    {"name", (PyCFunction)Noddy_name, METH_NOARGS,
     "Return the name, combining the first and last
    },
    {NULL} /* Sentinel */
};

static PyTypeObject NoddyType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    "noddy.Noddy",
    sizeof(Noddy), /* tp_basicsize */
    0, /* tp_itemsize */
    (destructor)Noddy_dealloc, /* tp_dealloc */
    0, /* tp_print */
    0, /* tp_getattr */
    0, /* tp_setattr */
    0, /* tp_reserved */
    0, /* tp_repr */
    0, /* tp_as_number */
    0, /* tp_as_sequence */
    0, /* tp_as_mapping */
    0, /* tp_hash */
    0, /* tp_call */
    0, /* tp_str */
    0, /* tp_getattro */
    0, /* tp_setattro */
    0, /* tp_as_buffer */
    Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE,
    "Noddy objects",
    0, /* tp_doc */
    0, /* tp_traverse */
    0, /* tp_clear */
    0, /* tp_richcompare */
};
```
```c
0,       /* tp_weaklistoffset */
0,       /* tp_iter */
0,       /* tp_iternext */
Noddy_methods,       /* tp_methods */
Noddy_members,       /* tp_members */
Noddy_getseters,     /* tp_getset */
0,       /* tp_base */
0,       /* tp_dict */
0,       /* tp_descr_get */
0,       /* tp_descr_set */
0,       /* tp_dictoffset */
(initproc)Noddy_init,       /* tp_init */
0,       /* tp_alloc */
Noddy_new,       /* tp_new */
};

static PyModuleDef noddy3module = {
    PyModuleDef_HEAD_INIT,
    "noddy3",
    "Example module that creates an extension type."
    -1,
    NULL, NULL, NULL, NULL, NULL,
};

PyMODINIT_FUNC
PyInit_noddy3(void)
{
    PyObject* m;

    if (PyType_Ready(&NoddyType) < 0)
        return NULL;

    m = PyModule_Create(&noddy3module);
    if (m == NULL)
        return NULL;

    Py_INCREF(&NoddyType);
```
PyModule_AddObject(m, "Noddy", (PyObject *)&NoddyType);

return m;

To provide greater control, over the first and last attributes, we'll use custom getter and setter functions. Here are the functions for getting and setting the first attribute:

```c
Noddy_getfirst(Noddy *self, void *closure)
{
    Py_INCREF(self->first);
    return self->first;
}

static int
Noddy_setfirst(Noddy *self, PyObject *value, void *closure)
{
    if (value == NULL) {
        PyErr_SetString(PyExc_TypeError, "Cannot delete first attribute");
        return -1;
    }

    if (!PyUnicode_Check(value)) {
        PyErr_SetString(PyExc_TypeError,
                        "The first attribute value must be a str");
        return -1;
    }

    Py_DECREF(self->first);
    Py_INCREF(value);
    self->first = value;

    return 0;
}
```
The getter function is passed a Noddy object and a “closure”, which is void pointer. In this case, the closure is ignored. (The closure supports an advanced usage in which definition data is passed to the getter and setter. This could, for example, be used to allow a single set of getter and setter functions that decide the attribute to get or set based on data in the closure.)

The setter function is passed the Noddy object, the new value, and the closure. The new value may be NULL, in which case the attribute is being deleted. In our setter, we raise an error if the attribute is deleted or if the attribute value is not a string.

We create an array of PyGetSetDef structures:

```c
static PyGetSetDef Noddy_getseters[] = {
    {"first",
     (getter)Noddy_getfirst, (setter)Noddy_setfirst,
     "first name",
     NULL},
    {"last",
     (getter)Noddy_getlast, (setter)Noddy_setlast,
     "last name",
     NULL},
    {NULL} /* Sentinel */
};
```

and register it in the tp_getset slot:

```c
Noddy_getseters, /* tp_getset */
```

to register our attribute getters and setters.

The last item in a PyGetSetDef structure is the closure mentioned above. In this case, we aren’t using the closure, so we just pass NULL.
We also remove the member definitions for these attributes:

```c
static PyMemberDef Noddy_members[] = {
    {"number", T_INT, offsetof(Noddy, number), 0,
     "noddy number"},
    {NULL} /* Sentinel */
};
```

We also need to update the `tp_init` handler to only allow strings [3] to be passed:

```c
static int Noddy_init(Noddy *self, PyObject *args, PyObject *kwds)
{
    PyObject *first=NULL, *last=NULL, *tmp;
    static char *kwlist[] = {"first", "last", "number"};

    if (! PyArg_ParseTupleAndKeywords(args, kwds, "|SSi", &first, &last, &self->number))
        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_DECREF(tmp);
    }

    if (last) {
        tmp = self->last;
        Py_INCREF(last);
        self->last = last;
        Py_DECREF(tmp);
    }
```
With these changes, we can assure that the first and last members are never NULL so we can remove checks for NULL values in almost all cases. This means that most of the Py_XDECREF() calls can be converted to Py_DECREF() calls. The only place we can't change these calls is in the deallocator, where there is the possibility that the initialization of these members failed in the constructor.

We also rename the module initialization function and module name in the initialization function, as we did before, and we add an extra definition to the setup.py file.

2.1.3. Supporting cyclic garbage collection

Python has a cyclic-garbage collector that can identify unneeded objects even when their reference counts are not zero. This can happen when objects are involved in cycles. For example, consider:

```python
>>> l = []
>>> l.append(l)
>>> del l
```

In this example, we create a list that contains itself. When we delete it, it still has a reference from itself. Its reference count doesn't drop to zero. Fortunately, Python's cyclic-garbage collector will eventually figure out that the list is garbage and free it.

In the second version of the Noddy example, we allowed any kind of object to be stored in the first or last attributes. [4] This means
that Noddy objects can participate in cycles:

```python
>>> import noddy2
>>> n = noddy2.Noddy()   
>>> l = [n]  
>>> n.first = l
```

This is pretty silly, but it gives us an excuse to add support for the cyclic-garbage collector to the Noddy example. To support cyclic garbage collection, types need to fill two slots and set a class flag that enables these slots:

```c
#include <Python.h>
#include "structmember.h"

typedef struct {
    PyObject_HEAD
    PyObject *first;
    PyObject *last;
    int number;
} Noddy;

static int
Noddy_traverse(Noddy *self, visitproc visit, void *arg)
{
    int vret;

    if (self->first) {
        vret = visit(self->first, arg);
        if (vret != 0)
            return vret;
    }

    if (self->last) {
        vret = visit(self->last, arg);
        if (vret != 0)
            return vret;
    }
}
```
static int Noddy_clear(Noddy *self)
{
    PyObject *tmp;

    tmp = self->first;
    self->first = NULL;
    Py_XDECREF(tmp);

    tmp = self->last;
    self->last = NULL;
    Py_XDECREF(tmp);

    return 0;
}

static void Noddy_dealloc(Noddy* self)
{
    Noddy_clear(self);
    Py_TYPE(self)->tp_free((PyObject*)self);
}

static PyObject *
Noddy_new(PyTypeObject *type, PyObject *args, PyObject *kwdict)
{
    Noddy *self;

    self = (Noddy *)type->tp_alloc(type, 0);
    if (self != NULL) {
        self->first = PyUnicode_FromString(""奇");
        if (self->first == NULL) {
            Py_DECREF(self);
            return NULL;
        }
    }
    return self;
}
Py_DECREF(self);
    
    return NULL;
}

self->last = PyUnicode_FromString(""");
if (self->last == NULL) {
    Py_DECREF(self);
    return NULL;
}

self->number = 0;

return (PyObject *)self;
}

static int
Noddy_init(Noddy *self, PyObject *args, PyObject *kwds)
{
    PyObject *first=NULL, *last=NULL, *tmp;

    static char *kwlist[] = {"first", "last", "number"};

    if (! PyArg_ParseTupleAndKeywords(args, kwds, "|OOi",
                                            &first, &last,
                                            &self->number))
        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_XDECREF(tmp);
    }

    if (last) {
        tmp = self->last;

Py_INCREF(last);
    self->last = last;
    Py_XDECREF(tmp);
}

return 0;
}

static PyMemberDef Noddy_members[] = {
    {"first", T_OBJECT_EX, offsetof(Noddy, first), 0,
     "first name"},
    {"last", T_OBJECT_EX, offsetof(Noddy, last), 0,
     "last name"},
    {"number", T_INT, offsetof(Noddy, number), 0,
     "noddy number"},
    {NULL} /* Sentinel */
};

static PyObject *
Noddy_name(Noddy* self)
{
    if (self->first == NULL) {
        PyErr_SetString(PyExc_AttributeError, "first name");
        return NULL;
    }

    if (self->last == NULL) {
        PyErr_SetString(PyExc_AttributeError, "last name");
        return NULL;
    }

    return PyUnicode_FromFormat("%S %S", self->first);
}

static PyMethodDef Noddy_methods[] = {
    {"name", (PyCFunction)Noddy_name, METH_NOARGS,
"Return the name, combining the first and last
},
{NULL}    /* Sentinel */
};

static PyTypeObject NoddyType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    "noddy.Noddy",    /* tp_name */
    sizeof(Noddy),    /* tp_basicsize */
    0,    /* tp_itemsize */
    (destructor)Noddy_dealloc,    /* tp_dealloc */
    0,    /* tp_print */
    0,    /* tp_getattr */
    0,    /* tp_setattr */
    0,    /* tp_reserved */
    0,    /* tp_repr */
    0,    /* tp_as_number */
    0,    /* tp_as_sequence */
    0,    /* tp_as_mapping */
    0,    /* tp_hash */
    0,    /* tp_call */
    0,    /* tp_str */
    0,    /* tp_getattro */
    0,    /* tp_setattro */
    0,    /* tp_as_buffer */
    Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE | Py_TPFLAGS_HAVE_GC,    /* tp_flags */
    "Noddy objects",    /* tp_doc */
    (traverseproc)Noddy_traverse,    /* tp_traverse */
    (inquiry)Noddy_clear,    /* tp_clear */
    0,    /* tp_richcompare */
    0,    /* tp_weaklistoffset */
    0,    /* tp_iter */
    0,    /* tp_iternext */
    Noddy_methods,    /* tp_methods */
    Noddy_members,    /* tp_members */
};
0,    /* tp_getset */
0,    /* tp_base */
0,    /* tp_dict */
0,    /* tp_descr_get */
0,    /* tp_descr_set */
0,    /* tp_dictoffset */
(initproc)Noddy_init,    /* tp_init */
0,    /* tp_alloc */
Noddy_new,    /* tp_new */
};

static PyModuleDef noddy4module = {
  PyModuleDef_HEAD_INIT,
  "noddy4",
  "Example module that creates an extension type."
-1,
  NULL, NULL, NULL, NULL, NULL
};

PyMODINIT_FUNC
PyInit_noddy4(void)
{
  PyObject* m;

  if (PyType_Ready(&NoddyType) < 0)
    return NULL;

  m = PyModule_Create(&noddy4module);
  if (m == NULL)
    return NULL;

  Py_INCREF(&NoddyType);
  PyModule_AddObject(m, "Noddy", (PyObject *)&NoddyType);
  return m;
}
The traversal method provides access to subobjects that could participate in cycles:

```c
static int
Noddy_traverse(Noddy *self, visitproc visit, void *arg)
{
    int vret;

    if (self->first) {
        vret = visit(self->first, arg);
        if (vret != 0)
            return vret;
    }
    if (self->last) {
        vret = visit(self->last, arg);
        if (vret != 0)
            return vret;
    }
    return 0;
}
```

For each subobject that can participate in cycles, we need to call the `visit()` function, which is passed to the traversal method. The `visit()` function takes as arguments the subobject and the extra argument `arg` passed to the traversal method. It returns an integer value that must be returned if it is non-zero.

Python provides a `Py_VISIT()` macro that automates calling visit functions. With `Py_VISIT()`, `Noddy_traverse()` can be simplified:

```c
static int
Noddy_traverse(Noddy *self, visitproc visit, void *arg)
{
```

Note: Note that the `tp_traverse` implementation must name its arguments exactly `visit` and `arg` in order to use `Py_VISIT()`. This is to encourage uniformity across these boring implementations.

We also need to provide a method for clearing any subobjects that can participate in cycles. We implement the method and reimplement the deallocator to use it:

```c
static int Noddy_clear(Noddy *self)
{
    PyObject *tmp;

    tmp = self->first;
    self->first = NULL;
    Py_XDECREF(tmp);

    tmp = self->last;
    self->last = NULL;
    Py_XDECREF(tmp);

    return 0;
}

static void Noddy_dealloc(Noddy* self)
{
    Noddy_clear(self);
    Py_TYPE(self)->tp_free((PyObject*)self);
}
```
Notice the use of a temporary variable in Noddy_clear(). We use the temporary variable so that we can set each member to NULL before decrementing its reference count. We do this because, as was discussed earlier, if the reference count drops to zero, we might cause code to run that calls back into the object. In addition, because we now support garbage collection, we also have to worry about code being run that triggers garbage collection. If garbage collection is run, our tp_traverse handler could get called. We can’t take a chance of having Noddy_traverse() called when a member’s reference count has dropped to zero and its value hasn’t been set to NULL.

Python provides a Py_CLEAR() that automates the careful decrementing of reference counts. With Py_CLEAR(), the Noddy_clear() function can be simplified:

```c
static int Noddy_clear(Noddy *self)
{
    Py_CLEAR(self->first);
    Py_CLEAR(self->last);
    return 0;
}
```

Finally, we add the Py_TPFLAGS_HAVE_GC flag to the class flags:

```c
Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE | Py_TPFLAGS_HAVE_GC
```

That’s pretty much it. If we had written custom tp_alloc or tp_free slots, we’d need to modify them for cyclic-garbage collection. Most extensions will use the versions automatically provided.
2.1.4. Subclassing other types

It is possible to create new extension types that are derived from existing types. It is easiest to inherit from the built-in types, since an extension can easily use the PyTypeObject it needs. It can be difficult to share these PyTypeObject structures between extension modules.

In this example we will create a Shoddy type that inherits from the built-in list type. The new type will be completely compatible with regular lists, but will have an additional increment() method that increases an internal counter.

```python
>>> import shoddy
>>> s = shoddy.Shoddy(range(3))
>>> s.extend(s)
>>> print(len(s))
6
>>> print(s.increment())
1
>>> print(s.increment())
2
```

```c
#include <Python.h>

typedef struct {
   PyListObject list;
   int state;
} Shoddy;

static PyObject *
Shoddy_increment(Shoddy *self, PyObject *unused)
{
```
self->state++;  
    \return PyLong_FromLong(self->state);
}

static PyMethodDef Shoddy_methods[] = {
    {"increment", (PyCFunction)Shoddy_increment, METH_NOARGS,
        PyDoc_STR("increment state counter")},
    {NULL, NULL},
};

static int
Shoddy_init(Shoddy *self, PyObject *args, PyObject *\)
    {
    if (PyList_Type.tp_init((PyObject *)self, args, \)
        return -1;
    self->state = 0;
    return 0;
}

static PyTypeObject ShoddyType = {
    PyObject_HEAD_INIT(NULL)  /* tp_name */
    "shoddy.Shoddy",           /* tp_basicsize */
    sizeof(Shoddy),            /* tp_itemsize */
    0,                         /* tp_dealloc */
    0,                         /* tp_print */
    0,                         /* tp_getattr */
    0,                         /* tp_setattr */
    0,                         /* tp_reserved */
    0,                         /* tp_repr */
    0,                         /* tp_as_number */
    0,                         /* tp_as_sequence */
    0,                         /* tp_as_mapping */
    0,                         /* tp_hash */
    0,                         /* tp_call */
0, /* tp_str */
0, /* tp_getattro */
0, /* tp_setattro */
0, /* tp_as_buffer */
Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE, /* tp_flags */
0, /* tp_doc */
0, /* tp_traverse */
0, /* tp_clear */
0, /* tp_richcompare */
0, /* tp_weaklistoffset */
0, /* tp_iter */
0, /* tp_iternext */
Shoddy_methods, /* tp_methods */
0, /* tp_members */
0, /* tp_getset */
0, /* tp_base */
0, /* tp_dict */
0, /* tp_descr_get */
0, /* tp_descr_set */
0, /* tp_dictoffset */
(initproc)Shoddy_init, /* tp_init */
0, /* tp_alloc */
0, /* tp_new */

};

static PyModuleDef shoddymodule = {
    PyModuleDef_HEAD_INIT,
    "shoddy",
    "Shoddy module",
    -1,
    NULL, NULL, NULL, NULL, NULL
};

PyMODINIT_FUNC
PyInit_shoddy(void)
{

As you can see, the source code closely resembles the Noddy examples in previous sections. We will break down the main differences between them.

The primary difference for derived type objects is that the base type's object structure must be the first value. The base type will already include the `PyObject_HEAD()` at the beginning of its structure.

When a Python object is a Shoddy instance, its `PyObject*` pointer can be safely cast to both `PyListObject*` and `Shoddy*`. 
In the `__init__` method for our type, we can see how to call through to the `__init__` method of the base type.

This pattern is important when writing a type with custom `new` and `dealloc` methods. The new method should not actually create the memory for the object with `tp_alloc`, that will be handled by the base class when calling its `tp_new`.

When filling out the `PyTypeObject()` for the Shoddy type, you see a slot for `tp_base()`. Due to cross platform compiler issues, you can’t fill that field directly with the `PyList_Type()`, it can be done later in the module’s `init()` function.
Before calling `PyType_Ready()`, the type structure must have the `tp_base` slot filled in. When we are deriving a new type, it is not necessary to fill out the `tp_alloc` slot with `PyType_GenericNew()` – the allocate function from the base type will be inherited.

After that, calling `PyType_Ready()` and adding the type object to the module is the same as with the basic Noddy examples.
2.2. Type Methods

This section aims to give a quick fly-by on the various type methods you can implement and what they do.

Here is the definition of `PyTypeObject`, with some fields only used in debug builds omitted:

```c
typedef struct _typeobject {
    PyObject_VAR_HEAD
    const char *tp_name; /* For printing, in format "<module>.<name>" */
    Py_ssize_t tp_basicsize, tp_itemsize; /* For allocation */
    /** Methods to implement standard operations */
    destructor tp_dealloc;
    printfunc tp_print;
    getattrfunc tp_getattr;
    setattrfunc tp_setattr;
    PyAsyncMethods *tp_as_async; /* formerly known as tp_compare (Python 2)
        or tp_reserved (Python 3) */
    reprfunc tp_repr;

    /** Method suites for standard classes */
    PyNumberMethods *tp_as_number;
    PySequenceMethods *tp_as_sequence;
    PyMappingMethods *tp_as_mapping;

    /** More standard operations (here for binary compatibility) */
    hashfunc tp_hash;
    ternaryfunc tp_call;
    reprfunc tp_str;
    getattrofunc tp_getattro;
```
setattrofunc tp_setattro;

/* Functions to access object as input/output buffer */
PyBufferProcs *tp_as_buffer;

/* Flags to define presence of optional/expanded features */
unsigned long tp_flags;

const char *tp_doc; /* Documentation string */

/* call function for all accessible objects */
traverseproc tp_traverse;

/* delete references to contained objects */
inquiry tp_clear;

/* rich comparisons */
richcmpfunc tp_richcompare;

/* weak reference enabler */
Py_ssize_t tp_weaklistoffset;

/* Iterators */
getiterfunc tp_iter;
iternextfunc tp_iternext;

/* Attribute descriptor and subclassing stuff */
struct PyMethodDef *tp_methods;
struct PyMemberDef *tp_members;
struct PyGetSetDef *tp_getset;
struct _typeobject *tp_base;
PyObject *tp_dict;
descrgetfunc tp_descr_get;
descrsetfunc tp_descr_set;
Py_ssize_t tp_dictoffset;
initproc tp_init;
allocfunc tp_alloc;
Now that's a lot of methods. Don't worry too much though - if you have a type you want to define, the chances are very good that you will only implement a handful of these.

As you probably expect by now, we're going to go over this and give more information about the various handlers. We won't go in the order they are defined in the structure, because there is a lot of historical baggage that impacts the ordering of the fields; be sure your type initialization keeps the fields in the right order! It's often easiest to find an example that includes all the fields you need (even if they're initialized to 0) and then change the values to suit your new type.

```c
const char *tp_name; /* For printing */
```

The name of the type - as mentioned in the last section, this will appear in various places, almost entirely for diagnostic purposes. Try to choose something that will be helpful in such a situation!
These fields tell the runtime how much memory to allocate when new objects of this type are created. Python has some built-in support for variable length structures (think: strings, lists) which is where the `tp_itemsize` field comes in. This will be dealt with later.

```c
const char *tp_doc;
```

Here you can put a string (or its address) that you want returned when the Python script references `obj.__doc__` to retrieve the doc string.

Now we come to the basic type methods—the ones most extension types will implement.

### 2.2.1. Finalization and De-allocation

```c
static void newdatatype_dealloc(newdatatypeobject * obj) {
    free(obj->obj_UnderlyingDatatypePtr);
    Py_TYPE(obj)->tp_free(obj);
}
```
One important requirement of the deallocator function is that it leaves any pending exceptions alone. This is important since deallocators are frequently called as the interpreter unwinds the Python stack; when the stack is unwound due to an exception (rather than normal returns), nothing is done to protect the deallocators from seeing that an exception has already been set. Any actions which a deallocator performs which may cause additional Python code to be executed may detect that an exception has been set. This can lead to misleading errors from the interpreter. The proper way to protect against this is to save a pending exception before performing the unsafe action, and restoring it when done. This can be done using the `PyErr_Fetch()` and `PyErr_Restore()` functions:

```c
static void
my_dealloc(PyObject *obj)
{
    MyObject *self = (MyObject *) obj;
    PyObject *cbresult;

    if (self->my_callback != NULL) {
        PyObject *err_type, *err_value, *err_traceback;

        /* This saves the current exception state */
        PyErr_Fetch(&err_type, &err_value, &err_traceback);

        cbresult = PyObject_CallObject(self->my_callback, NULL);
        if (cbresult == NULL)
            PyErr_WriteUnraisable(self->my_callback);
        else
            Py_DECREF(cbresult);

        /* This restores the saved exception state */
        PyErr_Restore(err_type, err_value, err_traceback);
        Py_DECREF(self->my_callback);
    }
}
```
Note: There are limitations to what you can safely do in a deallocator function. First, if your type supports garbage collection (using `tp_traverse` and/or `tp_clear`), some of the object's members can have been cleared or finalized by the time `tp_dealloc` is called. Second, in `tp_dealloc`, your object is in an unstable state: its reference count is equal to zero. Any call to a non-trivial object or API (as in the example above) might end up calling `tp_dealloc` again, causing a double free and a crash.

Starting with Python 3.4, it is recommended not to put any complex finalization code in `tp_dealloc`, and instead use the new `tp_finalize` type method.

See also: PEP 442 explains the new finalization scheme.

### 2.2.2. Object Presentation

In Python, there are two ways to generate a textual representation of an object: the `repr()` function, and the `str()` function. (The `print()` function just calls `str()`.) These handlers are both optional.

```c
reprfunc tp_repr;
reprfunc tp_str;
```

The `tp_repr` handler should return a string object containing a representation of the instance for which it is called. Here is a simple example:
If no \texttt{tp\_repr} handler is specified, the interpreter will supply a representation that uses the type's \texttt{tp\_name} and a uniquely-identifying value for the object.

The \texttt{tp\_str} handler is to \texttt{str()} what the \texttt{tp\_repr} handler described above is to \texttt{repr()}; that is, it is called when Python code calls \texttt{str()} on an instance of your object. Its implementation is very similar to the \texttt{tp\_repr} function, but the resulting string is intended for human consumption. If \texttt{tp\_str} is not specified, the \texttt{tp\_repr} handler is used instead.

Here is a simple example:

```c
static PyObject *
newdatatype\_str(newdatatypeobject * obj)
{
    return PyUnicode_FromFormat("Stringified_newdatatype{{size:\%d}}", obj->obj\_UnderlyingDP
}
```

\subsection*{2.2.3. Attribute Management}

For every object which can support attributes, the corresponding type must provide the functions that control how the attributes are resolved. There needs to be a function which can retrieve attributes (if any are
defined), and another to set attributes (if setting attributes is allowed). Removing an attribute is a special case, for which the new value passed to the handler is **NULL**.

Python supports two pairs of attribute handlers; a type that supports attributes only needs to implement the functions for one pair. The difference is that one pair takes the name of the attribute as a char*, while the other accepts a PyObject*. Each type can use whichever pair makes more sense for the implementation's convenience.

```c
getattrfunc tp_getattr; /* char * version */
setattrfunc tp_setattr;
/* ... */
getattrofunc tp_getattro; /* PyObject * version */
setattrofunc tp_setattro;
```

If accessing attributes of an object is always a simple operation (this will be explained shortly), there are generic implementations which can be used to provide the PyObject* version of the attribute management functions. The actual need for type-specific attribute handlers almost completely disappeared starting with Python 2.2, though there are many examples which have not been updated to use some of the new generic mechanism that is available.

**2.2.3.1. Generic Attribute Management**

Most extension types only use *simple* attributes. So, what makes the attributes simple? There are only a couple of conditions that must be met:

1. The name of the attributes must be known when `PyType_Ready()` is called.
2. No special processing is needed to record that an attribute was
looked up or set, nor do actions need to be taken based on the value.

Note that this list does not place any restrictions on the values of the attributes, when the values are computed, or how relevant data is stored.

When `PyType_Ready()` is called, it uses three tables referenced by the type object to create descriptors which are placed in the dictionary of the type object. Each descriptor controls access to one attribute of the instance object. Each of the tables is optional; if all three are `NULL`, instances of the type will only have attributes that are inherited from their base type, and should leave the `tp_getattro` and `tp_setattro` fields `NULL` as well, allowing the base type to handle attributes.

The tables are declared as three fields of the type object:

```c
struct PyMethodDef *tp_methods;
struct PyMemberDef *tp_members;
struct PyGetSetDef *tp_getset;
```

If `tp_methods` is not `NULL`, it must refer to an array of `PyMethodDef` structures. Each entry in the table is an instance of this structure:

```c
typedef struct PyMethodDef {
    char *ml_name;        /* method name */
    PyCFunction ml_meth;  /* implementation fun
    int ml_flags;         /* flags */
    char *ml_doc;         /* docstring */
} PyMethodDef;
```

One entry should be defined for each method provided by the type; no
entries are needed for methods inherited from a base type. One additional entry is needed at the end; it is a sentinel that marks the end of the array. The ml_name field of the sentinel must be *NULL*.

The second table is used to define attributes which map directly to data stored in the instance. A variety of primitive C types are supported, and access may be read-only or read-write. The structures in the table are defined as:

```c
typedef struct PyMemberDef {
    char *name;
    int type;
    int offset;
    int flags;
    char *doc;
} PyMemberDef;
```

For each entry in the table, a descriptor will be constructed and added to the type which will be able to extract a value from the instance structure. The *type* field should contain one of the type codes defined in the *structmember.h* header; the value will be used to determine how to convert Python values to and from C values. The *flags* field is used to store flags which control how the attribute can be accessed.

The following flag constants are defined in *structmember.h*; they may be combined using bitwise-OR.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>READONLY</td>
<td>Never writable.</td>
</tr>
<tr>
<td>READ.Restricted</td>
<td>Not readable in restricted mode.</td>
</tr>
<tr>
<td>WRITE.Restricted</td>
<td>Not writable in restricted mode.</td>
</tr>
<tr>
<td></td>
<td>Not readable or writable in restricted mode.</td>
</tr>
</tbody>
</table>
An interesting advantage of using the `tp_members` table to build descriptors that are used at runtime is that any attribute defined this way can have an associated doc string simply by providing the text in the table. An application can use the introspection API to retrieve the descriptor from the class object, and get the doc string using its `__doc__` attribute.

As with the `tp_methods` table, a sentinel entry with a name value of `NULL` is required.

### 2.2.3.2. Type-specific Attribute Management

For simplicity, only the `char*` version will be demonstrated here; the type of the name parameter is the only difference between the `char*` and `PyObject*` flavors of the interface. This example effectively does the same thing as the generic example above, but does not use the generic support added in Python 2.2. It explains how the handler functions are called, so that if you do need to extend their functionality, you'll understand what needs to be done.

The `tp_getattr` handler is called when the object requires an attribute look-up. It is called in the same situations where the `__getattr__()` method of a class would be called.

Here is an example:

```c
static PyObject *
newdatatype_getattr(newdatatypeobject *obj, char *name)
{
    if (strcmp(name, "data") == 0)
        return newdatatype_data_object;
```
The `tp_setattr` handler is called when the `__setattr__()` or `__delattr__()` method of a class instance would be called. When an attribute should be deleted, the third parameter will be `NULL`. Here is an example that simply raises an exception; if this were really all you wanted, the `tp_setattr` handler should be set to `NULL`.

```c
static int newdatatype_setattr(newdatatypeobject *obj, char *name) {
    (void)PyErr_Format(PyExc_RuntimeError, "Read-only attribute: \%s\n"
    return -1;
}
```

### 2.2.4. Object Comparison

The `tp_richcompare` handler is called when comparisons are needed. It is analogous to the rich comparison methods, like `__lt__()`, and also called by `PyObject_RichCompare()` and `PyObject_RichCompareBool()`.
This function is called with two Python objects and the operator as arguments, where the operator is one of Py_EQ, Py_NE, Py_LE, Py_GT, Py_LT or Py_GT. It should compare the two objects with respect to the specified operator and return Py_True or Py_False if the comparison is successful, Py_NotImplemented to indicate that comparison is not implemented and the other object's comparison method should be tried, or NULL if an exception was set.

Here is a sample implementation, for a datatype that is considered equal if the size of an internal pointer is equal:

```c
static PyObject *
newdatatype_richcmp(PyObject *obj1, PyObject *obj2,
{
    PyObject *result;
    int c, size1, size2;

    /* code to make sure that both arguments are of newdatatype omitted */

    size1 = obj1->obj_UnderlyingDatatypePtr->size;
    size2 = obj2->obj_UnderlyingDatatypePtr->size;

    switch (op) {
    case Py_LT: c = size1 < size2; break;
    case Py_LE: c = size1 <= size2; break;
    case Py_EQ: c = size1 == size2; break;
    case Py_NE: c = size1 != size2; break;
    case Py_GT: c = size1 > size2; break;
    case Py_GE: c = size1 >= size2; break;
    }
    result = c ? Py_True : Py_False;
    Py_INCREF(result);
    return result;
}
```
2.2.5. Abstract Protocol Support

Python supports a variety of abstract ‘protocols;’ the specific interfaces provided to use these interfaces are documented in Abstract Objects Layer.

A number of these abstract interfaces were defined early in the development of the Python implementation. In particular, the number, mapping, and sequence protocols have been part of Python since the beginning. Other protocols have been added over time. For protocols which depend on several handler routines from the type implementation, the older protocols have been defined as optional blocks of handlers referenced by the type object. For newer protocols there are additional slots in the main type object, with a flag bit being set to indicate that the slots are present and should be checked by the interpreter. (The flag bit does not indicate that the slot values are non-NULL. The flag may be set to indicate the presence of a slot, but a slot may still be unfilled.)

\[
\begin{align*}
\text{PyNumberMethods} & \quad \text{*tp}_\text{as_number}; \\
\text{PySequenceMethods} & \quad \text{*tp}_\text{as_sequence}; \\
\text{PyMappingMethods} & \quad \text{*tp}_\text{as_mapping};
\end{align*}
\]

If you wish your object to be able to act like a number, a sequence, or a mapping object, then you place the address of a structure that implements the C type PyNumberMethods, PySequenceMethods, or PyMappingMethods, respectively. It is up to you to fill in this structure with appropriate values. You can find examples of the use of each of these in the Objects directory of the Python source distribution.
hashfunc tp_hash;

This function, if you choose to provide it, should return a hash number for an instance of your data type. Here is a moderately pointless example:

```c
static long newdatatype_hash(newdatatypeobject *obj)
{
    long result;
    result = obj->obj_UnderlyingDatatypePtr->size;
    result = result * 3;
    return result;
}
```

ternaryfunc tp_call;

This function is called when an instance of your data type is “called”, for example, if obj1 is an instance of your data type and the Python script contains obj1('hello'), the tp_call handler is invoked.

This function takes three arguments:

1. `arg1` is the instance of the data type which is the subject of the call. If the call is obj1('hello'), then `arg1` is obj1.
2. `arg2` is a tuple containing the arguments to the call. You can use `PyArg_ParseTuple()` to extract the arguments.
3. `arg3` is a dictionary of keyword arguments that were passed. If this is non-NULL and you support keyword arguments, use `PyArg_ParseTupleAndKeywords()` to extract the arguments. If you do not want to support keyword arguments and this is non-NULL, raise a `TypeError` with a message saying that keyword arguments are not supported.
Here is a desultory example of the implementation of the call function.

```c
/* Implement the call function. 
 * obj1 is the instance receiving the call.
 * obj2 is a tuple containing the arguments to the case 3 strings. 
 */
static PyObject *
newdatatype_call(newdatatypeobject *obj, PyObject *args)
{
    PyObject *result;
    char *arg1;
    char *arg2;
    char *arg3;

    if (!PyArg_ParseTuple(args, "sss:call", &arg1, &arg2, &arg3))
        return NULL;
                                obj->obj_UnderlyingDatatypePtr->size,
                                arg1, arg2, arg3);
    return result;
}

/* Iterators */
getiterfunc tp_iter;
iternextfunc tp_iternext;
```

These functions provide support for the iterator protocol. Any object which wishes to support iteration over its contents (which may be generated during iteration) must implement the `tp_iter` handler. Objects which are returned by a `tp_iter` handler must implement both the `tp_iter` and `tp_iternext` handlers. Both handlers take
exactly one parameter, the instance for which they are being called, and return a new reference. In the case of an error, they should set an exception and return \texttt{NULL}.

For an object which represents an iterable collection, the \texttt{tp_iter} handler must return an iterator object. The iterator object is responsible for maintaining the state of the iteration. For collections which can support multiple iterators which do not interfere with each other (as lists and tuples do), a new iterator should be created and returned. Objects which can only be iterated over once (usually due to side effects of iteration) should implement this handler by returning a new reference to themselves, and should also implement the \texttt{tp_iternext} handler. File objects are an example of such an iterator.

Iterator objects should implement both handlers. The \texttt{tp_iter} handler should return a new reference to the iterator (this is the same as the \texttt{tp_iter} handler for objects which can only be iterated over destructively). The \texttt{tp_iternext} handler should return a new reference to the next object in the iteration if there is one. If the iteration has reached the end, it may return \texttt{NULL} without setting an exception or it may set \texttt{StopIteration}; avoiding the exception can yield slightly better performance. If an actual error occurs, it should set an exception and return \texttt{NULL}.

\section*{2.2.6. Weak Reference Support}

One of the goals of Python's weak-reference implementation is to allow any type to participate in the weak reference mechanism without incurring the overhead on those objects which do not benefit by weak referencing (such as numbers).
For an object to be weakly referencable, the extension must include a `PyObject*` field in the instance structure for the use of the weak reference mechanism; it must be initialized to `NULL` by the object's constructor. It must also set the `tp_weaklistoffset` field of the corresponding type object to the offset of the field. For example, the instance type is defined with the following structure:

```c
typedef struct {
    PyObject_HEAD
    PyClassObject *in_class;   /* The class object */
    PyObject     *in_dict;     /* A dictionary */
    PyObject     *in_weakreflist; /* List of weak references */
} PyInstanceObject;
```

The statically-declared type object for instances is defined this way:

```c
PyTypeObject PyInstance_Type = {
    PyVarObject_HEAD_INIT(&PyType_Type, 0)
    0,
    "module.instance",

    /* Lots of stuff omitted for brevity... */

    Py_TPFLAGS_DEFAULT,     /* tp_flags */
    0,                      /* tp_getattr */
    0,                      /* tp_setattr */
    0,                      /* tp_compare */
    0,                      /* tp_iter */
    0,                      /* tp_iternext */
    offsetof(PyInstanceObject, in_weakreflist), /* tp_weaklistoffset */
};
```

The type constructor is responsible for initializing the weak reference list to `NULL`:
static PyObject *
instance_new() {
    /* Other initialization stuff omitted for brevity */
    self->in_weakreflist = NULL;
    return (PyObject *) self;
}

The only further addition is that the destructor needs to call the weak reference manager to clear any weak references. This is only required if the weak reference list is non-NULL:

static void
instance_dealloc(PyInstanceObject *inst) {
    /* Allocate temporaries if needed, but do not begin destruction just yet. */
    if (inst->in_weakreflist != NULL)
        PyObject_ClearWeakRefs((PyObject *) inst);
    /* Proceed with object destruction normally. */
}

2.2.7. More Suggestions

Remember that you can omit most of these functions, in which case you provide 0 as a value. There are type definitions for each of the functions you must provide. They are in object.h in the Python include directory that comes with the source distribution of Python.
In order to learn how to implement any specific method for your new data type, do the following: Download and unpack the Python source distribution. Go to the Objects directory, then search the C source files for tp_ plus the function you want (for example, tp_richcompare). You will find examples of the function you want to implement.

When you need to verify that an object is an instance of the type you are implementing, use the `PyObject_TypeCheck()` function. A sample of its use might be something like the following:

```python
if (!PyObject_TypeCheck(some_object, &MyType)) {
    PyErr_SetString(PyExc_TypeError, "arg #1 not a mything";
    return NULL;
}
```

Footnotes

[1] This is true when we know that the object is a basic type, like a string or a float.

We relied on this in the `tp_dealloc` handler in this example, because our type doesn’t support garbage collection. Even if a type supports garbage collection, there are calls that can be made to “untrack” the object from garbage collection, however, these calls are advanced and not covered here.

[2] We now know that the first and last members are strings, so perhaps we could be less careful about decrementing their reference counts, however, we accept instances of string subclasses. Even though deallocating normal strings won’t call back into our objects, we can’t guarantee that deallocating an instance of a string subclass won’t call back into our objects.

[3] Even in the third version, we aren’t guaranteed to avoid cycles.
Instances of string subclasses are allowed and string subclasses could allow cycles even if normal strings don’t.
3. Building C and C++ Extensions

A C extension for CPython is a shared library (e.g. a .so file on Linux, .pyd on Windows), which exports an initialization function.

To be importable, the shared library must be available on PYTHONPATH, and must be named after the module name, with an appropriate extension. When using distutils, the correct filename is generated automatically.

The initialization function has the signature:

\[
\text{PyObject}^* \text{PyInit\_modulename}(\text{void})
\]

It returns either a fully-initialized module, or a \text{PyModuleDef} instance. See Initializing C modules for details.

For modules with ASCII-only names, the function must be named \text{PyInit\_<modulename>}, with \text{<modulename>} replaced by the name of the module. When using Multi-phase initialization, non-ASCII module names are allowed. In this case, the initialization function name is \text{PyInitU\_<modulename>}, with \text{<modulename>} encoded using Python’s \text{punycode} encoding with hyphens replaced by underscores. In Python:

```python
def initfunc_name(name):
    try:
        suffix = b’_’ + name.encode(’ascii’)
    except UnicodeEncodeError:
        suffix = b’U_’ + name.encode(’punycode’).replace(b’-’, b’_’)
    return b’PyInit’ + suffix
```
It is possible to export multiple modules from a single shared library by defining multiple initialization functions. However, importing them requires using symbolic links or a custom importer, because by default only the function corresponding to the filename is found. See PEP 489#multiple-modules-in-one-library for details.
3.1. Building C and C++ Extensions with distutils

Extension modules can be built using distutils, which is included in Python. Since distutils also supports creation of binary packages, users don't necessarily need a compiler and distutils to install the extension.

A distutils package contains a driver script, setup.py. This is a plain Python file, which, in the most simple case, could look like this:

```python
from distutils.core import setup, Extension

module1 = Extension('demo',
                     sources = ['demo.c'])

setup (name = 'PackageName',
        version = '1.0',
        description = 'This is a demo package',
        ext_modules = [module1])
```

With this setup.py, and a file demo.c, running

```
python setup.py build
```

will compile demo.c, and produce an extension module named demo in the build directory. Depending on the system, the module file will end up in a subdirectory build/lib.system, and may have a name like demo.so or demo.pyd.

In the setup.py, all execution is performed by calling the setup function. This takes a variable number of keyword arguments, of which
the example above uses only a subset. Specifically, the example specifies meta-information to build packages, and it specifies the contents of the package. Normally, a package will contain of addition modules, like Python source modules, documentation, subpackages, etc. Please refer to the distutils documentation in Distributing Python Modules (Legacy version) to learn more about the features of distutils; this section explains building extension modules only.

It is common to pre-compute arguments to setup(), to better structure the driver script. In the example above, the ext_modules argument to setup() is a list of extension modules, each of which is an instance of the Extension. In the example, the instance defines an extension named demo which is build by compiling a single source file, demo.c.

In many cases, building an extension is more complex, since additional preprocessor defines and libraries may be needed. This is demonstrated in the example below.

```python
from distutils.core import setup, Extension

module1 = Extension('demo',
    define_macros = [('MAJOR_VERSION', '1'),
                     ('MINOR_VERSION', '0')],
    include_dirs = ['/usr/local/include'],
    libraries = ['tcl83'],
    library_dirs = ['/usr/local/lib'],
    sources = ['demo.c'])

setup (name = 'PackageName',
       version = '1.0',
       description = 'This is a demo package',
       author = 'Martin v. Loewis',
       author_email = 'martin@v.loewis.de',
       ext_modules = [module1])
```
url = 'https://docs.python.org/extending/building/
long_description = '''
This is really just a demo package.
''',
ext_modules = [module1])

In this example, setup() is called with additional meta-information, which is recommended when distribution packages have to be built. For the extension itself, it specifies preprocessor defines, include directories, library directories, and libraries. Depending on the compiler, distutils passes this information in different ways to the compiler. For example, on Unix, this may result in the compilation commands

gcc -DNDEBUG -g -O3 -Wall -Wstrict-prototypes -fPIC

gcc -shared build/temp.linux-i686-2.2/demo.o -L/usr/

These lines are for demonstration purposes only; distutils users should trust that distutils gets the invocations right.
3.2. Distributing your extension modules

When an extension has been successfully build, there are three ways to use it.

End-users will typically want to install the module, they do so by running

```
python setup.py install
```

Module maintainers should produce source packages; to do so, they run

```
python setup.py sdist
```

In some cases, additional files need to be included in a source distribution; this is done through a MANIFEST.in file; see the distutils documentation for details.

If the source distribution has been build successfully, maintainers can also create binary distributions. Depending on the platform, one of the following commands can be used to do so.

```
python setup.py bdist_wininst
python setup.py bdist_rpm
python setup.py bdist_dumb
```
4. Building C and C++ Extensions on Windows

This chapter briefly explains how to create a Windows extension module for Python using Microsoft Visual C++, and follows with more detailed background information on how it works. The explanatory material is useful for both the Windows programmer learning to build Python extensions and the Unix programmer interested in producing software which can be successfully built on both Unix and Windows.

Module authors are encouraged to use the distutils approach for building extension modules, instead of the one described in this section. You will still need the C compiler that was used to build Python; typically Microsoft Visual C++.

**Note:** This chapter mentions a number of filenames that include an encoded Python version number. These filenames are represented with the version number shown as XY; in practice, 'X' will be the major version number and 'Y' will be the minor version number of the Python release you’re working with. For example, if you are using Python 2.2.1, XY will actually be 22.
4.1. A Cookbook Approach

There are two approaches to building extension modules on Windows, just as there are on Unix: use the distutils package to control the build process, or do things manually. The distutils approach works well for most extensions; documentation on using distutils to build and package extension modules is available in Distributing Python Modules (Legacy version). If you find you really need to do things manually, it may be instructive to study the project file for the winsound standard library module.
4.2. Differences Between Unix and Windows

Unix and Windows use completely different paradigms for run-time loading of code. Before you try to build a module that can be dynamically loaded, be aware of how your system works.

In Unix, a shared object (.so) file contains code to be used by the program, and also the names of functions and data that it expects to find in the program. When the file is joined to the program, all references to those functions and data in the file's code are changed to point to the actual locations in the program where the functions and data are placed in memory. This is basically a link operation.

In Windows, a dynamic-link library (.dll) file has no dangling references. Instead, an access to functions or data goes through a lookup table. So the DLL code does not have to be fixed up at runtime to refer to the program's memory; instead, the code already uses the DLL's lookup table, and the lookup table is modified at runtime to point to the functions and data.

In Unix, there is only one type of library file (.a) which contains code from several object files (.o). During the link step to create a shared object file (.so), the linker may find that it doesn't know where an identifier is defined. The linker will look for it in the object files in the libraries; if it finds it, it will include all the code from that object file.

In Windows, there are two types of library, a static library and an import library (both called .lib). A static library is like a Unix .a file; it contains code to be included as necessary. An import library is basically used only to reassure the linker that a certain identifier is
legal, and will be present in the program when the DLL is loaded. So the linker uses the information from the import library to build the lookup table for using identifiers that are not included in the DLL. When an application or a DLL is linked, an import library may be generated, which will need to be used for all future DLLs that depend on the symbols in the application or DLL.

Suppose you are building two dynamic-load modules, B and C, which should share another block of code A. On Unix, you would not pass A.a to the linker for B.so and C.so; that would cause it to be included twice, so that B and C would each have their own copy. In Windows, building A.dll will also build A.lib. You do pass A.lib to the linker for B and C. A.lib does not contain code; it just contains information which will be used at runtime to access A's code.

In Windows, using an import library is sort of like using import spam; it gives you access to spam’s names, but does not create a separate copy. On Unix, linking with a library is more like from spam import *; it does create a separate copy.
4.3. Using DLLs in Practice

Windows Python is built in Microsoft Visual C++; using other compilers may or may not work (though Borland seems to). The rest of this section is MSVC++ specific.

When creating DLLs in Windows, you must pass pythonXY.lib to the linker. To build two DLLs, spam and ni (which uses C functions found in spam), you could use these commands:

```
cl /LD /I/python/include spam.c ../libs/pythonXY.lib
cl /LD /I/python/include ni.c spam.lib ../libs/pythonXY.lib
```

The first command created three files: spam.obj, spam.dll and spam.lib. Spam.dll does not contain any Python functions (such as `PyArg_ParseTuple()`), but it does know how to find the Python code thanks to pythonXY.lib.

The second command created ni.dll (and .obj and .lib), which knows how to find the necessary functions from spam, and also from the Python executable.

Not every identifier is exported to the lookup table. If you want any other modules (including Python) to be able to see your identifiers, you have to say `_declspec(dllexport)`, as in `void _declspec(dllexport) initspam(void)` or `PyObject _declspec(dllexport) *NiGetSpamData(void)`.

Developer Studio will throw in a lot of import libraries that you do not really need, adding about 100K to your executable. To get rid of them, use the Project Settings dialog, Link tab, to specify `ignore default`
libraries. Add the correct msvcrtxx.lib to the list of libraries.
1. Embedding Python in Another Application

The previous chapters discussed how to extend Python, that is, how to extend the functionality of Python by attaching a library of C functions to it. It is also possible to do it the other way around: enrich your C/C++ application by embedding Python in it. Embedding provides your application with the ability to implement some of the functionality of your application in Python rather than C or C++. This can be used for many purposes; one example would be to allow users to tailor the application to their needs by writing some scripts in Python. You can also use it yourself if some of the functionality can be written in Python more easily.

Embedding Python is similar to extending it, but not quite. The difference is that when you extend Python, the main program of the application is still the Python interpreter, while if you embed Python, the main program may have nothing to do with Python — instead, some parts of the application occasionally call the Python interpreter to run some Python code.

So if you are embedding Python, you are providing your own main program. One of the things this main program has to do is initialize the Python interpreter. At the very least, you have to call the function `Py_Initialize()`. There are optional calls to pass command line arguments to Python. Then later you can call the interpreter from any part of the application.

There are several different ways to call the interpreter: you can pass a string containing Python statements to `PyRun_SimpleString()`, or
you can pass a stdio file pointer and a file name (for identification in error messages only) to `PyRun_SimpleFile()`. You can also call the lower-level operations described in the previous chapters to construct and use Python objects.

**See also:**

**Python/C API Reference Manual**

The details of Python’s C interface are given in this manual. A great deal of necessary information can be found here.
1.1. Very High Level Embedding

The simplest form of embedding Python is the use of the very high level interface. This interface is intended to execute a Python script without needing to interact with the application directly. This can for example be used to perform some operation on a file.

```c
#include <Python.h>

int main(int argc, char *argv[]) {
    wchar_t *program = Py_DecodeLocale(argv[0], NULL);
    if (program == NULL) {
        fprintf(stderr, "Fatal error: cannot decode argv[0]");
        exit(1);
    }
    Py_SetProgramName(program); /* optional but recommended */
    Py_Initialize();
    PyRun_SimpleString("from time import time,ctime
                        print('Today is', ctime(time()))");
    Py_Finalize();
    PyMem_RawFree(program);
    return 0;
}
```

The `Py_SetProgramName()` function should be called before `Py_Initialize()` to inform the interpreter about paths to Python run-time libraries. Next, the Python interpreter is initialized with `Py_Initialize()`, followed by the execution of a hard-coded Python script that prints the date and time. Afterwards, the `Py_Finalize()` call shuts the interpreter down, followed by the end of the program. In a real program, you may want to get the Python
script from another source, perhaps a text-editor routine, a file, or a
database. Getting the Python code from a file can better be done by
using the `PyRun_SimpleFile()` function, which saves you the
trouble of allocating memory space and loading the file contents.
1.2. Beyond Very High Level Embedding: An overview

The high level interface gives you the ability to execute arbitrary pieces of Python code from your application, but exchanging data values is quite cumbersome to say the least. If you want that, you should use lower level calls. At the cost of having to write more C code, you can achieve almost anything.

It should be noted that extending Python and embedding Python is quite the same activity, despite the different intent. Most topics discussed in the previous chapters are still valid. To show this, consider what the extension code from Python to C really does:

1. Convert data values from Python to C,
2. Perform a function call to a C routine using the converted values, and
3. Convert the data values from the call from C to Python.

When embedding Python, the interface code does:

1. Convert data values from C to Python,
2. Perform a function call to a Python interface routine using the converted values, and
3. Convert the data values from the call from Python to C.

As you can see, the data conversion steps are simply swapped to accommodate the different direction of the cross-language transfer. The only difference is the routine that you call between both data conversions. When extending, you call a C routine, when embedding, you call a Python routine.

This chapter will not discuss how to convert data from Python to C and
vice versa. Also, proper use of references and dealing with errors is assumed to be understood. Since these aspects do not differ from extending the interpreter, you can refer to earlier chapters for the required information.
1.3. Pure Embedding

The first program aims to execute a function in a Python script. Like in the section about the very high level interface, the Python interpreter does not directly interact with the application (but that will change in the next section).

The code to run a function defined in a Python script is:

```c
#include <Python.h>

int main(int argc, char *argv[]) {
    PyObject *pName, *pModule, *pDict, *pFunc;
    PyObject *pArgs, *pValue;
    int i;

    if (argc < 3) {
        fprintf(stderr,"Usage: call pythonfile funcname [args] return 1;"
        return 1;
    }

    Py_Initialize();
    pName = PyUnicode_DecodeFSDefault(argv[1]);
    /* Error checking of pName left out */

    pModule = PyImport_Import(pName);
    Py_DECREF(pName);

    if (pModule != NULL) {
        pFunc = PyObject_GetAttrString(pModule, argv[2]);
        /* pFunc is a new reference */
        if (pFunc && PyCallable_Check(pFunc)) {
```
pArgs = PyTuple_New(argc - 3);
for (i = 0; i < argc - 3; ++i) {
    pValue = PyLong_FromLong(atoi(argv[i]);
    if (!pValue) {
        Py_DECREF(pArgs);
        Py_DECREF(pModule);
        fprintf(stderr, "Cannot convert return 1;
    }
    /* pValue reference stolen here: */
    PyTuple_SetItem(pArgs, i, pValue);
}
    pValue = PyObject_CallObject(pFunc, pArgs);
    Py_DECREF(pArgs);
    if (pValue != NULL) {
        printf("Result of call: %ld\n", PyLong_AsLong(pValue);
        Py_DECREF(pValue);
    } else {
        Py_DECREF(pFunc);
        Py_DECREF(pModule);
        PyErr_Print();
        fprintf(stderr,"Call failed\n";
        return 1;
    }
} else {
    if (PyErr_Occurred())
        PyErr_Print();
    fprintf(stderr, "Cannot find function ");
}
Py_XDECREF(pFunc);
Py_DECREF(pModule);
}
else {
    PyErr_Print();
    fprintf(stderr, "Failed to load ":s":\n" , argv[1];
"}
This code loads a Python script using `argv[1]`, and calls the function named in `argv[2]`. Its integer arguments are the other values of the `argv` array. If you compile and link this program (let's call the finished executable call), and use it to execute a Python script, such as:

```python
def multiply(a, b):
    print("Will compute", a, "times", b)
    c = 0
    for i in range(0, a):
        c = c + b
    return c
```

then the result should be:

```bash
$ call multiply multiply 3 2
Will compute 3 times 2
Result of call: 6
```

Although the program is quite large for its functionality, most of the code is for data conversion between Python and C, and for error reporting. The interesting part with respect to embedding Python starts with

```c
Py_Initialize();
pName = PyUnicode_DecodeFSDefault(argv[1]);
/* Error checking of pName left out */
pModule = PyImport_Import(pName);
```
After initializing the interpreter, the script is loaded using `PyImport_Import()`. This routine needs a Python string as its argument, which is constructed using the `PyUnicode_FromString()` data conversion routine.

```c
pFunc = PyObject_GetAttrString(pModule, argv[2]);
/* pFunc is a new reference */
if (pFunc && PyCallable_Check(pFunc)) {
    ...
}
Py_XDECREF(pFunc);
```

Once the script is loaded, the name we're looking for is retrieved using `PyObject_GetAttrString()`. If the name exists, and the object returned is callable, you can safely assume that it is a function. The program then proceeds by constructing a tuple of arguments as normal. The call to the Python function is then made with:

```c
pValue = PyObject_CallObject(pFunc, pArgs);
```

Upon return of the function, `pValue` is either `NULL` or it contains a reference to the return value of the function. Be sure to release the reference after examining the value.
1.4. Extending Embedded Python

Until now, the embedded Python interpreter had no access to functionality from the application itself. The Python API allows this by extending the embedded interpreter. That is, the embedded interpreter gets extended with routines provided by the application. While it sounds complex, it is not so bad. Simply forget for a while that the application starts the Python interpreter. Instead, consider the application to be a set of subroutines, and write some glue code that gives Python access to those routines, just like you would write a normal Python extension. For example:

```c
static int numargs=0;

/* Return the number of arguments of the application */
static PyObject*
emb_numargs(PyObject *self, PyObject *args)
{
    if(!PyArg_ParseTuple(args, "::numargs"))
        return NULL;
    return PyLong_FromLong(numargs);
}

static PyMethodDef EmbMethods[] = {
    {"numargs", emb_numargs, METH_VARARGS, "Return the number of arguments received by the
     process."}, {NULL, NULL, 0, NULL}
};

static PyModuleDef EmbModule = {
    PyModuleDef_HEAD_INIT, "emb", NULL, -1, EmbMethods
    NULL, NULL, NULL, NULL
};
```


```c
static PyObject*
PyInit_emb(void)
{
    return PyModule_Create(&EmbModule);
}
```

Insert the above code just above the `main()` function. Also, insert the following two statements before the call to `Py_Initialize()`:

```c
numargs = argc;
PyImport_AppendInittab("emb", &PyInit_emb);
```

These two lines initialize the `numargs` variable, and make the `emb.numargs()` function accessible to the embedded Python interpreter. With these extensions, the Python script can do things like:

```python
import emb
print("Number of arguments", emb.numargs())
```

In a real application, the methods will expose an API of the application to Python.
1.5. Embedding Python in C++

It is also possible to embed Python in a C++ program; precisely how this is done will depend on the details of the C++ system used; in general you will need to write the main program in C++, and use the C++ compiler to compile and link your program. There is no need to recompile Python itself using C++.
1.6. Compiling and Linking under Unix-like systems

It is not necessarily trivial to find the right flags to pass to your compiler (and linker) in order to embed the Python interpreter into your application, particularly because Python needs to load library modules implemented as C dynamic extensions (.so files) linked against it.

To find out the required compiler and linker flags, you can execute the pythonX.Y-config script which is generated as part of the installation process (a python3-config script may also be available). This script has several options, of which the following will be directly useful to you:

- pythonX.Y-config --cflags will give you the recommended flags when compiling:

  ```
  $ /opt/bin/python3.4-config --cflags
  -I/opt/include/python3.4m -I/opt/include/python3
  ```

- pythonX.Y-config --ldflags will give you the recommended flags when linking:

  ```
  $ /opt/bin/python3.4-config --ldflags
  -L/opt/lib/python3.4/config-3.4m -lpthread -ldl
  ```

**Note:** To avoid confusion between several Python installations (and especially between the system Python and your own compiled Python), it is recommended that you use the absolute path to pythonX.Y-config, as in the above example.
If this procedure doesn’t work for you (it is not guaranteed to work for all Unix-like platforms; however, we welcome bug reports) you will have to read your system’s documentation about dynamic linking and/or examine Python’s Makefile (use `sysconfig.get_makefile_filename()` to find its location) and compilation options. In this case, the `sysconfig` module is a useful tool to programmatically extract the configuration values that you will want to combine together. For example:

```python
>>> import sysconfig
>>> sysconfig.get_config_var('LIBS')
'-lpthread -ldl -lutil'
>>> sysconfig.get_config_var('LINKFORSHARED')
'-Xlinker -export-dynamic'
```
Introduction

The Application Programmer’s Interface to Python gives C and C++ programmers access to the Python interpreter at a variety of levels. The API is equally usable from C++, but for brevity it is generally referred to as the Python/C API. There are two fundamentally different reasons for using the Python/C API. The first reason is to write extension modules for specific purposes; these are C modules that extend the Python interpreter. This is probably the most common use. The second reason is to use Python as a component in a larger application; this technique is generally referred to as embedding Python in an application.

Writing an extension module is a relatively well-understood process, where a “cookbook” approach works well. There are several tools that automate the process to some extent. While people have embedded Python in other applications since its early existence, the process of embedding Python is less straightforward than writing an extension.

Many API functions are useful independent of whether you’re embedding or extending Python; moreover, most applications that embed Python will need to provide a custom extension as well, so it’s probably a good idea to become familiar with writing an extension before attempting to embed Python in a real application.
Include Files

All function, type and macro definitions needed to use the Python/C API are included in your code by the following line:

```
#include "Python.h"
```

This implies inclusion of the following standard headers: `<stdio.h>`, `<string.h>`, `<errno.h>`, `<limits.h>`, `<assert.h>` and `<stdlib.h>` (if available).

**Note:** Since Python may define some pre-processor definitions which affect the standard headers on some systems, you *must* include `Python.h` before any standard headers are included.

All user visible names defined by Python.h (except those defined by the included standard headers) have one of the prefixes `Py` or `_Py`. Names beginning with `_Py` are for internal use by the Python implementation and should not be used by extension writers. Structure member names do not have a reserved prefix.

**Important:** user code should never define names that begin with `Py` or `_Py`. This confuses the reader, and jeopardizes the portability of the user code to future Python versions, which may define additional names beginning with one of these prefixes.

The header files are typically installed with Python. On Unix, these are located in the directories `prefix/include/pythonversion/` and `exec_prefix/include/pythonversion/`, where `prefix` and `exec_prefix` are defined by the corresponding parameters to Python’s `configure` script and `version` is `sys.version[:3]`. On
Windows, the headers are installed in `prefix/include`, where `prefix` is the installation directory specified to the installer.

To include the headers, place both directories (if different) on your compiler's search path for includes. Do *not* place the parent directories on the search path and then use `#include <pythonX.Y/Python.h>`; this will break on multi-platform builds since the platform independent headers under `prefix` include the platform specific headers from `exec_prefix`.

C++ users should note that though the API is defined entirely using C, the header files do properly declare the entry points to be `extern "C"`, so there is no need to do anything special to use the API from C++. 
Objects, Types and Reference Counts

Most Python/C API functions have one or more arguments as well as a return value of type `PyObject*`. This type is a pointer to an opaque data type representing an arbitrary Python object. Since all Python object types are treated the same way by the Python language in most situations (e.g., assignments, scope rules, and argument passing), it is only fitting that they should be represented by a single C type. Almost all Python objects live on the heap: you never declare an automatic or static variable of type `PyObject`, only pointer variables of type `PyObject*` can be declared. The sole exception are the type objects; since these must never be deallocated, they are typically static `PyTypeObject` objects.

All Python objects (even Python integers) have a type and a reference count. An object’s type determines what kind of object it is (e.g., an integer, a list, or a user-defined function; there are many more as explained in The standard type hierarchy). For each of the well-known types there is a macro to check whether an object is of that type; for instance, `PyList_Check(a)` is true if (and only if) the object pointed to by `a` is a Python list.

Reference Counts

The reference count is important because today's computers have a finite (and often severely limited) memory size; it counts how many different places there are that have a reference to an object. Such a place could be another object, or a global (or static) C variable, or a local variable in some C function. When an object’s reference count becomes zero, the object is deallocated. If it contains references to other objects, their reference count is decremented. Those other
objects may be deallocated in turn, if this decrement makes their reference count become zero, and so on. (There's an obvious problem with objects that reference each other here; for now, the solution is “don’t do that.”)

Reference counts are always manipulated explicitly. The normal way is to use the macro `Py_INCREF()` to increment an object's reference count by one, and `Py_DECREF()` to decrement it by one. The `Py_DECREF()` macro is considerably more complex than the incref one, since it must check whether the reference count becomes zero and then cause the object's deallocator to be called. The deallocator is a function pointer contained in the object's type structure. The type-specific deallocator takes care of decrementing the reference counts for other objects contained in the object if this is a compound object type, such as a list, as well as performing any additional finalization that's needed. There's no chance that the reference count can overflow; at least as many bits are used to hold the reference count as there are distinct memory locations in virtual memory (assuming `sizeof(Py_ssize_t) >= sizeof(void*)`). Thus, the reference count increment is a simple operation.

It is not necessary to increment an object’s reference count for every local variable that contains a pointer to an object. In theory, the object's reference count goes up by one when the variable is made to point to it and it goes down by one when the variable goes out of scope. However, these two cancel each other out, so at the end the reference count hasn’t changed. The only real reason to use the reference count is to prevent the object from being deallocated as long as our variable is pointing to it. If we know that there is at least one other reference to the object that lives at least as long as our variable, there is no need to increment the reference count temporarily. An important situation where this arises is in objects that are passed as
arguments to C functions in an extension module that are called from Python; the call mechanism guarantees to hold a reference to every argument for the duration of the call.

However, a common pitfall is to extract an object from a list and hold on to it for a while without incrementing its reference count. Some other operation might conceivably remove the object from the list, decrementing its reference count and possible deallocating it. The real danger is that innocent-looking operations may invoke arbitrary Python code which could do this; there is a code path which allows control to flow back to the user from a `Py_DECREF()`, so almost any operation is potentially dangerous.

A safe approach is to always use the generic operations (functions whose name begins with `PyObject_`, `PyNumber_`, `PySequence_` or `PyMapping_`). These operations always increment the reference count of the object they return. This leaves the caller with the responsibility to call `Py_DECREF()` when they are done with the result; this soon becomes second nature.

Reference Count Details

The reference count behavior of functions in the Python/C API is best explained in terms of ownership of references. Ownership pertains to references, never to objects (objects are not owned: they are always shared). “Owning a reference” means being responsible for calling `Py_DECREF` on it when the reference is no longer needed. Ownership can also be transferred, meaning that the code that receives ownership of the reference then becomes responsible for eventually decref'ing it by calling `Py_DECREF()` or `Py_XDECREF()` when it’s no longer needed—or passing on this responsibility (usually to its caller). When a function passes ownership of a reference on to its caller, the
caller is said to receive a new reference. When no ownership is transferred, the caller is said to borrow the reference. Nothing needs to be done for a borrowed reference.

Conversely, when a calling function passes in a reference to an object, there are two possibilities: the function steals a reference to the object, or it does not. Stealing a reference means that when you pass a reference to a function, that function assumes that it now owns that reference, and you are not responsible for it any longer.

Few functions steal references; the two notable exceptions are PyList_SetItem() and PyTuple_SetItem(), which steal a reference to the item (but not to the tuple or list into which the item is put!). These functions were designed to steal a reference because of a common idiom for populating a tuple or list with newly created objects; for example, the code to create the tuple (1, 2, "three") could look like this (forgetting about error handling for the moment; a better way to code this is shown below):

```c
PyObject *t;

    t = PyTuple_New(3);
    PyTuple_SetItem(t, 0, PyLong_FromLong(1L));
    PyTuple_SetItem(t, 1, PyLong_FromLong(2L));
    PyTuple_SetItem(t, 2, PyUnicode_FromString("three"));
```

Here, PyLong_FromLong() returns a new reference which is immediately stolen by PyTuple_SetItem(). When you want to keep using an object although the reference to it will be stolen, use Py_INCREF() to grab another reference before calling the reference-stealing function.

Incidentally, PyTuple_SetItem() is the only way to set tuple items;
PySequence_SetItem() and PyObject_SetItem() refuse to do this since tuples are an immutable data type. You should only use PyTuple_SetItem() for tuples that you are creating yourself.

Equivalent code for populating a list can be written using PyList_New() and PyList_SetItem().

However, in practice, you will rarely use these ways of creating and populating a tuple or list. There's a generic function, Py_BuildValue(), that can create most common objects from C values, directed by a format string. For example, the above two blocks of code could be replaced by the following (which also takes care of the error checking):

```c
PyObject *tuple, *list;

tuple = Py_BuildValue("(iis)", 1, 2, "three");
list = Py_BuildValue("[iis]", 1, 2, "three");
```

It is much more common to use PyObject_SetItem() and friends with items whose references you are only borrowing, like arguments that were passed in to the function you are writing. In that case, their behaviour regarding reference counts is much saner, since you don't have to increment a reference count so you can give a reference away (“have it be stolen”). For example, this function sets all items of a list (actually, any mutable sequence) to a given item:

```c
int set_all(PyObject *target, PyObject *item)
{
    Py_ssize_t i, n;

    n = PyObject_Length(target);
    if (n < 0)
```
The situation is slightly different for function return values. While passing a reference to most functions does not change your ownership responsibilities for that reference, many functions that return a reference to an object give you ownership of the reference. The reason is simple: in many cases, the returned object is created on the fly, and the reference you get is the only reference to the object. Therefore, the generic functions that return object references, like `PyObject_GetItem()` and `PySequence_GetItem()`, always return a new reference (the caller becomes the owner of the reference).

It is important to realize that whether you own a reference returned by a function depends on which function you call only — the plumage (the type of the object passed as an argument to the function) doesn’t enter into it! Thus, if you extract an item from a list using `PyList_GetItem()`, you don’t own the reference — but if you obtain the same item from the same list using `PySequence_GetItem()` (which happens to take exactly the same arguments), you do own a reference to the returned object.
Here is an example of how you could write a function that computes the sum of the items in a list of integers; once using `PyList_GetItem()`, and once using `PySequence_GetItem()`.

```c
long
sum_list(PyObject *list)
{
    Py_ssize_t i, n;
    long total = 0, value;
    PyObject *item;

    n = PyList_Size(list);
    if (n < 0)
        return -1; /* Not a list */
    for (i = 0; i < n; i++) {
        item = PyList_GetItem(list, i); /* Can't fail */
        if (!PyLong_Check(item)) continue; /* Skip non-integers */
        value = PyLong_AsLong(item);
        if (value == -1 && PyErr_Occurred())
            /* Integer too big to fit in a C long, bail out */
            return -1;
        total += value;
    }
    return total;
}
```

```c
long
sum_sequence(PyObject *sequence)
{
    Py_ssize_t i, n;
    long total = 0, value;
    PyObject *item;
    n = PySequence_Length(sequence);
    if (n < 0)
        return -1; /* Has no length */
```
for (i = 0; i < n; i++) {
    item = PySequence_GetItem(sequence, i);
    if (item == NULL)
        return -1; /* Not a sequence, or other failure */
    if (PyLong_Check(item)) {
        value = PyLong_AsLong(item);
        Py_INCREF(item);
        if (value == -1 && PyErr_Occurred())
            /* Integer too big to fit in a C long */
            return -1;
        total += value;
    }
    else {
        Py_DECREF(item); /* Discard reference ownership */
    }
}
return total;

Types

There are few other data types that play a significant role in the Python/C API; most are simple C types such as int, long, double and char*. A few structure types are used to describe static tables used to list the functions exported by a module or the data attributes of a new object type, and another is used to describe the value of a complex number. These will be discussed together with the functions that use them.
Exceptions

The Python programmer only needs to deal with exceptions if specific error handling is required; unhandled exceptions are automatically propagated to the caller, then to the caller’s caller, and so on, until they reach the top-level interpreter, where they are reported to the user accompanied by a stack traceback.

For C programmers, however, error checking always has to be explicit. All functions in the Python/C API can raise exceptions, unless an explicit claim is made otherwise in a function’s documentation. In general, when a function encounters an error, it sets an exception, discards any object references that it owns, and returns an error indicator. If not documented otherwise, this indicator is either NULL or -1, depending on the function’s return type. A few functions return a Boolean true/false result, with false indicating an error. Very few functions return no explicit error indicator or have an ambiguous return value, and require explicit testing for errors with PyErr_Occurred(). These exceptions are always explicitly documented.

Exception state is maintained in per-thread storage (this is equivalent to using global storage in an unthreaded application). A thread can be in one of two states: an exception has occurred, or not. The function PyErr_Occurred() can be used to check for this: it returns a borrowed reference to the exception type object when an exception has occurred, and NULL otherwise. There are a number of functions to set the exception state: PyErr_SetString() is the most common (though not the most general) function to set the exception state, and PyErr_Clear() clears the exception state.

The full exception state consists of three objects (all of which can be
the exception type, the corresponding exception value, and the traceback. These have the same meanings as the Python result of
`syst.exc_info();` however, they are not the same: the Python objects represent the last exception being handled by a Python try ...
except statement, while the C level exception state only exists while an exception is being passed on between C functions until it reaches
the Python bytecode interpreter’s main loop, which takes care of transferring it to `syst.exc_info() and friends.

Note that starting with Python 1.5, the preferred, thread-safe way to access the exception state from Python code is to call the function
`syst.exc_info()`, which returns the per-thread exception state for Python code. Also, the semantics of both ways to access the exception state have changed so that a function which catches an exception will save and restore its thread’s exception state so as to preserve the exception state of its caller. This prevents common bugs in exception handling code caused by an innocent-looking function overwriting the exception being handled; it also reduces the often unwanted lifetime extension for objects that are referenced by the stack frames in the traceback.

As a general principle, a function that calls another function to perform some task should check whether the called function raised an exception, and if so, pass the exception state on to its caller. It should discard any object references that it owns, and return an error indicator, but it should not set another exception — that would overwrite the exception that was just raised, and lose important information about the exact cause of the error.

A simple example of detecting exceptions and passing them on is shown in the `sum_sequence()` example above. It so happens that this example doesn’t need to clean up any owned references when it
detects an error. The following example function shows some error cleanup. First, to remind you why you like Python, we show the equivalent Python code:

```python
def incr_item(dict, key):
    try:
        item = dict[key]
    except KeyError:
        item = 0
    dict[key] = item + 1
```

Here is the corresponding C code, in all its glory:

```c
int incr_item(PyObject *dict, PyObject *key)
{
    /* Objects all initialized to NULL for Py_XDECREF */
    PyObject *item = NULL, *const_one = NULL, *incremented_item;
    int rv = -1; /* Return value initialized to -1 (failure) */

    item = PyObject_GetItem(dict, key);
    if (item == NULL) {
        /* Handle KeyError only: */
        if (!PyErr_ExceptionMatches(PyExc_KeyError))
            goto error;

        /* Clear the error and use zero: */
        PyErr_Clear();
        item = PyLong_FromLong(0L);
        if (item == NULL)
            goto error;
    }

    const_one = PyLong_FromLong(1L);
    if (const_one == NULL)
        goto error;
```
incremented_item = PyNumber_Add(item, const_one)
if (incremented_item == NULL)
    goto error;

if (PyObject_SetItem(dict, key, incremented_item)
    goto error;
rv = 0; /* Success */
/* Continue with cleanup code */

error:
    /* Cleanup code, shared by success and failure path */
    Py_XDECREF(item);
    Py_XDECREF(const_one);
    Py_XDECREF(incremented_item);

    return rv; /* -1 for error, 0 for success */

This example represents an endorsed use of the goto statement in C!
It illustrates the use of PyErr_ExceptionMatches() and PyErr_Clear() to handle specific exceptions, and the use of
Py_XDECRF() to dispose of owned references that may be NULL (note the 'X' in the name; Py_DECREF() would crash when
confronted with a NULL reference). It is important that the variables
used to hold owned references are initialized to NULL for this to work;
likewise, the proposed return value is initialized to -1 (failure) and only
set to success after the final call made is successful.
Embedding Python

The one important task that only embedders (as opposed to extension writers) of the Python interpreter have to worry about is the initialization, and possibly the finalization, of the Python interpreter. Most functionality of the interpreter can only be used after the interpreter has been initialized.

The basic initialization function is `Py_Initialize()`. This initializes the table of loaded modules, and creates the fundamental modules `builtins`, `__main__`, and `sys`. It also initializes the module search path (`sys.path`).

`Py_Initialize()` does not set the “script argument list” (`sys.argv`). If this variable is needed by Python code that will be executed later, it must be set explicitly with a call to `PySys_SetArgvEx(argc, argv, updatepath)` after the call to `Py_Initialize()`.

On most systems (in particular, on Unix and Windows, although the details are slightly different), `Py_Initialize()` calculates the module search path based upon its best guess for the location of the standard Python interpreter executable, assuming that the Python library is found in a fixed location relative to the Python interpreter executable. In particular, it looks for a directory named `lib/pythonX.Y` relative to the parent directory where the executable named `python` is found on the shell command search path (the environment variable PATH).

For instance, if the Python executable is found in `/usr/local/bin/python`, it will assume that the libraries are in
/usr/local/lib/pythonX.Y. (In fact, this particular path is also the “fallback” location, used when no executable file named python is found along PATH.) The user can override this behavior by setting the environment variable PYTHONHOME, or insert additional directories in front of the standard path by setting PYTHONPATH.

The embedding application can steer the search by calling Py_SetProgramName(file) before calling Py_Initialize(). Note that PYTHONHOME still overrides this and PYTHONPATH is still inserted in front of the standard path. An application that requires total control has to provide its own implementation of Py_GetPath(), Py_GetPrefix(), Py_GetExecPrefix(), and Py_GetProgramFullPath() (all defined in Modules/getpath.c).

Sometimes, it is desirable to “uninitialize” Python. For instance, the application may want to start over (make another call to Py_Initialize()) or the application is simply done with its use of Python and wants to free memory allocated by Python. This can be accomplished by calling Py_Finalize(). The function Py_IsInitialized() returns true if Python is currently in the initialized state. More information about these functions is given in a later chapter. Notice that Py_Finalize() does not free all memory allocated by the Python interpreter, e.g. memory allocated by extension modules currently cannot be released.
Debugging Builds

Python can be built with several macros to enable extra checks of the interpreter and extension modules. These checks tend to add a large amount of overhead to the runtime so they are not enabled by default.

A full list of the various types of debugging builds is in the file Misc/SpecialBuilds.txt in the Python source distribution. Builds are available that support tracing of reference counts, debugging the memory allocator, or low-level profiling of the main interpreter loop. Only the most frequently-used builds will be described in the remainder of this section.

Compiling the interpreter with the Py_DEBUG macro defined produces what is generally meant by “a debug build” of Python. Py_DEBUG is enabled in the Unix build by adding --with-pydebug to the ./configure command. It is also implied by the presence of the not-Python-specific _DEBUG macro. When Py_DEBUG is enabled in the Unix build, compiler optimization is disabled.

In addition to the reference count debugging described below, the following extra checks are performed:

- Extra checks are added to the object allocator.
- Extra checks are added to the parser and compiler.
- Downcasts from wide types to narrow types are checked for loss of information.
- A number of assertions are added to the dictionary and set implementations. In addition, the set object acquires a test_c_api() method.
- Sanity checks of the input arguments are added to frame creation.
- The storage for ints is initialized with a known invalid pattern to
catch reference to uninitialized digits.

- Low-level tracing and extra exception checking are added to the runtime virtual machine.
- Extra checks are added to the memory arena implementation.
- Extra debugging is added to the thread module.

There may be additional checks not mentioned here.

Defining Py_TRACE_REFS enables reference tracing. When defined, a circular doubly linked list of active objects is maintained by adding two extra fields to every PyObject. Total allocations are tracked as well. Upon exit, all existing references are printed. (In interactive mode this happens after every statement run by the interpreter.) Implied by Py_DEBUG.

Please refer to Misc/SpecialBuilds.txt in the Python source distribution for more detailed information.
Stable Application Binary Interface

Traditionally, the C API of Python will change with every release. Most changes will be source-compatible, typically by only adding API, rather than changing existing API or removing API (although some interfaces do get removed after being deprecated first).

Unfortunately, the API compatibility does not extend to binary compatibility (the ABI). The reason is primarily the evolution of struct definitions, where addition of a new field, or changing the type of a field, might not break the API, but can break the ABI. As a consequence, extension modules need to be recompiled for every Python release (although an exception is possible on Unix when none of the affected interfaces are used). In addition, on Windows, extension modules link with a specific pythonXY.dll and need to be recompiled to link with a newer one.

Since Python 3.2, a subset of the API has been declared to guarantee a stable ABI. Extension modules wishing to use this API (called “limited API”) need to define Py_LIMITED_API. A number of interpreter details then become hidden from the extension module; in return, a module is built that works on any 3.x version (x>=2) without recompilation.

In some cases, the stable ABI needs to be extended with new functions. Extension modules wishing to use these new APIs need to set Py_LIMITED_API to the PY_VERSION_HEX value (see API and ABI Versioning) of the minimum Python version they want to support (e.g. 0x03030000 for Python 3.3). Such modules will work on all subsequent Python releases, but fail to load (because of missing symbols) on the older releases.
As of Python 3.2, the set of functions available to the limited API is documented in PEP 384. In the C API documentation, API elements that are not part of the limited API are marked as “Not part of the limited API.”
The Very High Level Layer

The functions in this chapter will let you execute Python source code given in a file or a buffer, but they will not let you interact in a more detailed way with the interpreter.

Several of these functions accept a start symbol from the grammar as a parameter. The available start symbols are Py_eval_input, Py_file_input, and Py_single_input. These are described following the functions which accept them as parameters.

Note also that several of these functions take FILE* parameters. One particular issue which needs to be handled carefully is that the FILE structure for different C libraries can be different and incompatible. Under Windows (at least), it is possible for dynamically linked extensions to actually use different libraries, so care should be taken that FILE* parameters are only passed to these functions if it is certain that they were created by the same library that the Python runtime is using.

int **Py_Main**(int argc, wchar_t **argv)

The main program for the standard interpreter. This is made available for programs which embed Python. The argc and argv parameters should be prepared exactly as those which are passed to a C program’s main() function (converted to wchar_t according to the user’s locale). It is important to note that the argument list may be modified (but the contents of the strings pointed to by the argument list are not). The return value will be 0 if the interpreter exits normally (i.e., without an exception), 1 if the interpreter exits due to an exception, or 2 if the parameter list does not represent a
valid Python command line.

Note that if an otherwise unhandled `SystemExit` is raised, this function will not return 1, but exit the process, as long as `Py_InspectFlag` is not set.

```c
int PyRun_AnyFile(FILE *fp, const char *filename)

This is a simplified interface to `PyRun_AnyFileExFlags()` below, leaving `closeit` set to 0 and `flags` set to NULL.
```

```c
int PyRun_AnyFileFlags(FILE *fp, const char *filename, PyCompilerFlags *flags)

This is a simplified interface to `PyRun_AnyFileExFlags()` below, leaving the `closeit` argument set to 0.
```

```c
int PyRun_AnyFileEx(FILE *fp, const char *filename, int closeit)

This is a simplified interface to `PyRun_AnyFileExFlags()` below, leaving the `flags` argument set to NULL.
```

```c
int PyRun_AnyFileExFlags(FILE *fp, const char *filename, int closeit, PyCompilerFlags *flags)

If `fp` refers to a file associated with an interactive device (console or terminal input or Unix pseudo-terminal), return the value of `PyRun_InteractiveLoop()`, otherwise return the result of `PyRun_SimpleFile()`. `filename` is decoded from the filesystem encoding (`sys.getfilesystemencoding()`). If `filename` is `NULL`, this function uses "???" as the filename.
```

```c
int PyRun_SimpleString(const char *command)

This is a simplified interface to `PyRun_SimpleStringFlags()` below, leaving the `PyCompilerFlags`* argument set to NULL.
```
int **PyRun_SimpleStringFlags**(const char *command, PyCompilerFlags *flags)

Executes the Python source code from `command` in the `__main__` module according to the `flags` argument. If `__main__` does not already exist, it is created. Returns 0 on success or -1 if an exception was raised. If there was an error, there is no way to get the exception information. For the meaning of `flags`, see below.

Note that if an otherwise unhandled `SystemExit` is raised, this function will not return -1, but exit the process, as long as `Py_InspectFlag` is not set.

int **PyRun_SimpleFile**(FILE *fp, const char *filename)

This is a simplified interface to `PyRun_SimpleFileExFlags()` below, leaving `closeit` set to 0 and `flags` set to `NULL`.

int **PyRun_SimpleFileEx**(FILE *fp, const char *filename, int closeit)

This is a simplified interface to `PyRun_SimpleFileExFlags()` below, leaving `flags` set to `NULL`.

int **PyRun_SimpleFileExFlags**(FILE *fp, const char *filename, int closeit, PyCompilerFlags *flags)

Similar to `PyRun_SimpleStringFlags()`, but the Python source code is read from `fp` instead of an in-memory string. `filename` should be the name of the file, it is decoded from the filesystem encoding (`sys.getfilesystemencoding()`). If `closeit` is true, the file is closed before `PyRun_SimpleFileExFlags` returns.

int **PyRun_InteractiveOne**(FILE *fp, const char *filename)

This is a simplified interface to `PyRun_InteractiveOneFlags()` below, leaving `flags` set to
int PyRun_InteractiveOneFlags(FILE *fp, const char *filename, PyCompilerFlags *flags)
    Read and execute a single statement from a file associated with an interactive device according to the flags argument. The user will be prompted using sys.ps1 and sys.ps2. filename is decoded from the filesystem encoding (sys.getfilesystemencoding()).

    Returns 0 when the input was executed successfully, -1 if there was an exception, or an error code from the errcode.h include file distributed as part of Python if there was a parse error. (Note that errcode.h is not included by Python.h, so must be included specifically if needed.)

int PyRun_InteractiveLoop(FILE *fp, const char *filename)
    This is a simplified interface to PyRun_InteractiveLoopFlags() below, leaving flags set to NULL.

int PyRun_InteractiveLoopFlags(FILE *fp, const char *filename, PyCompilerFlags *flags)
    Read and execute statements from a file associated with an interactive device until EOF is reached. The user will be prompted using sys.ps1 and sys.ps2. filename is decoded from the filesystem encoding (sys.getfilesystemencoding()). Returns 0 at EOF.

int (*PyOS_InputHook)(void)
    Can be set to point to a function with the prototype int func(void). The function will be called when Python's interpreter prompt is about to become idle and wait for user input from the
terminal. The return value is ignored. Overriding this hook can be
used to integrate the interpreter’s prompt with other event loops, as
done in the Modules/_tkinter.c in the Python source code.

```c
char* (*PyOS_ReadlineFunctionPointer)(FILE *, FILE *,
const char *)
```

Can be set to point to a function with the prototype char
*func(FILE *stdin, FILE *stdout, char *prompt),
overriding the default function used to read a single line of input at
the interpreter’s prompt. The function is expected to output the
string prompt if it’s not NULL, and then read a line of input from the
provided standard input file, returning the resulting string. For
example, The readline module sets this hook to provide line-
editing and tab-completion features.

The result must be a string allocated by PyMem_RawMalloc() or
PyMem_RawRealloc(), or NULL if an error occurred.

*Changed in version 3.4:* The result must be allocated by
PyMem_RawMalloc() or PyMem_RawRealloc(), instead of
being allocated by PyMem_Malloc() or PyMem_Realloc().

```c
struct _node* PyParser_SimpleParseString(const char *str,
int start)
```

This is a simplified interface to
PyParser_SimpleParseStringFlagsFilename() below, leaving filename set to NULL and flags set to 0.

```c
struct _node* PyParser_SimpleParseStringFlags(const char *str,
int start, int flags)
```

This is a simplified interface to
PyParser_SimpleParseStringFlagsFilename() below,
leaving \textit{filename} set to \textit{NULL}.

\begin{verbatim}
struct _node*
PyParser_SimpleParseStringFlagsFilename(const char *str, const char *filename, int start, int flags)
    Parse Python source code from \textit{str} using the start token \textit{start} according to the \textit{flags} argument. The result can be used to create a code object which can be evaluated efficiently. This is useful if a code fragment must be evaluated many times. \textit{filename} is decoded from the filesystem encoding (\texttt{sys.getfilesystemencoding()}).

struct _node* PyParser_SimpleParseFile(FILE *fp, const char *filename, int start)
    This is a simplified interface to \texttt{PyParser_SimpleParseFileFlags()} below, leaving \textit{flags} set to 0.

struct _node* PyParser_SimpleParseFileFlags(FILE *fp, const char *filename, int start, int flags)
    Similar to \texttt{PyParser_SimpleParseStringFlagsFilename()}, but the Python source code is read from \texttt{fp} instead of an in-memory string.

PyObject* PyRun_String(const char *str, int start, PyObject *globals, PyObject *locals)
    \textit{Return value: New reference.}
    This is a simplified interface to \texttt{PyRun_StringFlags()} below, leaving \textit{flags} set to \textit{NULL}.

PyObject* PyRun_StringFlags(const char *str, int start, PyObject *globals, PyObject *locals, PyCompilerFlags *flags)
    \textit{Return value: New reference.}
\end{verbatim}
Execute Python source code from \textit{str} in the context specified by the dictionaries \textit{globals} and \textit{locals} with the compiler flags specified by \textit{flags}. The parameter \textit{start} specifies the start token that should be used to parse the source code.

Returns the result of executing the code as a Python object, or \textit{NULL} if an exception was raised.

\texttt{PyObject* PyRun\_File(FILE \*fp, const char \*filename, int start, PyObject *globals, PyObject *locals)}

\textit{Return value: New reference.}
This is a simplified interface to \texttt{PyRun\_FileExFlags()} below, leaving \textit{closeit} set to 0 and \textit{flags} set to \textit{NULL}.

\texttt{PyObject* PyRun\_FileEx(FILE \*fp, const char \*filename, int start, PyObject *globals, PyObject *locals, int closeit)}

\textit{Return value: New reference.}
This is a simplified interface to \texttt{PyRun\_FileExFlags()} below, leaving \textit{flags} set to \textit{NULL}.

\texttt{PyObject* PyRun\_FileFlags(FILE \*fp, const char \*filename, int start, PyObject *globals, PyObject *locals, PyCompilerFlags \*flags)}

\textit{Return value: New reference.}
This is a simplified interface to \texttt{PyRun\_FileExFlags()} below, leaving \textit{closeit} set to 0.

\texttt{PyObject* PyRun\_FileExFlags(FILE \*fp, const char \*filename, int start, PyObject *globals, PyObject *locals, int closeit, PyCompilerFlags \*flags)}

\textit{Return value: New reference.}
Similar to \texttt{PyRun\_StringFlags()}, but the Python source code is read from \texttt{fp} instead of an in-memory string. \textit{filename} should be the name of the file, it is decoded from the filesystem encoding
If closeit is true, the file is closed before `PyRun_FileExFlags()` returns.

**PyObject** * `Py_CompileString`(const char *str, const char *filename, int start)

*Return value: New reference.*
This is a simplified interface to `Py_CompileStringFlags()` below, leaving flags set to `NULL`.

**PyObject** * `Py_CompileStringFlags`(const char *str, const char *filename, int start, PyCompilerFlags *flags)

*Return value: New reference.*
This is a simplified interface to `Py_CompileStringExFlags()` below, with optimize set to -1.

**PyObject** * `Py_CompileStringObject`(const char *str, PyObject *filename, int start, PyCompilerFlags *flags, int optimize)

Parse and compile the Python source code in str, returning the resulting code object. The start token is given by start; this can be used to constrain the code which can be compiled and should be Py_eval_input, Py_file_input, or Py_single_input. The filename specified by filename is used to construct the code object and may appear in tracebacks or SyntaxError exception messages. This returns NULL if the code cannot be parsed or compiled.

The integer optimize specifies the optimization level of the compiler; a value of -1 selects the optimization level of the interpreter as given by -0 options. Explicit levels are 0 (no optimization; __debug__ is true), 1 (asserts are removed, __debug__ is false) or 2 (docstrings are removed too).
New in version 3.4.

PyObject* Py_CompileStringExFlags(const char *str, const char *filename, int start, PyCompilerFlags *flags, int optimize)

Like Py_CompileStringExFlags(), but filename is a byte string decoded from the filesystem encoding (os.fsdecode()).

New in version 3.2.

PyObject* PyEval_EvalCode(PyObject *co, PyObject *globals, PyObject *locals)

This is a simplified interface to PyEval_EvalCodeEx(), with just the code object, and the dictionaries of global and local variables. The other arguments are set to NULL.

PyObject* PyEval_EvalCodeEx(PyObject *co, PyObject *globals, PyObject *locals, PyObject **args, int argcount,
PyObject **kws, int kwcount, PyObject **defs, int defcount,
PyObject *closure)

Evaluate a precompiled code object, given a particular environment for its evaluation. This environment consists of dictionaries of global and local variables, arrays of arguments, keywords and defaults, and a closure tuple of cells.

PyObject* PyEval_EvalFrame(PyFrameObject *f)

Evaluate an execution frame. This is a simplified interface to PyEval_EvalFrameEx, for backward compatibility.

PyObject* PyEval_EvalFrameEx(PyFrameObject *f, int throwflag)

This is the main, unvarnished function of Python interpretation. It is literally 2000 lines long. The code object associated with the
execution frame \( f \) is executed, interpreting bytecode and executing calls as needed. The additional \textit{throwflag} parameter can mostly be ignored - if true, then it causes an exception to immediately be thrown; this is used for the \texttt{throw()} methods of generator objects.

\textit{Changed in version 3.4}: This function now includes a debug assertion to help ensure that it does not silently discard an active exception.

\texttt{int PyEval_MergeCompilerFlags(PyCompilerFlags *cf)}

This function changes the flags of the current evaluation frame, and returns true on success, false on failure.

\texttt{int Py_eval_input}

The start symbol from the Python grammar for isolated expressions; for use with \texttt{Py_CompileString()}. 

\texttt{int Py_file_input}

The start symbol from the Python grammar for sequences of statements as read from a file or other source; for use with \texttt{Py_CompileString()}. This is the symbol to use when compiling arbitrarily long Python source code.

\texttt{int Py_single_input}

The start symbol from the Python grammar for a single statement; for use with \texttt{Py_CompileString()}. This is the symbol used for the interactive interpreter loop.

\texttt{struct PyCompilerFlags}

This is the structure used to hold compiler flags. In cases where code is only being compiled, it is passed as \texttt{int flags}, and in cases where code is being executed, it is passed as \texttt{PyCompilerFlags *flags}. In this case, from \texttt{__future__}
import can modify flags.

Whenever PyCompilerFlags *flags is NULL, cf_flags is treated as equal to 0, and any modification due to from __future__ import is discarded.

```c
struct PyCompilerFlags {
    int cf_flags;
}
```

int **CO_FUTURE_DIVISION**

This bit can be set in flags to cause division operator / to be interpreted as “true division” according to PEP 238.
Reference Counting

The macros in this section are used for managing reference counts of Python objects.

void **Py**__**INCREF**(PyObject *o)

Increment the reference count for object o. The object must not be NULL; if you aren’t sure that it isn’t NULL, use **Py**__**XINCREF**().

void **Py**__**XINCREF**(PyObject *o)

Increment the reference count for object o. The object may be NULL, in which case the macro has no effect.

void **Py**__**DECREF**(PyObject *o)

Decrement the reference count for object o. The object must not be NULL; if you aren’t sure that it isn’t NULL, use **Py**__**XDECRE**(). If the reference count reaches zero, the object’s type’s deallocation function (which must not be NULL) is invoked.

**Warning:** The deallocation function can cause arbitrary Python code to be invoked (e.g. when a class instance with a __del__() method is deallocated). While exceptions in such code are not propagated, the executed code has free access to all Python global variables. This means that any object that is reachable from a global variable should be in a consistent state before **Py**__**DECREF**() is invoked. For example, code to delete an object from a list should copy a reference to the deleted object in a temporary variable, update the list data structure, and then call **Py**__**DECREF**() for the temporary variable.
void **Py_XDECREF**(PyObject *o)

Decrement the reference count for object o. The object may be *NULL*, in which case the macro has no effect; otherwise the effect is the same as for **Py_DECREF()**, and the same warning applies.

void **Py_CLEAR**(PyObject *o)

Decrement the reference count for object o. The object may be *NULL*, in which case the macro has no effect; otherwise the effect is the same as for **Py_DECREF()**, except that the argument is also set to *NULL*. The warning for **Py_DECREF()** does not apply with respect to the object passed because the macro carefully uses a temporary variable and sets the argument to *NULL* before decrementing its reference count.

It is a good idea to use this macro whenever decrementing the value of a variable that might be traversed during garbage collection.

The following functions are for runtime dynamic embedding of Python: **Py_IncRef**(PyObject *o), **Py_DecRef**(PyObject *o). They are simply exported function versions of **Py_XINCREF**() and **Py_XDECREF**(), respectively.

The following functions or macros are only for use within the interpreter core: **_Py_Dealloc()**, **_Py_ForgetReference()**, **_Py_NewReference()**, as well as the global variable **_Py_RefTotal**.
Exception Handling

The functions described in this chapter will let you handle and raise Python exceptions. It is important to understand some of the basics of Python exception handling. It works somewhat like the POSIX errno variable: there is a global indicator (per thread) of the last error that occurred. Most C API functions don’t clear this on success, but will set it to indicate the cause of the error on failure. Most C API functions also return an error indicator, usually NULL if they are supposed to return a pointer, or -1 if they return an integer (exception: the PyArg_*() functions return 1 for success and 0 for failure).

Concretely, the error indicator consists of three object pointers: the exception’s type, the exception's value, and the traceback object. Any of those pointers can be NULL if non-set (although some combinations are forbidden, for example you can’t have a non-NULL traceback if the exception type is NULL).

When a function must fail because some function it called failed, it generally doesn’t set the error indicator; the function it called already set it. It is responsible for either handling the error and clearing the exception or returning after cleaning up any resources it holds (such as object references or memory allocations); it should not continue normally if it is not prepared to handle the error. If returning due to an error, it is important to indicate to the caller that an error has been set. If the error is not handled or carefully propagated, additional calls into the Python/C API may not behave as intended and may fail in mysterious ways.

Note: The error indicator is not the result of sys.exc_info(). The former corresponds to an exception that is not yet caught (and is
therefore still propagating), while the latter returns an exception after it is caught (and has therefore stopped propagating).
Printing and clearing

void **PyErr_Clear**()

Clear the error indicator. If the error indicator is not set, there is no effect.

void **PyErr_PrintEx**(int **set_sys_last_vars**)

Print a standard traceback to sys.stderr and clear the error indicator. Call this function only when the error indicator is set. (Otherwise it will cause a fatal error!)

If **set_sys_last_vars** is nonzero, the variables **sys.last_type**, **sys.last_value** and **sys.last_traceback** will be set to the type, value and traceback of the printed exception, respectively.

void **PyErr_Print**()

Alias for PyErr_PrintEx(1).

void **PyErr_WriteUnraisable**(PyObject *obj)

This utility function prints a warning message to sys.stderr when an exception has been set but it is impossible for the interpreter to actually raise the exception. It is used, for example, when an exception occurs in an __del__() method.

The function is called with a single argument **obj** that identifies the context in which the unraisable exception occurred. The repr of **obj** will be printed in the warning message.
Raising exceptions

These functions help you set the current thread’s error indicator. For convenience, some of these functions will always return a NULL pointer for use in a return statement.

```c
void PyErr_SetString(PyObject *type, const char *message)
```

This is the most common way to set the error indicator. The first argument specifies the exception type; it is normally one of the standard exceptions, e.g. PyExc_RuntimeError. You need not increment its reference count. The second argument is an error message; it is decoded from 'utf-8'.

```c
void PyErr_SetObject(PyObject *type, PyObject *value)
```

This function is similar to PyErr_SetString() but lets you specify an arbitrary Python object for the “value” of the exception.

```c
PyObject* PyErr_Format(PyObject *exception, const char *format, ...)
```

*Return value: Always NULL.*

This function sets the error indicator and returns NULL. exception should be a Python exception class. The format and subsequent parameters help format the error message; they have the same meaning and values as in PyUnicode_FromFormat(). format is an ASCII-encoded string.

```c
PyObject* PyErr_FormatV(PyObject *exception, const char *format, va_list vars)
```

*Return value: Always NULL.*

Same as PyErr_Format(), but taking a va_list argument rather than a variable number of arguments.
void **PyErr_SetNone(PyObject *type)
This is a shorthand for PyErr_SetObject(type, Py_None).

int **PyErr_BadArgument()
This is a shorthand for PyErr_SetString(PyExc_TypeError, message), where message indicates that a built-in operation was invoked with an illegal argument. It is mostly for internal use.

PyObject** **PyErr_NoMemory()
Return value: Always NULL.
This is a shorthand for PyErr_SetNone(PyExc_MemoryError); it returns NULL so an object allocation function can write return PyErr_NoMemory(); when it runs out of memory.

PyObject** **PyErr_SetFromErrno(PyObject *type)
Return value: Always NULL.
This is a convenience function to raise an exception when a C library function has returned an error and set the C variable errno. It constructs a tuple object whose first item is the integer errno value and whose second item is the corresponding error message (gotten from strerror()), and then calls PyErr_SetObject(type, object). On Unix, when the errno value is EINTR, indicating an interrupted system call, this calls PyErr_CheckSignals(), and if that set the error indicator, leaves it set to that. The function always returns NULL, so a wrapper function around a system call can write return PyErr_SetFromErrno(type); when the system call returns an error.
**PyErr_SetFromErrnoWithFilenameObject**(PyObject *type, PyObject *filenameObject)

Similar to **PyErr_SetFromErrno()**, with the additional behavior that if `filenameObject` is not `NULL`, it is passed to the constructor of `type` as a third parameter. In the case of `OSError` exception, this is used to define the filename attribute of the exception instance.

**PyErr*  
**PyErr_SetFromErrnoWithFilenameObjects**(PyObject *type, PyObject *filenameObject, PyObject *filenameObject2)

Similar to **PyErr_SetFromErrnoWithFilenameObject()**, but takes a second filename object, for raising errors when a function that takes two filenames fails.

*New in version 3.4.*

**PyErr*  
**PyErr_SetFromErrnoWithFilename**(PyObject *type, const char *filename)

*Return value: Always NULL.*

Similar to **PyErr_SetFromErrnoWithFilenameObject()**, but the filename is given as a C string. `filename` is decoded from the filesystem encoding (`os.fsdecode()`).

**PyErr*  
**PyErr_SetFromWindowsErr**(int ierr)

*Return value: Always NULL.*

This is a convenience function to raise `WindowsError`. If called with `ierr` of 0, the error code returned by a call to `GetLastError()` is used instead. It calls the Win32 function `FormatMessage()` to retrieve the Windows description of error code given by `ierr` or `GetLastError()`, then it constructs a tuple object whose first item is the `ierr` value and whose second item is
the corresponding error message (gotten from FormatMessage()), and then calls PyErr_SetObject(PyExc_WindowsError, object). This function always returns NULL. Availability: Windows.

PyObject* **PyErr_SetExcFromWindowsErr** (PyObject *type, int ierr)

*Return value: Always NULL.*
Similar to PyErr_SetFromWindowsErr(), with an additional parameter specifying the exception type to be raised. Availability: Windows.

PyObject*
**PyErr_SetFromWindowsErrWithFilename**(int ierr, const char *filename)

*Return value: Always NULL.*
Similar to PyErr_SetFromWindowsErrWithFilenameObject(), but the filename is given as a C string. filename is decoded from the filesystem encoding (os.fsdecode()). Availability: Windows.

PyObject*
**PyErr_SetExcFromWindowsErrWithFilenameObject**(int ierr, PyObject *filename)

Similar to PyErr_SetFromWindowsErrWithFilenameObject(), with an additional parameter specifying the exception type to be raised. Availability: Windows.

PyObject*
**PyErr_SetExcFromWindowsErrWithFilenameObjects**(int ierr, PyObject *filename, PyObject *filename2)

Similar to
PyErr_SetExcFromWindowsErrWithFilenameObject(), but accepts a second filename object. Availability: Windows.

New in version 3.4.

PyObject*
PyErr_SetExcFromWindowsErrWithFilenameObject(PyObject *type, int ierr, const char *filename)

Return value: Always NULL.

Similar to PyErr_SetFromWindowsErrWithFilename(), with an additional parameter specifying the exception type to be raised. Availability: Windows.

PyObject* PyErr_SetImportError(PyObject *msg, PyObject *name, PyObject *path)

This is a convenience function to raise ImportError. msg will be set as the exception’s message string. name and path, both of which can be NULL, will be set as the ImportError’s respective name and path attributes.

New in version 3.3.

void PyErr_SyntaxLocationObject(PyObject *filename, int lineno, int col_offset)

Set file, line, and offset information for the current exception. If the current exception is not a SyntaxError, then it sets additional attributes, which make the exception printing subsystem think the exception is a SyntaxError.

New in version 3.4.

void PyErr_SyntaxLocationEx(const char *filename, int lineno, int col_offset)
Like `PyErr_SyntaxLocationObject()`, but `filename` is a byte string decoded from the filesystem encoding (`os.fsdecode()`).

*New in version 3.2.*

```c
void PyErr_SyntaxLocation(const char *filename, int lineno)
```

Like `PyErr_SyntaxLocationEx()`, but the `col_offset` parameter is omitted.

```c
void PyErr_BadInternalCall()
```

This is a shorthand for `PyErr_SetString(PyExc_SystemError, message)`, where `message` indicates that an internal operation (e.g. a Python/C API function) was invoked with an illegal argument. It is mostly for internal use.
Issuing warnings

Use these functions to issue warnings from C code. They mirror similar functions exported by the Python `warnings` module. They normally print a warning message to `sys.stderr`; however, it is also possible that the user has specified that warnings are to be turned into errors, and in that case they will raise an exception. It is also possible that the functions raise an exception because of a problem with the warning machinery. The return value is 0 if no exception is raised, or -1 if an exception is raised. (It is not possible to determine whether a warning message is actually printed, nor what the reason is for the exception; this is intentional.) If an exception is raised, the caller should do its normal exception handling (for example, `Py_XDECREF()` owned references and return an error value).

```c
int PyErr_WarnEx(PyObject *category, const char *message,
Py_ssize_t stack_level)
```

Issue a warning message. The `category` argument is a warning category (see below) or `NULL`; the `message` argument is an UTF-8 encoded string. `stack_level` is a positive number giving a number of stack frames; the warning will be issued from the currently executing line of code in that stack frame. A `stack_level` of 1 is the function calling `PyErr_WarnEx()`, 2 is the function above that, and so forth.

Warning categories must be subclasses of `Warning`; the default warning category is `RuntimeWarning`. The standard Python warning categories are available as global variables whose names are `PyExc_` followed by the Python exception name. These have the type `PyObject*`; they are all class objects. Their names are `PyExc_Warning`, `PyExc_UserWarning`, `PyExc_DeprecationWarning`, etc.
PyExc_UnicodeWarning, PyExc_DeprecationWarning, PyExc_SyntaxWarning, PyExc_RuntimeWarning, and PyExc_FutureWarning. PyExc_Warning is a subclass of PyExc_Exception; the other warning categories are subclasses of PyExc_Warning.

For information about warning control, see the documentation for the `warnings` module and the `-W` option in the command line documentation. There is no C API for warning control.

```c
int PyErr_WarnExplicitObject(PyObject *category, PyObject *message, PyObject *filename, int lineno, PyObject *module, PyObject *registry)
```

Issue a warning message with explicit control over all warning attributes. This is a straightforward wrapper around the Python function `warnings.warn_explicit()`, see there for more information. The `module` and `registry` arguments may be set to `NULL` to get the default effect described there.

*New in version 3.4.*

```c
int PyErr_WarnExplicit(PyObject *category, const char *message, const char *filename, int lineno, const char *module, PyObject *registry)
```

Similar to `PyErr_WarnExplicitObject()` except that `message` and `module` are UTF-8 encoded strings, and `filename` is decoded from the filesystem encoding (`os.fsdecode()`).

```c
int PyErr_WarnFormat(PyObject *category, Py_ssize_t stack_level, const char *format, ...)
```

Function similar to `PyErr_WarnEx()`, but use `PyUnicode_FromFormat()` to format the warning message.
format is an ASCII-encoded string.

New in version 3.2.
Querying the error indicator

PyObject* **PyErr_Occurred()**

*Return value: Borrowed reference.*

Test whether the error indicator is set. If set, return the exception type (the first argument to the last call to one of the PyErr_Set*() functions or to PyErr_Restore()). If not set, return NULL. You do not own a reference to the return value, so you do not need to Py_DECREF() it.

**Note:** Do not compare the return value to a specific exception; use PyErr_ExceptionMatches() instead, shown below. (The comparison could easily fail since the exception may be an instance instead of a class, in the case of a class exception, or it may be a subclass of the expected exception.)

```c
int PyErr_ExceptionMatches(PyObject *exc)
```

Equivalent to PyErr_GivenExceptionMatches(PyErr_Occurred(), exc). This should only be called when an exception is actually set; a memory access violation will occur if no exception has been raised.

```c
int PyErr_GivenExceptionMatches(PyObject *given, PyObject *exc)
```

Return true if the given exception matches the exception type in exc. If exc is a class object, this also returns true when given is an instance of a subclass. If exc is a tuple, all exception types in the tuple (and recursively in subtuples) are searched for a match.

```c
void PyErr_Fetch(PyObject **ptype, PyObject **pvalue,
```
**PyObject **ptraceback**
Retrieve the error indicator into three variables whose addresses are passed. If the error indicator is not set, set all three variables to NULL. If it is set, it will be cleared and you own a reference to each object retrieved. The value and traceback object may be NULL even when the type object is not.

**Note:** This function is normally only used by code that needs to catch exceptions or by code that needs to save and restore the error indicator temporarily, e.g.:

```
{  
    PyObject **type, **value, **traceback;  
    PyErr_Fetch(&type, &value, &traceback);  
    /* ... code that might produce other errors */  
    PyErr_Restore(type, value, traceback);  
}
```

void **PyErr_Restore**(PyObject *type, PyObject *value, PyObject *traceback)
Set the error indicator from the three objects. If the error indicator is already set, it is cleared first. If the objects are NULL, the error indicator is cleared. Do not pass a NULL type and non-NULL value or traceback. The exception type should be a class. Do not pass an invalid exception type or value. (Violating these rules will cause subtle problems later.) This call takes away a reference to each object: you must own a reference to each object before the call and after the call you no longer own these references. (If you don’t understand this, don’t use this function. I warned you.)
void **PyErr_NormalizeException(\PyObject** exc, 
\PyObject** val, \PyObject** tb)
Under certain circumstances, the values returned by 
\PyErr_Fetch() below can be “unnormalized”, meaning that 
*exc is a class object but *val is not an instance of the same 
class. This function can be used to instantiate the class in that 
case. If the values are already normalized, nothing happens. The 
delayed normalization is implemented to improve performance.

Note: This function does not implicitly set the __traceback__ 
attribute on the exception value. If setting the traceback 
appropriately is desired, the following additional snippet is 
needed:

```c
if (tb != NULL) {
    PyErr_SetTraceback(val, tb);
}
```

void **PyErr_GetExcInfo(\PyObject **ptype, \PyObject **pvalue, 
\PyObject **ptraceback)
Retrieve the exception info, as known from sys.exc_info(). 
This refers to an exception that was already caught, not to an 
exception that was freshly raised. Returns new references for the 
three objects, any of which may be NULL. Does not modify the 
exception info state.

Note: This function is not normally used by code that wants to
handle exceptions. Rather, it can be used when code needs to save and restore the exception state temporarily. Use `PyErr_SetExcInfo()` to restore or clear the exception state.

New in version 3.3.

```c
void PyErr_SetExcInfo(PyObject *type, PyObject *value, PyObject *traceback)
```

Set the exception info, as known from `sys.exc_info()`. This refers to an exception that was already caught, not to an exception that was freshly raised. This function steals the references of the arguments. To clear the exception state, pass `NULL` for all three arguments. For general rules about the three arguments, see `PyErr_Restore()`.

**Note:** This function is not normally used by code that wants to handle exceptions. Rather, it can be used when code needs to save and restore the exception state temporarily. Use `PyErr_GetExcInfo()` to read the exception state.

New in version 3.3.
Signal Handling

int PyErr_CheckSignals()

This function interacts with Python’s signal handling. It checks whether a signal has been sent to the processes and if so, invokes the corresponding signal handler. If the signal module is supported, this can invoke a signal handler written in Python. In all cases, the default effect for SIGINT is to raise the KeyboardInterrupt exception. If an exception is raised the error indicator is set and the function returns -1; otherwise the function returns 0. The error indicator may or may not be cleared if it was previously set.

void PyErr_SetInterrupt()

This function simulates the effect of a SIGINT signal arriving — the next time PyErr_CheckSignals() is called, KeyboardInterrupt will be raised. It may be called without holding the interpreter lock.

int PySignal_SetWakeupFd(int fd)

This utility function specifies a file descriptor to which the signal number is written as a single byte whenever a signal is received. fd must be non-blocking. It returns the previous such file descriptor.

The value -1 disables the feature; this is the initial state. This is equivalent to signal.set_interrupt() in Python, but without any error checking. fd should be a valid file descriptor. The function should only be called from the main thread.

Changed in version 3.5: On Windows, the function now also supports socket handles.
Exception Classes

`PyObject* PyErr_NewException(const char *name, PyObject *base, PyObject *dict)`

*Return value: New reference.*

This utility function creates and returns a new exception class. The `name` argument must be the name of the new exception, a C string of the form `module.classname`. The `base` and `dict` arguments are normally `NULL`. This creates a class object derived from `Exception` (accessible in C as `PyExc_Exception`).

The `__module__` attribute of the new class is set to the first part (up to the last dot) of the `name` argument, and the class name is set to the last part (after the last dot). The `base` argument can be used to specify alternate base classes; it can either be only one class or a tuple of classes. The `dict` argument can be used to specify a dictionary of class variables and methods.

`PyObject* PyErr_NewExceptionWithDoc(const char *name, const char *doc, PyObject *base, PyObject *dict)`

*Return value: New reference.*

Same as `PyErr_NewException()`, except that the new exception class can easily be given a docstring: If `doc` is non-`NULL`, it will be used as the docstring for the exception class.

*New in version 3.2.*
Exception Objects

PyObject* PyException_GetTraceback(PyObject *ex)

*Return value: New reference.*
Return the traceback associated with the exception as a new reference, as accessible from Python through __traceback__. If there is no traceback associated, this returns NULL.

int PyException_SetTraceback(PyObject *ex, PyObject *tb)
Set the traceback associated with the exception to tb. Use Py_None to clear it.

PyObject* PyException_GetContext(PyObject *ex)
Return the context (another exception instance during whose handling ex was raised) associated with the exception as a new reference, as accessible from Python through __context__. If there is no context associated, this returns NULL.

void PyException_SetContext(PyObject *ex, PyObject *ctx)
Set the context associated with the exception to ctx. Use NULL to clear it. There is no type check to make sure that ctx is an exception instance. This steals a reference to ctx.

PyObject* PyException_GetCause(PyObject *ex)
Return the cause (either an exception instance, or None, set by raise ... from ...) associated with the exception as a new reference, as accessible from Python through __cause__.

void PyException_SetCause(PyObject *ex, PyObject *cause)
Set the cause associated with the exception to cause. Use NULL to clear it. There is no type check to make sure that cause is either an
exception instance or \texttt{None}. This steals a reference to \texttt{cause}.

\texttt{__suppress_context__} is implicitly set to \texttt{True} by this function.
Unicode Exception Objects

The following functions are used to create and modify Unicode exceptions from C.

PyObject* PyUnicodeDecodeError_Create(const char *encoding, const char *object, Py_ssize_t length, Py_ssize_t start, Py_ssize_t end, const char *reason)

Create a UnicodeDecodeError object with the attributes encoding, object, length, start, end and reason. encoding and reason are UTF-8 encoded strings.

PyObject* PyUnicodeEncodeError_Create(const char *encoding, const Py_UNICODE *object, Py_ssize_t length, Py_ssize_t start, Py_ssize_t end, const char *reason)

Create a UnicodeEncodeError object with the attributes encoding, object, length, start, end and reason. encoding and reason are UTF-8 encoded strings.

PyObject* PyUnicodeTranslateError_Create(const Py_UNICODE *object, Py_ssize_t length, Py_ssize_t start, Py_ssize_t end, const char *reason)

Create a UnicodeTranslateError object with the attributes object, length, start, end and reason. reason is an UTF-8 encoded string.

PyObject* PyUnicodeDecodeError_GetEncoding(PyObject *exc)

PyObject* PyUnicodeEncodeError_GetEncoding(PyObject *exc)

Return the encoding attribute of the given exception object.
PyUnicodeDecodeError_GetObject(PyObject *exc)  
PyObject*  
PyUnicodeEncodeError_GetObject(PyObject *exc)  
PyObject*  
PyUnicodeTranslateError_GetObject(PyObject *exc)  

Return the object attribute of the given exception object.

int PyUnicodeDecodeError_GetStart(PyObject *exc, Py_ssize_t *start)  
int PyUnicodeEncodeError_GetStart(PyObject *exc, Py_ssize_t *start)  
int PyUnicodeTranslateError_GetStart(PyObject *exc, Py_ssize_t *start)  

Get the start attribute of the given exception object and place it into *start. start must not be NULL. Return 0 on success, -1 on failure.

int PyUnicodeDecodeError_SetStart(PyObject *exc, Py_ssize_t start)  
int PyUnicodeEncodeError_SetStart(PyObject *exc, Py_ssize_t start)  
int PyUnicodeTranslateError_SetStart(PyObject *exc, Py_ssize_t start)  

Set the start attribute of the given exception object to start. Return 0 on success, -1 on failure.

int PyUnicodeDecodeError_GetEnd(PyObject *exc, Py_ssize_t *end)  
int PyUnicodeEncodeError_GetEnd(PyObject *exc, Py_ssize_t *end)  
int PyUnicodeTranslateError_GetEnd(PyObject *exc, Py_ssize_t *end)  

Get the end attribute of the given exception object and place it into
*end. end must not be NULL. Return 0 on success, -1 on failure.

```c
int PyUnicodeDecodeError_SetEnd(PyObject *exc, Py_ssize_t end)
int PyUnicodeEncodeError_SetEnd(PyObject *exc, Py_ssize_t end)
int PyUnicodeTranslateError_SetEnd(PyObject *exc, Py_ssize_t end)
```

Set the end attribute of the given exception object to end. Return 0 on success, -1 on failure.

```c
PyObject* PyUnicodeDecodeError_GetReason(PyObject *exc)
PyObject* PyUnicodeEncodeError_GetReason(PyObject *exc)
PyObject* PyUnicodeTranslateError_GetReason(PyObject *exc)
```

Return the reason attribute of the given exception object.

```c
int PyUnicodeDecodeError_SetReason(PyObject *exc, const char *reason)
int PyUnicodeEncodeError_SetReason(PyObject *exc, const char *reason)
int PyUnicodeTranslateError_SetReason(PyObject *exc, const char *reason)
```

Set the reason attribute of the given exception object to reason. Return 0 on success, -1 on failure.
Recursion Control

These two functions provide a way to perform safe recursive calls at the C level, both in the core and in extension modules. They are needed if the recursive code does not necessarily invoke Python code (which tracks its recursion depth automatically).

```c
int Py_EnterRecursiveCall(const char *where)
```

Marks a point where a recursive C-level call is about to be performed.

If USE_STACKCHECK is defined, this function checks if the OS stack overflowed using `PyOS_CheckStack()`. In this case, it sets a `MemoryError` and returns a nonzero value.

The function then checks if the recursion limit is reached. If this is the case, a `RecursionError` is set and a nonzero value is returned. Otherwise, zero is returned.

*where* should be a string such as "in instance check" to be concatenated to the `RecursionError` message caused by the recursion depth limit.

```c
void Py_LeaveRecursiveCall()
```

Ends a `Py_EnterRecursiveCall()`. Must be called once for each *successful* invocation of `Py_EnterRecursiveCall()`.

Properly implementing `tp_repr` for container types requires special recursion handling. In addition to protecting the stack, `tp_repr` also needs to track objects to prevent cycles. The following two functions facilitate this functionality. Effectively, these are the C equivalent to...
reprlib.recursive_repr().

int Py_ReprEnter(PyObject *object)
   Called at the beginning of the tp_repr implementation to detect cycles.

   If the object has already been processed, the function returns a positive integer. In that case the tp_repr implementation should return a string object indicating a cycle. As examples, dict objects return {...} and list objects return [...].

   The function will return a negative integer if the recursion limit is reached. In that case the tp_repr implementation should typically return NULL.

   Otherwise, the function returns zero and the tp_repr implementation can continue normally.

void Py_ReprLeave(PyObject *object)
   Ends a Py_ReprEnter(). Must be called once for each invocation of Py_ReprEnter() that returns zero.
Standard Exceptions

All standard Python exceptions are available as global variables whose names are PyExc_ followed by the Python exception name. These have the type PyObject*; they are all class objects. For completeness, here are all the variables:

<table>
<thead>
<tr>
<th>C Name</th>
<th>Python Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>PyExc_BaseException</td>
<td>BaseException</td>
</tr>
<tr>
<td>PyExc_Exception</td>
<td>Exception</td>
</tr>
<tr>
<td>PyExc_ArithmeticError</td>
<td>ArithmeticError</td>
</tr>
<tr>
<td>PyExc_LookupError</td>
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<td>PyExc_AssertionError</td>
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<tr>
<td>PyExc_AttributeError</td>
<td>AttributeError</td>
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<tr>
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<tr>
<td>PyExc_BrokenPipeError</td>
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<td>PyExc_IndexError</td>
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<tr>
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<tr>
<td>PyExc_MemoryError</td>
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<td>PyExc_NameError</td>
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<tr>
<td>PyExc_NotADirectoryError</td>
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<td>PyExc_RecursionError</td>
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<td>PyExc_ReferenceError</td>
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<tr>
<td>PyExc_ZeroDivisionError</td>
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</tbody>
</table>

*New in version 3.3:* PyExc_BlockingIOError,
PyExc_BrokenPipeError, PyExc_ChildProcessError, PyExc_ConnectionError, PyExc_ConnectionAbortedError, PyExc_ConnectionRefusedError, PyExc_ConnectionResetError, PyExc_FileExistsError, PyExc_FileNotFoundError, PyExc_InterruptedError, PyExc_IsADirectoryError, PyExc_NotADirectoryError, PyExc_PermissionError, PyExc_ProcessLookupError and PyExc_TimeoutError were introduced following PEP 3151.

New in version 3.5: PyExc_RecursionError.

These are compatibility aliases to PyExc_OSError:

<table>
<thead>
<tr>
<th>C Name</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PyExc_EnvironmentError</td>
<td></td>
</tr>
<tr>
<td>PyExc_IOError</td>
<td></td>
</tr>
<tr>
<td>PyExc_WindowsError</td>
<td>(3)</td>
</tr>
</tbody>
</table>

Changed in version 3.3: These aliases used to be separate exception types.

Notes:

1. This is a base class for other standard exceptions.
2. This is the same as weakref.ReferenceError.
3. Only defined on Windows; protect code that uses this by testing that the preprocessor macro MS_WINDOWS is defined.
Utilities

The functions in this chapter perform various utility tasks, ranging from helping C code be more portable across platforms, using Python modules from C, and parsing function arguments and constructing Python values from C values.

- Operating System Utilities
- System Functions
- Process Control
- Importing Modules
- Data marshalling support
- Parsing arguments and building values
  - Parsing arguments
    - Strings and buffers
    - Numbers
    - Other objects
    - API Functions
  - Building values
- String conversion and formatting
- Reflection
- Codec registry and support functions
  - Codec lookup API
  - Registry API for Unicode encoding error handlers
Operating System Utilities

int **Py_FdIsInteractive((FILE *fp, const char *filename)**

Return true (nonzero) if the standard I/O file *fp* with name *filename* is deemed interactive. This is the case for files for which isatty(fileno(fp)) is true. If the global flag Py_InteractiveFlag is true, this function also returns true if the *filename* pointer is NULL or if the name is equal to one of the strings '<stdin>' or '???'.

void **PyOS_AfterFork()**

Function to update some internal state after a process fork; this should be called in the new process if the Python interpreter will continue to be used. If a new executable is loaded into the new process, this function does not need to be called.

int **PyOS_CheckStack()**

Return true when the interpreter runs out of stack space. This is a reliable check, but is only available when USE_STACKCHECK is defined (currently on Windows using the Microsoft Visual C++ compiler). USE_STACKCHECK will be defined automatically; you should never change the definition in your own code.

PyOS_sighandler_t **PyOS_getsig(int i)**

Return the current signal handler for signal *i*. This is a thin wrapper around either sigaction() or signal(). Do not call those functions directly! PyOS_sighandler_t is a typedef alias for void (*)(int).

PyOS_sighandler_t **PyOS_setsig(int i, PyOS_sighandler_t h)**


Set the signal handler for signal \( i \) to be \( h \); return the old signal handler. This is a thin wrapper around either `sigaction()` or `signal()`. Do not call those functions directly! `PyOS_sighandler_t` is a typedef alias for `void (*)(int)`.

```c
wchar_t* Py_DecodeLocale(const char* arg, size_t *size)
```

Decode a byte string from the locale encoding with the **surrogateescape error handler**: undecodable bytes are decoded as characters in range \( \text{U+DC80..U+DCFF} \). If a byte sequence can be decoded as a surrogate character, escape the bytes using the surrogateescape error handler instead of decoding them.

Return a pointer to a newly allocated wide character string, use `PyMem_RawFree()` to free the memory. If `size` is not NULL, write the number of wide characters excluding the null character into `*size`

Return NULL on decoding error or memory allocation error. If `size` is not NULL, `*size` is set to `(size_t)-1` on memory error or set to `(size_t)-2` on decoding error.

Decoding errors should never happen, unless there is a bug in the C library.

Use the `Py_EncodeLocale()` function to encode the character string back to a byte string.

**See also:** The `PyUnicode_DecodeFSDefaultAndSize()` and `PyUnicode_DecodeLocaleAndSize()` functions.

*New in version 3.5.*

```c
char* Py_EncodeLocale(const wchar_t *text, size_t *error_pos)
```
Encode a wide character string to the locale encoding with the surrogateescape error handler: surrogate characters in the range U+DC80..U+DCFF are converted to bytes 0x80..0xFF.

Return a pointer to a newly allocated byte string, use PyMem_Free() to free the memory. Return NULL on encoding error or memory allocation error.

If error_pos is not NULL, *error_pos is set to the index of the invalid character on encoding error, or set to (size_t)-1 otherwise.

Use the Py_DecodeLocale() function to decode the bytes string back to a wide character string.

See also: The PyUnicode_EncodeFSDefault() and PyUnicode_EncodeLocale() functions.

New in version 3.5.
System Functions

These are utility functions that make functionality from the `sys` module accessible to C code. They all work with the current interpreter thread's `sys` module's dict, which is contained in the internal thread state structure.

```c
PyObject *PySys_GetObject(const char *name)
```

*Return value: Borrowed reference.*

Return the object `name` from the `sys` module or `NULL` if it does not exist, without setting an exception.

```c
int PySys_SetObject(const char *name, PyObject *v)
```

Set `name` in the `sys` module to `v` unless `v` is `NULL`, in which case `name` is deleted from the sys module. Returns 0 on success, -1 on error.

```c
void PySys_ResetWarnOptions()
```

Reset `sys.warnoptions` to an empty list.

```c
void PySys_AddWarnOption(wchar_t *s)
```

Append `s` to `sys.warnoptions`.

```c
void PySys_AddWarnOptionUnicode(PyObject *unicode)
```

Append `unicode` to `sys.warnoptions`.

```c
void PySys_SetPath(wchar_t *path)
```

Set `sys.path` to a list object of paths found in `path` which should be a list of paths separated with the platform's search path delimiter (: on Unix, ; on Windows).
void **PySys_WriteStdout**(const char *format, ...)

Write the output string described by format to **sys.stdout**. No exceptions are raised, even if truncation occurs (see below).

format should limit the total size of the formatted output string to 1000 bytes or less – after 1000 bytes, the output string is truncated. In particular, this means that no unrestricted “%s” formats should occur; these should be limited using “%.<N>s” where <N> is a decimal number calculated so that <N> plus the maximum size of other formatted text does not exceed 1000 bytes. Also watch out for “%f”, which can print hundreds of digits for very large numbers.

If a problem occurs, or **sys.stdout** is unset, the formatted message is written to the real (C level) stdout.

void **PySys_WriteStderr**(const char *format, ...)

As **PySys_WriteStdout()**, but write to **sys.stderr** or stderr instead.

void **PySys_FormatStdout**(const char *format, ...)

Function similar to **PySys_WriteStdout()** but format the message using **PyUnicode_FromFormatV()** and don’t truncate the message to an arbitrary length.

New in version 3.2.

void **PySys_FormatStderr**(const char *format, ...)

As **PySys_FormatStdout()**, but write to **sys.stderr** or stderr instead.

New in version 3.2.
void **PySys_AddXOption**(const wchar_t *s)

Parse s as a set of -X options and add them to the current options mapping as returned by **PySys_GetXOptions()**.

*New in version 3.2.*

**PyObject **PySys_GetXOptions**()

*Return value: Borrowed reference.*

Return the current dictionary of -X options, similarly to **sys._xoptions**. On error, **NULL** is returned and an exception is set.

*New in version 3.2.*
Process Control

void **PyFatalError**(const char *`message`)  
Print a fatal error message and kill the process. No cleanup is performed. This function should only be invoked when a condition is detected that would make it dangerous to continue using the Python interpreter; e.g., when the object administration appears to be corrupted. On Unix, the standard C library function `abort()` is called which will attempt to produce a core file.

void **PyExit**(int `status`)  
Exit the current process. This calls `Py_Finalize()` and then calls the standard C library function `exit(status)`.

int **PyAtExit**(void (*`func`)())  
Register a cleanup function to be called by `Py_Finalize()`. The cleanup function will be called with no arguments and should return no value. At most 32 cleanup functions can be registered. When the registration is successful, `PyAtExit()` returns 0; on failure, it returns -1. The cleanup function registered last is called first. Each cleanup function will be called at most once. Since Python's internal finalization will have completed before the cleanup function, no Python APIs should be called by `func`. 

Importing Modules

PyObject* PyImport_ImportModule(const char *name)

This is a simplified interface to PyImport_ImportModuleEx() below, leaving the globals and locals arguments set to NULL and level set to 0. When the name argument contains a dot (when it specifies a submodule of a package), the fromlist argument is set to the list ['*'] so that the return value is the named module rather than the top-level package containing it as would otherwise be the case. (Unfortunately, this has an additional side effect when name in fact specifies a subpackage instead of a submodule: the submodules specified in the package's __all__ variable are loaded.) Return a new reference to the imported module, or NULL with an exception set on failure. A failing import of a module doesn't leave the module in sys.modules.

This function always uses absolute imports.

PyObject* PyImport_ImportModuleNoBlock(const char *name)

This function is a deprecated alias of PyImport_ImportModule().

Changed in version 3.3: This function used to fail immediately when the import lock was held by another thread. In Python 3.3 though, the locking scheme switched to per-module locks for most purposes, so this function's special behaviour isn't needed anymore.

PyObject* PyImport_ImportModuleEx(const char *name,
PyObject *globals, PyObject *locals, PyObject *fromlist)


Import a module. This is best described by referring to the built-in Python function __import__().

The return value is a new reference to the imported module or top-level package, or NULL with an exception set on failure. Like for __import__(), the return value when a submodule of a package was requested is normally the top-level package, unless a non-empty fromlist was given.

Failing imports remove incomplete module objects, like with PyImport_ImportModule().

PyObject*
PyImport_ImportModuleLevelObject(PyObject *name,
PyObject *globals, PyObject *locals, PyObject *fromlist, int level)

Import a module. This is best described by referring to the built-in Python function __import__(), as the standard __import__() function calls this function directly.

The return value is a new reference to the imported module or top-level package, or NULL with an exception set on failure. Like for __import__(), the return value when a submodule of a package was requested is normally the top-level package, unless a non-empty fromlist was given.

New in version 3.3.

PyObject* PyImport_ImportModuleLevel(const char *name,
PyObject *globals, PyObject *locals, PyObject *fromlist, int level)


Similar to PyImport_ImportModuleLevelObject(), but the
name is an UTF-8 encoded string instead of a Unicode object.

*Changed in version 3.3:* Negative values for *level* are no longer accepted.

**PyObject** `PyImport_Import(PyObject *name)`  
*Return value: New reference.*  
This is a higher-level interface that calls the current “import hook function” (with an explicit *level* of 0, meaning absolute import). It invokes the `__import__()` function from the `__builtins__` of the current globals. This means that the import is done using whatever import hooks are installed in the current environment.

This function always uses absolute imports.

**PyObject** `PyImport_ReloadModule(PyObject *m)`  
*Return value: New reference.*  
Reload a module. Return a new reference to the reloaded module, or *NULL* with an exception set on failure (the module still exists in this case).

**PyObject** `PyImport_AddModuleObject(PyObject *name)`  
Return the module object corresponding to a module name. The *name* argument may be of the form package.module. First check the modules dictionary if there’s one there, and if not, create a new one and insert it in the modules dictionary. Return *NULL* with an exception set on failure.

**Note:** This function does not load or import the module; if the module wasn’t already loaded, you will get an empty module object. Use `PyImport_ImportModule()` or one of its variants to import a module. Package structures implied by a dotted name for *name* are not created if not already present.
New in version 3.3.

**PyObject** `PyImport_AddModule(const char *name)`

*Return value: Borrowed reference.*

Similar to `PyImport_AddModuleObject()`, but the name is a UTF-8 encoded string instead of a Unicode object.

**PyObject** `PyImport_ExecCodeModule(const char *name, PyObject *co)`

*Return value: New reference.*

Given a module name (possibly of the form package.module) and a code object read from a Python bytecode file or obtained from the built-in function `compile()`, load the module. Return a new reference to the module object, or `NULL` with an exception set if an error occurred. `name` is removed from `sys.modules` in error cases, even if `name` was already in `sys.modules` on entry to `PyImport_ExecCodeModule()`. Leaving incompletely initialized modules in `sys.modules` is dangerous, as imports of such modules have no way to know that the module object is an unknown (and probably damaged with respect to the module author's intents) state.

The module's `__spec__` and `__loader__` will be set, if not set already, with the appropriate values. The spec's loader will be set to the module's `__loader__` (if set) and to an instance of `SourceFileLoader` otherwise.

The module's `__file__` attribute will be set to the code object's `co_filename`. If applicable, `__cached__` will also be set.

This function will reload the module if it was already imported. See
PyImport_ReloadModule() for the intended way to reload a module.

If name points to a dotted name of the form package.module, any package structures not already created will still not be created.

See also PyImport_ExecCodeModuleEx() and PyImport_ExecCodeModuleWithPathnames().

PyObject* PyImport_ExecCodeModuleEx(const char *name, PyObject *co, const char *pathname)


Like PyImport_ExecCodeModule(), but the __file__ attribute of the module object is set to pathname if it is non-NULL.

See also PyImport_ExecCodeModuleWithPathnames().

PyObject*

PyImport_ExecCodeModuleObject(PyObject *name, PyObject *co, PyObject *pathname, PyObject *cpathname)

Like PyImport_ExecCodeModuleEx(), but the __cached__ attribute of the module object is set to cpathname if it is non-NULL.

Of the three functions, this is the preferred one to use.

New in version 3.3.

PyObject*

PyImport_ExecCodeModuleWithPathnames(const char *name, PyObject *co, const char *pathname, const char *cpathname)

Like PyImport_ExecCodeModuleObject(), but name, pathname and cpathname are UTF-8 encoded strings. Attempts are also made to figure out what the value for pathname should be
from cpathname if the former is set to NULL.

New in version 3.2.

Changed in version 3.3: Uses imp.source_from_cache() in calculating the source path if only the bytecode path is provided.

long PyImport_GetMagicNumber()
Return the magic number for Python bytecode files (a.k.a. .pyc file). The magic number should be present in the first four bytes of the bytecode file, in little-endian byte order. Returns -1 on error.

Changed in version 3.3: Return value of -1 upon failure.

const char * PyImport_GetMagicTag()
Return the magic tag string for PEP 3147 format Python bytecode file names. Keep in mind that the value at sys.implementation.cache_tag is authoritative and should be used instead of this function.

New in version 3.2.

PyObject* PyImport_GetModuleDict()
Return value: Borrowed reference.
Return the dictionary used for the module administration (a.k.a. sys.modules). Note that this is a per-interpreter variable.

PyObject* PyImport_GetImporter(PyObject *path)
Return an importer object for a sys.path/pkg.__path__ item path, possibly by fetching it from the sys.path_importer_cache dict. If it wasn’t yet cached, traverse sys.path_hooks until a hook is found that can handle the path item. Return None if no hook could; this tells our caller it
should fall back to the built-in import mechanism. Cache the result in `sys.path_importer_cache`. Return a new reference to the importer object.

```c
void _PyImport_Init()
Initialize the import mechanism. For internal use only.
```

```c
void PyImport_Cleanup()
Empty the module table. For internal use only.
```

```c
void _PyImport_Fini()
Finalize the import mechanism. For internal use only.
```

```c
PyObject* _PyImport_FindExtension(char *, char *)
For internal use only.
```

```c
PyObject* _PyImport_FixupExtension(char *, char *)
For internal use only.
```

```c
int PyImport_ImportFrozenModuleObject(PyObject *name)
Load a frozen module named `name`. Return 1 for success, 0 if the module is not found, and -1 with an exception set if the initialization failed. To access the imported module on a successful load, use `PyImport_ImportModule()`. (Note the misnomer — this function would reload the module if it was already imported.)

New in version 3.3.

Changed in version 3.4: The `__file__` attribute is no longer set on the module.

```c
int PyImport_ImportFrozenModule(const char *name)
```
Similar to `PyImport_ImportFrozenModuleObject()`, but the name is a UTF-8 encoded string instead of a Unicode object.

**struct _frozen**

This is the structure type definition for frozen module descriptors, as generated by the `freeze` utility (see Tools/freeze/ in the Python source distribution). Its definition, found in Include/import.h, is:

```c
struct _frozen {
    char *name;
    unsigned char *code;
    int size;
};
```

**struct _frozen* PyImport_FrozenModules**

This pointer is initialized to point to an array of `struct _frozen` records, terminated by one whose members are all `NULL` or zero. When a frozen module is imported, it is searched in this table. Third-party code could play tricks with this to provide a dynamically created collection of frozen modules.

**int PyImport_AppendInittab(const char *name, PyObject *( *initfunc)(void))**

Add a single module to the existing table of built-in modules. This is a convenience wrapper around `PyImport_ExtendInittab()`, returning -1 if the table could not be extended. The new module can be imported by the name `name`, and uses the function `initfunc` as the initialization function called on the first attempted import. This should be called before `Py_Initialize()`.

**struct _inittab**

Structure describing a single entry in the list of built-in modules.
Each of these structures gives the name and initialization function for a module built into the interpreter. The name is an ASCII encoded string. Programs which embed Python may use an array of these structures in conjunction with `PyImport_ExtendInittab()` to provide additional built-in modules. The structure is defined in `Include/import.h` as:

```c
struct _inittab {
    char *name; /* ASCII encoded
    PyObject* (*initfunc)(void);
};
```

```c
int PyImport_ExtendInittab(struct _inittab *newtab)
```

Add a collection of modules to the table of built-in modules. The `newtab` array must end with a sentinel entry which contains `NULL` for the name field; failure to provide the sentinel value can result in a memory fault. Returns 0 on success or -1 if insufficient memory could be allocated to extend the internal table. In the event of failure, no modules are added to the internal table. This should be called before `Py_Initialize()`.
Data marshalling support

These routines allow C code to work with serialized objects using the same data format as the `marshal` module. There are functions to write data into the serialization format, and additional functions that can be used to read the data back. Files used to store marshalled data must be opened in binary mode.

Numeric values are stored with the least significant byte first.

The module supports two versions of the data format: version 0 is the historical version, version 1 shares interned strings in the file, and upon unmarshalling. Version 2 uses a binary format for floating point numbers. `Py_MARSHAL_VERSION` indicates the current file format (currently 2).

```c
void PyMarshal_WriteLongToFile(long value, FILE *file, int version)
    Marshal a long integer, `value`, to `file`. This will only write the least-significant 32 bits of `value`; regardless of the size of the native long type. `version` indicates the file format.

void PyMarshal_WriteObjectToFile(PyObject *value, FILE *file, int version)
    Marshal a Python object, `value`, to `file`. `version` indicates the file format.

PyObject*
PyMarshal_WriteObjectToString(PyObject *value, int version)
    Return a string object containing the marshalled representation of
value. version indicates the file format.

The following functions allow marshalled values to be read back in.

XXX What about error detection? It appears that reading past the end of the file will always result in a negative numeric value (where that's relevant), but it's not clear that negative values won't be handled properly when there's no error. What's the right way to tell? Should only non-negative values be written using these routines?

long **PyMarshal_ReadLongFromFile**(FILE *file)

Return a C long from the data stream in a FILE* opened for reading. Only a 32-bit value can be read in using this function, regardless of the native size of long.

On error, raise an exception and return -1.

int **PyMarshal_ReadShortFromFile**(FILE *file)

Return a C short from the data stream in a FILE* opened for reading. Only a 16-bit value can be read in using this function, regardless of the native size of short.

On error, raise an exception and return -1.

PyObject* **PyMarshal_ReadObjectFromFile**(FILE *file)

*Return value: New reference.*

Return a Python object from the data stream in a FILE* opened for reading.

On error, sets the appropriate exception (**EOFError** or **TypeError**) and returns **NULL**.

PyObject*
PyMarshal_ReadLastObjectFromFile(FILE *file)

Return a Python object from the data stream in a FILE* opened for reading. Unlike PyMarshal_ReadObjectFromFile(), this function assumes that no further objects will be read from the file, allowing it to aggressively load file data into memory so that the de-serialization can operate from data in memory rather than reading a byte at a time from the file. Only use these variant if you are certain that you won’t be reading anything else from the file.

On error, sets the appropriate exception (EOFError or TypeError) and returns NULL.

PyObject* PyMarshal_ReadObjectFromString(const char *string, Py_ssize_t len)

Return a Python object from the data stream in a character buffer containing len bytes pointed to by string.

On error, sets the appropriate exception (EOFError or TypeError) and returns NULL.
Parsing arguments and building values

These functions are useful when creating your own extensions functions and methods. Additional information and examples are available in *Extending and Embedding the Python Interpreter*.

The first three of these functions described, `PyArg_ParseTuple()`, `PyArg_ParseTupleAndKeywords()`, and `PyArg_Parse()`, all use *format strings* which are used to tell the function about the expected arguments. The format strings use the same syntax for each of these functions.
Parsing arguments

A format string consists of zero or more “format units.” A format unit describes one Python object; it is usually a single character or a parenthesized sequence of format units. With a few exceptions, a format unit that is not a parenthesized sequence normally corresponds to a single address argument to these functions. In the following description, the quoted form is the format unit; the entry in (round) parentheses is the Python object type that matches the format unit; and the entry in [square] brackets is the type of the C variable(s) whose address should be passed.

Strings and buffers

These formats allow to access an object as a contiguous chunk of memory. You don’t have to provide raw storage for the returned unicode or bytes area. Also, you won’t have to release any memory yourself, except with the es, es#, et and et# formats.

However, when a Py_buffer structure gets filled, the underlying buffer is locked so that the caller can subsequently use the buffer even inside a Py_BEGIN_ALLOW_THREADS block without the risk of mutable data being resized or destroyed. As a result, you have to call PyBuffer_Release() after you have finished processing the data (or in any early abort case).

Unless otherwise stated, buffers are not NUL-terminated.

**Note:** For all # variants of formats (s#, y#, etc.), the type of the length argument (int or Py_ssize_t) is controlled by defining the macro PY_SSIZE_T_CLEAN before including Python.h. If the
A macro was defined, length is a Py_ssize_t rather than an int. This behavior will change in a future Python version to only support Py_ssize_t and drop int support. It is best to always define PY_SSIZE_T_CLEAN.

s (str) [const char *]
Convert a Unicode object to a C pointer to a character string. A pointer to an existing string is stored in the character pointer variable whose address you pass. The C string is NUL-terminated. The Python string must not contain embedded NUL bytes; if it does, a TypeError exception is raised. Unicode objects are converted to C strings using 'utf-8' encoding. If this conversion fails, a UnicodeError is raised.

Note: This format does not accept bytes-like objects. If you want to accept filesystem paths and convert them to C character strings, it is preferable to use the 0& format with PyUnicode_FSConverter() as converter.

s* (str or bytes-like object) [Py_buffer]
This format accepts Unicode objects as well as bytes-like objects. It fills a Py_buffer structure provided by the caller. In this case the resulting C string may contain embedded NUL bytes. Unicode objects are converted to C strings using 'utf-8' encoding.

s# (str, read-only bytes-like object) [const char *, int or Py_ssize_t]
Like s*, except that it doesn't accept mutable bytes-like objects such as bytearray. The result is stored into two C variables, the first one a pointer to a C string, the second one its length. The string may contain embedded null bytes. Unicode objects are converted to C strings using 'utf-8' encoding.

z (str or None) [const char *]
Like s, but the Python object may also be None, in which case the C pointer is set to NULL.

z* (str, bytes-like object or None) [Py_buffer]
Like s*, but the Python object may also be None, in which case the buf member of the Py_buffer structure is set to NULL.

z# (str, read-only bytes-like object or None) [const char *, int]
Like s#, but the Python object may also be None, in which case the C pointer is set to NULL.

y (read-only bytes-like object) [const char *]
This format converts a bytes-like object to a C pointer to a character string; it does not accept Unicode objects. The bytes buffer must not contain embedded NUL bytes; if it does, a TypeError exception is raised.

y* (bytes-like object) [Py_buffer]
This variant on s* doesn't accept Unicode objects, only bytes-like objects. This is the recommended way to accept binary data.

y# (read-only bytes-like object) [const char *, int]
This variant on s# doesn't accept Unicode objects, only bytes-like objects.

S (bytes) [PyBytesObject *]
Requires that the Python object is a bytes object, without attempting any conversion. Raises TypeError if the object is not a bytes object. The C variable may also be declared as PyObject*.

Y (bytearray) [PyByteArrayObject *]
Requires that the Python object is a bytearray object, without attempting any conversion. Raises TypeError if the object is not a bytearray object. The C variable may also be declared as PyObject*.

u (str) [Py_UNICODE *]
Convert a Python Unicode object to a C pointer to a NUL-terminated buffer of Unicode characters. You must pass the address of a `Py_UNICODE` pointer variable, which will be filled with the pointer to an existing Unicode buffer. Please note that the width of a `Py_UNICODE` character depends on compilation options (it is either 16 or 32 bits). The Python string must not contain embedded NUL characters; if it does, a `TypeError` exception is raised.

**Note:** Since `u` doesn’t give you back the length of the string, and it may contain embedded NUL characters, it is recommended to use `u#` or `U` instead.

`u#` (**str**) [`Py_UNICODE *`, int]
This variant on `u` stores into two C variables, the first one a pointer to a Unicode data buffer, the second one its length.

`Z` (**str** or None) [`Py_UNICODE *`]
Like `u`, but the Python object may also be None, in which case the `Py_UNICODE` pointer is set to `NULL`.

`Z#` (**str** or None) [`Py_UNICODE *`, int]
Like `u#`, but the Python object may also be None, in which case the `Py_UNICODE` pointer is set to `NULL`.

`U` (**str**) [PyObject *]
Requires that the Python object is a Unicode object, without attempting any conversion. Raises `TypeError` if the object is not a Unicode object. The C variable may also be declared as `PyObject *`.

`w` (read-write bytes-like object) [Py_buffer]
This format accepts any object which implements the read-write buffer interface. It fills a `Py_buffer` structure provided by the caller. The buffer may contain embedded null bytes. The caller have to call `PyBuffer_Release()` when it is done with the
buffer.

**es (str)** [const char *encoding, char **buffer]
This variant on \( s \) is used for encoding Unicode into a character buffer. It only works for encoded data without embedded NUL bytes.

This format requires two arguments. The first is only used as input, and must be a const char* which points to the name of an encoding as a NUL-terminated string, or NULL, in which case 'utf-8' encoding is used. An exception is raised if the named encoding is not known to Python. The second argument must be a char**; the value of the pointer it references will be set to a buffer with the contents of the argument text. The text will be encoded in the encoding specified by the first argument.

**PyArg_ParseTuple()** will allocate a buffer of the needed size, copy the encoded data into this buffer and adjust *buffer to reference the newly allocated storage. The caller is responsible for calling **PyMem_Free()** to free the allocated buffer after use.

**et (str, bytes or bytearray)** [const char *encoding, char **buffer]
Same as es except that byte string objects are passed through without recoding them. Instead, the implementation assumes that the byte string object uses the encoding passed in as parameter.

**es# (str)** [const char *encoding, char **buffer, int *buffer_length]
This variant on \( s# \) is used for encoding Unicode into a character buffer. Unlike the es format, this variant allows input data which contains NUL characters.

It requires three arguments. The first is only used as input, and must be a const char* which points to the name of an encoding as a NUL-terminated string, or NULL, in which case 'utf-8'
encoding is used. An exception is raised if the named encoding is not known to Python. The second argument must be a char**; the value of the pointer it references will be set to a buffer with the contents of the argument text. The text will be encoded in the encoding specified by the first argument. The third argument must be a pointer to an integer; the referenced integer will be set to the number of bytes in the output buffer.

There are two modes of operation:

If *buffer points a NULL pointer, the function will allocate a buffer of the needed size, copy the encoded data into this buffer and set *buffer to reference the newly allocated storage. The caller is responsible for calling PyMem_Free() to free the allocated buffer after usage.

If *buffer points to a non-NULL pointer (an already allocated buffer), PyArg_ParseTuple() will use this location as the buffer and interpret the initial value of *buffer_length as the buffer size. It will then copy the encoded data into the buffer and NUL-terminate it. If the buffer is not large enough, a ValueError will be set.

In both cases, *buffer_length is set to the length of the encoded data without the trailing NUL byte.

et# (str, bytes or bytearray) [const char *encoding, char **buffer, int *buffer_length]
Same as es# except that byte string objects are passed through without recoding them. Instead, the implementation assumes that the byte string object uses the encoding passed in as parameter.

Numbers
b (int) [unsigned char]
   Convert a nonnegative Python integer to an unsigned tiny int, stored in a C unsigned char.

B (int) [unsigned char]
   Convert a Python integer to a tiny int without overflow checking, stored in a C unsigned char.

h (int) [short int]
   Convert a Python integer to a C short int.

H (int) [unsigned short int]
   Convert a Python integer to a C unsigned short int, without overflow checking.

i (int) [int]
   Convert a Python integer to a plain C int.

I (int) [unsigned int]
   Convert a Python integer to a C unsigned int, without overflow checking.

l (int) [long int]
   Convert a Python integer to a C long int.

k (int) [unsigned long]
   Convert a Python integer to a C unsigned long without overflow checking.

L (int) [PY_LONG_LONG]
   Convert a Python integer to a C long long. This format is only available on platforms that support long long (or _int64 on Windows).

K (int) [unsigned PY_LONG_LONG]
   Convert a Python integer to a C unsigned long long without overflow checking. This format is only available on platforms that support unsigned long long (or unsigned _int64 on
Windows).

n (int) [Py_ssize_t]
  Convert a Python integer to a C Py_ssize_t.

c (bytes or bytearray of length 1) [char]
  Convert a Python byte, represented as a bytes or bytearray object of length 1, to a C char.

  Changed in version 3.3: Allow bytearray objects.

C (str of length 1) [int]
  Convert a Python character, represented as a str object of length 1, to a C int.

f (float) [float]
  Convert a Python floating point number to a C float.

d (float) [double]
  Convert a Python floating point number to a C double.

D (complex) [Py_complex]
  Convert a Python complex number to a C Py_complex structure.

Other objects

0 (object) [PyObject *]
  Store a Python object (without any conversion) in a C object pointer. The C program thus receives the actual object that was passed. The object’s reference count is not increased. The pointer stored is not NULL.

0! (object) [typeobject, PyObject *]
  Store a Python object in a C object pointer. This is similar to 0, but takes two C arguments: the first is the address of a Python type object, the second is the address of the C variable (of type PyObject*) into which the object pointer is stored. If the Python
object does not have the required type, **TypeError** is raised.

0& (object) [converter, anything]

Convert a Python object to a C variable through a *converter* function. This takes two arguments: the first is a function, the second is the address of a C variable (of arbitrary type), converted to `void*`. The *converter* function in turn is called as follows:

```c
status = converter(object, address);
```

where *object* is the Python object to be converted and *address* is the `void*` argument that was passed to the **PyArg_Parse** function. The returned *status* should be 1 for a successful conversion and 0 if the conversion has failed. When the conversion fails, the *converter* function should raise an exception and leave the content of *address* unmodified.

If the *converter* returns **Py_CLEANUP_SUPPORTED**, it may get called a second time if the argument parsing eventually fails, giving the converter a chance to release any memory that it had already allocated. In this second call, the *object* parameter will be NULL; *address* will have the same value as in the original call.

*Changed in version 3.1:* **Py_CLEANUP_SUPPORTED** was added.

p (bool) [int]

Tests the value passed in for truth (a boolean *predicate*) and converts the result to its equivalent C true/false integer value. Sets the int to 1 if the expression was true and 0 if it was false. This accepts any valid Python value. See **Truth Value Testing** for more information about how Python tests values for truth.

*New in version 3.3.*
The object must be a Python sequence whose length is the number of format units in `items`. The C arguments must correspond to the individual format units in `items`. Format units for sequences may be nested.

It is possible to pass “long” integers (integers whose value exceeds the platform’s `LONG_MAX`) however no proper range checking is done — the most significant bits are silently truncated when the receiving field is too small to receive the value (actually, the semantics are inherited from downcasts in C — your mileage may vary).

A few other characters have a meaning in a format string. These may not occur inside nested parentheses. They are:

| Indicates that the remaining arguments in the Python argument list are optional. The C variables corresponding to optional arguments should be initialized to their default value — when an optional argument is not specified, `PyArg_ParseTuple()` does not touch the contents of the corresponding C variable(s).

$ `PyArg_ParseTupleAndKeywords()` only: Indicates that the remaining arguments in the Python argument list are keyword-only. Currently, all keyword-only arguments must also be optional arguments, so | must always be specified before $ in the format string.

`New in version 3.3`. 

: The list of format units ends here; the string after the colon is used as the function name in error messages (the “associated value” of
the exception that PyArg_ParseTuple() raises).

; The list of format units ends here; the string after the semicolon is used as the error message instead of the default error message. ; and ; mutually exclude each other.

Note that any Python object references which are provided to the caller are borrowed references; do not decrement their reference count!

Additional arguments passed to these functions must be addresses of variables whose type is determined by the format string; these are used to store values from the input tuple. There are a few cases, as described in the list of format units above, where these parameters are used as input values; they should match what is specified for the corresponding format unit in that case.

For the conversion to succeed, the arg object must match the format and the format must be exhausted. On success, the PyArg_Parse*() functions return true, otherwise they return false and raise an appropriate exception. When the PyArg_Parse*() functions fail due to conversion failure in one of the format units, the variables at the addresses corresponding to that and the following format units are left untouched.

API Functions

int PyArg_ParseTuple(PyObject *args, const char *format, ...) Parse the parameters of a function that takes only positional parameters into local variables. Returns true on success; on failure, it returns false and raises the appropriate exception.
int **PyArg__VaParse**(PyObject *args, const char *format, va_list vars)

Identical to **PyArg_ParseTuple()**, except that it accepts a va_list rather than a variable number of arguments.

int **PyArg__ParseTupleAndKeywords**(PyObject *args, PyObject *kw, const char *format, char *keywords[], ...)

Parse the parameters of a function that takes both positional and keyword parameters into local variables. Returns true on success; on failure, it returns false and raises the appropriate exception.

int **PyArg__VaParseTupleAndKeywords**(PyObject *args, PyObject *kw, const char *format, char *keywords[], va_list vars)

Identical to **PyArg_ParseTupleAndKeywords()**, except that it accepts a va_list rather than a variable number of arguments.

int **PyArg__ValidateKeywordArguments**(PyObject *)

Ensure that the keys in the keywords argument dictionary are strings. This is only needed if **PyArg_ParseTupleAndKeywords()** is not used, since the latter already does this check.

*New in version 3.2.*

int **PyArg__Parse**(PyObject *args, const char *format, ...)

Function used to deconstruct the argument lists of “old-style” functions — these are functions which use the METH_OLDARGS parameter parsing method, which has been removed in Python 3. This is not recommended for use in parameter parsing in new code, and most code in the standard interpreter has been modified to no longer use this for that purpose. It does remain a convenient way to decompose other tuples, however, and may continue to be
used for that purpose.

```c
int PyArg_UnpackTuple(PyObject *args, const char *name,
Py_ssize_t min, Py_ssize_t max, ...)
```

A simpler form of parameter retrieval which does not use a format string to specify the types of the arguments. Functions which use this method to retrieve their parameters should be declared as `METH_VARARGS` in function or method tables. The tuple containing the actual parameters should be passed as `args`; it must actually be a tuple. The length of the tuple must be at least `min` and no more than `max`; `min` and `max` may be equal. Additional arguments must be passed to the function, each of which should be a pointer to a `PyObject`* variable; these will be filled in with the values from `args`; they will contain borrowed references. The variables which correspond to optional parameters not given by `args` will not be filled in; these should be initialized by the caller. This function returns true on success and false if `args` is not a tuple or contains the wrong number of elements; an exception will be set if there was a failure.

This is an example of the use of this function, taken from the sources for the _weakref helper module for weak references:

```c
static PyObject *
weakref_ref(PyObject *self, PyObject *args)
{
    PyObject *object;
    PyObject *callback = NULL;
    PyObject *result = NULL;

    if (PyArg_UnpackTuple(args, "ref", 1, 2, &obj
        result = PyWeakref_NewRef(object, callbac
    }
    return result;
```
The call to `PyArg_UnpackTuple()` in this example is entirely equivalent to this call to `PyArg_ParseTuple()`:

```python
PyArg_ParseTuple(args, "O|O:ref", &object, &callback)
```
Building values

PyObject* Py_BuildValue(const char *format, ...)

Create a new value based on a format string similar to those accepted by the PyArg_Parse*() family of functions and a sequence of values. Returns the value or NULL in the case of an error; an exception will be raised if NULL is returned.

Py_BuildValue() does not always build a tuple. It builds a tuple only if its format string contains two or more format units. If the format string is empty, it returns None; if it contains exactly one format unit, it returns whatever object is described by that format unit. To force it to return a tuple of size 0 or one, parenthesize the format string.

When memory buffers are passed as parameters to supply data to build objects, as for the s and s# formats, the required data is copied. Buffers provided by the caller are never referenced by the objects created by Py_BuildValue(). In other words, if your code invokes malloc() and passes the allocated memory to Py_BuildValue(), your code is responsible for calling free() for that memory once Py_BuildValue() returns.

In the following description, the quoted form is the format unit; the entry in (round) parentheses is the Python object type that the format unit will return; and the entry in [square] brackets is the type of the C value(s) to be passed.

The characters space, tab, colon and comma are ignored in format strings (but not within format units such as s#). This can be used to
make long format strings a tad more readable.

`s (str or None) [char *]`
Convert a null-terminated C string to a Python `str` object using ‘utf-8’ encoding. If the C string pointer is `NULL`, None is used.

`s# (str or None) [char *, int]`
Convert a C string and its length to a Python `str` object using ‘utf-8’ encoding. If the C string pointer is `NULL`, the length is ignored and None is returned.

`y (bytes) [char *]`
This converts a C string to a Python `bytes` object. If the C string pointer is `NULL`, None is returned.

`y# (bytes) [char *, int]`
This converts a C string and its lengths to a Python object. If the C string pointer is `NULL`, None is returned.

`z (str or None) [char *]`
Same as `s`.

`z# (str or None) [char *, int]`
Same as `s#`.

`u (str) [Py_UNICODE *}]
Convert a null-terminated buffer of Unicode (UCS-2 or UCS-4) data to a Python Unicode object. If the Unicode buffer pointer is `NULL`, None is returned.

`u# (str) [Py_UNICODE *, int]`
Convert a Unicode (UCS-2 or UCS-4) data buffer and its length to a Python Unicode object. If the Unicode buffer pointer is `NULL`, the length is ignored and None is returned.

`U (str or None) [char *]`
Same as s.

U# (str or None) [char *, int]
  Same as s#.

i (int) [int]
  Convert a plain C int to a Python integer object.

b (int) [char]
  Convert a plain C char to a Python integer object.

h (int) [short int]
  Convert a plain C short int to a Python integer object.

l (int) [long int]
  Convert a C long int to a Python integer object.

B (int) [unsigned char]
  Convert a C unsigned char to a Python integer object.

H (int) [unsigned short int]
  Convert a C unsigned short int to a Python integer object.

I (int) [unsigned int]
  Convert a C unsigned int to a Python integer object.

k (int) [unsigned long]
  Convert a C unsigned long to a Python integer object.

L (int) [PY_LONG_LONG]
  Convert a C long long to a Python integer object. Only available on platforms that support long long (or _int64 on Windows).

K (int) [unsigned PY_LONG_LONG]
  Convert a C unsigned long long to a Python integer object. Only available on platforms that support unsigned long long (or unsigned _int64 on Windows).
n (int) [Py_ssize_t]
  Convert a C Py_ssize_t to a Python integer.

c (bytes of length 1) [char]
  Convert a C int representing a byte to a Python bytes object of length 1.

C (str of length 1) [int]
  Convert a C int representing a character to Python str object of length 1.

d (float) [double]
  Convert a C double to a Python floating point number.

f (float) [float]
  Convert a C float to a Python floating point number.

D (complex) [Py_complex *]
  Convert a C Py_complex structure to a Python complex number.

O (object) [PyObject *]
  Pass a Python object untouched (except for its reference count, which is incremented by one). If the object passed in is a NULL pointer, it is assumed that this was caused because the call producing the argument found an error and set an exception. Therefore, Py_BuildValue() will return NULL but won’t raise an exception. If no exception has been raised yet, SystemError is set.

S (object) [PyObject *]
  Same as O.

N (object) [PyObject *]
  Same as O, except it doesn’t increment the reference count on the object. Useful when the object is created by a call to an object constructor in the argument list.
0& (object) [converter, anything]

Convert anything to a Python object through a converter function. The function is called with anything (which should be compatible with void *) as its argument and should return a “new” Python object, or NULL if an error occurred.

(items) (tuple) [matching-items]

Convert a sequence of C values to a Python tuple with the same number of items.

[items] (list) [matching-items]

Convert a sequence of C values to a Python list with the same number of items.

{items} (dict) [matching-items]

Convert a sequence of C values to a Python dictionary. Each pair of consecutive C values adds one item to the dictionary, serving as key and value, respectively.

If there is an error in the format string, the SystemError exception is set and NULL returned.

PyObject* Py_VaBuildValue(const char *format, va_list vars)

Identical to Py_BuildValue(), except that it accepts a va_list rather than a variable number of arguments.
String conversion and formatting

Functions for number conversion and formatted string output.

```c
int PyOS_snprintf(char *str, size_t size, const char *format, ...)
```

Output not more than `size` bytes to `str` according to the format string `format` and the extra arguments. See the Unix man page `snprintf(2)`.

```c
int PyOS_vsnprintf(char *str, size_t size, const char *format, va_list va)
```

Output not more than `size` bytes to `str` according to the format string `format` and the variable argument list `va`. Unix man page `vsnprintf(2)`.

`PyOS_snprintf()` and `PyOS_vsnprintf()` wrap the Standard C library functions `snprintf()` and `vsnprintf()`. Their purpose is to guarantee consistent behavior in corner cases, which the Standard C functions do not.

The wrappers ensure that `str[*(size-1)]` is always '\0' upon return. They never write more than `size` bytes (including the trailing '\0') into `str`. Both functions require that `str` != NULL, `size` > 0 and `format` != NULL.

If the platform doesn't have `vsnprintf()` and the buffer size needed to avoid truncation exceeds `size` by more than 512 bytes, Python aborts with a `Py_FatalError`.

The return value (`rv`) for these functions should be interpreted as follows:
• When $0 \leq rv < \text{size}$, the output conversion was successful and $rv$ characters were written to $str$ (excluding the trailing '\0' byte at $str[\text{size}]$).

• When $rv \geq \text{size}$, the output conversion was truncated and a buffer with $rv + 1$ bytes would have been needed to succeed. $str[\text{size}-1]$ is '\0' in this case.

• When $rv < 0$, “something bad happened.” $str[\text{size}-1]$ is '\0' in this case too, but the rest of $str$ is undefined. The exact cause of the error depends on the underlying platform.

The following functions provide locale-independent string to number conversions.

double **PyOS_string_to_double**(const char *s, char **endptr, PyObject *overflow_exception)

Convert a string $s$ to a double, raising a Python exception on failure. The set of accepted strings corresponds to the set of strings accepted by Python’s $\text{float()}$ constructor, except that $s$ must not have leading or trailing whitespace. The conversion is independent of the current locale.

If endptr is NULL, convert the whole string. Raise ValueError and return -1.0 if the string is not a valid representation of a floating-point number.

If endptr is not NULL, convert as much of the string as possible and set *endptr to point to the first unconverted character. If no initial segment of the string is the valid representation of a floating-point number, set *endptr to point to the beginning of the string, raise ValueError, and return -1.0.

If $s$ represents a value that is too large to store in a float (for
example, "1e500" is such a string on many platforms) then if overflow_exception is NULL return Py_HUGE_VAL (with an appropriate sign) and don’t set any exception. Otherwise, overflow_exception must point to a Python exception object; raise that exception and return -1.0. In both cases, set *endptr to point to the first character after the converted value.

If any other error occurs during the conversion (for example an out-of-memory error), set the appropriate Python exception and return -1.0.

*New in version 3.1.*

char* **PyOS_double_to_string**(double *val*, char *format_code*, int *precision*, int *flags*, int *ptype*)

Convert a double *val* to a string using supplied *format_code*, *precision*, and *flags*.

*format_code* must be one of 'e', 'E', 'f', 'F', 'g', 'G' or 'r'. For 'r', the supplied *precision* must be 0 and is ignored. The 'r' format code specifies the standard *repr()* format.

*flags* can be zero or more of the values *Py_DTSF_SIGN*, *Py_DTSF_ADD_DOT_0*, or *Py_DTSF_ALT*, or-ed together:

- **Py_DTSF_SIGN** means to always precede the returned string with a sign character, even if *val* is non-negative.
- **Py_DTSF_ADD_DOT_0** means to ensure that the returned string will not look like an integer.
- **Py_DTSF_ALT** means to apply “alternate” formatting rules. See the documentation for the *PyOS_snprintf()* '#*' specifier for details.

If *ptype* is non-NULL, then the value it points to will be set to one of
Py_DTST_FINITE, Py_DTST_INFINITY, or Py_DTST_NAN, signifying that val is a finite number, an infinite number, or not a number, respectively.

The return value is a pointer to buffer with the converted string or NULL if the conversion failed. The caller is responsible for freeing the returned string by calling PyMem_Free().

New in version 3.1.

int PyOS_stricmp(const char *s1, const char *s2)

Case insensitive comparison of strings. The function works almost identically to strcmp() except that it ignores the case.

int PyOS_strnicmp(const char *s1, const char *s2, Py_ssize_t size)

Case insensitive comparison of strings. The function works almost identically to strncmp() except that it ignores the case.
Reflection

PyObject* PyEval_GetBuiltins()

_Return value: Borrowed reference._
Return a dictionary of the builtins in the current execution frame, or the interpreter of the thread state if no frame is currently executing.

PyObject* PyEval_GetLocals()

_Return value: Borrowed reference._
Return a dictionary of the local variables in the current execution frame, or _NULL_ if no frame is currently executing.

PyObject* PyEval_GetGlobals()

_Return value: Borrowed reference._
Return a dictionary of the global variables in the current execution frame, or _NULL_ if no frame is currently executing.

PyFrameObject* PyEval_GetFrame()

_Return value: Borrowed reference._
Return the current thread state’s frame, which is _NULL_ if no frame is currently executing.

int PyFrame_GetLineNumber(PyFrameObject *frame)

Return the line number that _frame_ is currently executing.

const char* PyEval_GetFuncName(PyObject *func)

Return the name of _func_ if it is a function, class or instance object, else the name of _func’s_ type.

const char* PyEval_GetFuncDesc(PyObject *func)

Return a description string, depending on the type of _func_. Return
values include “()” for functions and methods, ” constructor”, ” instance”, and ” object”. Concatenated with the result of `PyEval_GetFuncName()`, the result will be a description of `func`. 
Codec registry and support functions

int PyCodec_Register(PyObject *search_function)
    Register a new codec search function.
    As side effect, this tries to load the encodings package, if not yet done, to make sure that it is always first in the list of search functions.

int PyCodec_KnownEncoding(const char *encoding)
    Return 1 or 0 depending on whether there is a registered codec for the given encoding.

PyObject* PyCodec_Encode(PyObject *object, const char *encoding, const char *errors)
    Generic codec based encoding API.
    object is passed through the encoder function found for the given encoding using the error handling method defined by errors. errors may be NULL to use the default method defined for the codec. Raises a LookupError if no encoder can be found.

PyObject* PyCodec_Decode(PyObject *object, const char *encoding, const char *errors)
    Generic codec based decoding API.
    object is passed through the decoder function found for the given encoding using the error handling method defined by errors. errors may be NULL to use the default method defined for the codec. Raises a LookupError if no encoder can be found.
Codec lookup API

In the following functions, the *encoding* string is looked up converted to all lower-case characters, which makes encodings looked up through this mechanism effectively case-insensitive. If no codec is found, a *KeyError* is set and *NULL* returned.

**PyObject**\* **PyCodec**\_**Encoder** (const char \*\*encoding)  
Get an encoder function for the given *encoding*.

**PyObject**\* **PyCodec**\_**Decoder** (const char \*\*encoding)  
Get a decoder function for the given *encoding*.

**PyObject**\* **PyCodec**\_**IncrementalEncoder** (const char \*\*encoding, const char \*\*errors)  
Get an *IncrementalEncoder* object for the given *encoding*.

**PyObject**\* **PyCodec**\_**IncrementalDecoder** (const char \*\*encoding, const char \*\*errors)  
Get an *IncrementalDecoder* object for the given *encoding*.

**PyObject**\* **PyCodec**\_**StreamReader** (const char \*\*encoding, PyObject \*\*stream, const char \*\*errors)  
Get a *StreamReader* factory function for the given *encoding*.

**PyObject**\* **PyCodec**\_**StreamWriter** (const char \*\*encoding, PyObject \*\*stream, const char \*\*errors)  
Get a *StreamWriter* factory function for the given *encoding*. 
Registry API for Unicode encoding error handlers

```c
int PyCodec_RegisterError(const char *name, PyObject *error)
```

Register the error handling callback function `error` under the given `name`. This callback function will be called by a codec when it encounters unencodable characters/undecodable bytes and `name` is specified as the error parameter in the call to the encode/decode function.

The callback gets a single argument, an instance of `UnicodeEncodeError`, `UnicodeDecodeError` or `UnicodeTranslateError` that holds information about the problematic sequence of characters or bytes and their offset in the original string (see Unicode Exception Objects for functions to extract this information). The callback must either raise the given exception, or return a two-item tuple containing the replacement for the problematic sequence, and an integer giving the offset in the original string at which encoding/decoding should be resumed.

Return 0 on success, -1 on error.

```c
PyObject* PyCodec_LookupError(const char *name)
```

Lookup the error handling callback function registered under `name`. As a special case `NULL` can be passed, in which case the error handling callback for “strict” will be returned.

```c
PyObject* PyCodec_StrictErrors(PyObject *exc)
```

Raise `exc` as an exception.
PyObject* PyCodec_IgnoreErrors(PyObject *exc)
Ignore the unicode error, skipping the faulty input.

PyObject* PyCodec_ReplaceErrors(PyObject *exc)
Replace the unicode encode error with ? or U+FFFD.

PyObject*
PyCodec_XMLCharRefReplaceErrors(PyObject *exc)
Replace the unicode encode error with XML character references.

PyObject*
PyCodec_BackslashReplaceErrors(PyObject *exc)
Replace the unicode encode error with backslash escapes (\x, \u and \U).

PyObject* PyCodec_NameReplaceErrors(PyObject *exc)
Replace the unicode encode error with \N{...} escapes.

*New in version 3.5.*
Abstract Objects Layer

The functions in this chapter interact with Python objects regardless of their type, or with wide classes of object types (e.g. all numerical types, or all sequence types). When used on object types for which they do not apply, they will raise a Python exception.

It is not possible to use these functions on objects that are not properly initialized, such as a list object that has been created by `PyList_New()`, but whose items have not been set to some non-NULL value yet.

- Object Protocol
- Number Protocol
- Sequence Protocol
- Mapping Protocol
- Iterator Protocol
- Buffer Protocol
  - Buffer structure
  - Buffer request types
    - request-independent fields
    - readonly, format
    - shape, strides, suboffsets
    - contiguity requests
    - compound requests
  - Complex arrays
    - NumPy-style: shape and strides
    - PIL-style: shape, strides and suboffsets
  - Buffer-related functions
- Old Buffer Protocol
Object Protocol

PyObject* Py_NotImplemented
    The NotImplemented singleton, used to signal that an operation is not implemented for the given type combination.

Py_RETURN_NOTIMPLEMENTED
    Properly handle returning Py_NotImplemented from within a C function (that is, increment the reference count of NotImplemented and return it).

intPyObject_Print(PyObject *o, FILE *fp, int flags)
    Print an object o, on file fp. Returns -1 on error. The flags argument is used to enable certain printing options. The only option currently supported is Py_PRINT_RAW; if given, the str() of the object is written instead of the repr().

intPyObject_HasAttr(PyObject *o, PyObject *attr_name)
    Returns 1 if o has the attribute attr_name, and 0 otherwise. This is equivalent to the Python expression hasattr(o, attr_name). This function always succeeds.

intPyObject_HasAttrString(PyObject *o, const char *attr_name)
    Returns 1 if o has the attribute attr_name, and 0 otherwise. This is equivalent to the Python expression hasattr(o, attr_name). This function always succeeds.

PyObject*PyObject_GetAttr(PyObject *o, PyObject *attr_name)

Retrieve an attribute named *attr_name* from object *o*. Returns the attribute value on success, or *NULL* on failure. This is the equivalent of the Python expression *o*.attr_name.

**PyObject**\* **PyObject\_GetAttrString**(*PyObject\* o, const char\* *attr\_name*)

*Return value: New reference.*
Retrieve an attribute named *attr_name* from object *o*. Returns the attribute value on success, or *NULL* on failure. This is the equivalent of the Python expression *o*.attr_name.

**PyObject**\* **PyObject\_GenericGetAttr**(*PyObject\* o, PyObject\* *name*)

Generic attribute getter function that is meant to be put into a type object's *tp\_getattr* slot. It looks for a descriptor in the dictionary of classes in the object's MRO as well as an attribute in the object's __dict__ (if present). As outlined in Implementing Descriptors, data descriptors take preference over instance attributes, while non-data descriptors don’t. Otherwise, an AttributeError is raised.

**int** **PyObject\_SetAttr**(*PyObject\* o, PyObject\* *attr\_name*, PyObject\* *v*)

Set the value of the attribute named *attr_name*, for object *o*, to the value *v*. Returns -1 on failure. This is the equivalent of the Python statement *o*.attr_name = *v*.

**int** **PyObject\_SetAttrString**(*PyObject\* o, const char\* *attr\_name*, PyObject\* *v*)

Set the value of the attribute named *attr_name*, for object *o*, to the value *v*. Returns -1 on failure. This is the equivalent of the Python statement *o*.attr_name = *v*. 
int PyObject_GenericSetAttr(PyObject *o, PyObject *name, PyObject *value)
    Generic attribute setter function that is meant to be put into a type object's tp_setattro slot. It looks for a data descriptor in the dictionary of classes in the object's MRO, and if found it takes preference over setting the attribute in the instance dictionary. Otherwise, the attribute is set in the object’s __dict__ (if present). Otherwise, an AttributeError is raised and -1 is returned.

int PyObject_DeleteAttr(PyObject *o, PyObject *attr_name)
    Delete attribute named attr_name, for object o. Returns -1 on failure. This is the equivalent of the Python statement del o.attr_name.

int PyObject_DeleteAttrString(PyObject *o, const char *attr_name)
    Delete attribute named attr_name, for object o. Returns -1 on failure. This is the equivalent of the Python statement del o.attr_name.

PyObject* PyObject_GenericGetDict(PyObject *o, void *context)
    A generic implementation for the getter of a __dict__ descriptor. It creates the dictionary if necessary.

    New in version 3.3.

int PyObject_GenericSetDict(PyObject *o, void *context)
    A generic implementation for the setter of a __dict__ descriptor. This implementation does not allow the dictionary to be deleted.

    New in version 3.3.
PyObject* `PyObject_RichCompare(PyObject *o1, PyObject *o2, int opid)`

*Return value: New reference.*

Compare the values of `o1` and `o2` using the operation specified by `opid`, which must be one of `Py_LT`, `Py_LE`, `Py_EQ`, `Py_NE`, `Py_GT`, or `Py_GE`, corresponding to `<`, `<=`, `==`, `!=`, `>`, or `>=` respectively. This is the equivalent of the Python expression `o1 op o2`, where `op` is the operator corresponding to `opid`. Returns the value of the comparison on success, or `NULL` on failure.

`int PyObject_RichCompareBool(PyObject *o1, PyObject *o2, int opid)`

Compare the values of `o1` and `o2` using the operation specified by `opid`, which must be one of `Py_LT`, `Py_LE`, `Py_EQ`, `Py_NE`, `Py_GT`, or `Py_GE`, corresponding to `<`, `<=`, `==`, `!=`, `>`, or `>=` respectively. Returns -1 on error, 0 if the result is false, 1 otherwise. This is the equivalent of the Python expression `o1 op o2`, where `op` is the operator corresponding to `opid`.

**Note:** If `o1` and `o2` are the same object, `PyObject_RichCompareBool()` will always return 1 for `Py_EQ` and 0 for `Py_NE`.

PyObject* `PyObject_Repr(PyObject *o)`

*Return value: New reference.*

Compute a string representation of object `o`. Returns the string representation on success, `NULL` on failure. This is the equivalent of the Python expression `repr(o)`. Called by the `repr()` built-in function.

*Changed in version 3.4:* This function now includes a debug
assertion to help ensure that it does not silently discard an active exception.

PyObject* **PyObject_ASCII(PyObject *o)**

As PyObject_Repr(), compute a string representation of object o, but escape the non-ASCII characters in the string returned by PyObject_Repr() with \x, \u or \U escapes. This generates a string similar to that returned by PyObject_Repr() in Python 2. Called by the ascii() built-in function.

PyObject* **PyObject_Str(PyObject *o)**


Compute a string representation of object o. Returns the string representation on success, NULL on failure. This is the equivalent of the Python expression str(o). Called by the str() built-in function and, therefore, by the print() function.

*Changed in version 3.4:* This function now includes a debug assertion to help ensure that it does not silently discard an active exception.

PyObject* **PyObject_Bytes(PyObject *o)**

Compute a bytes representation of object o. NULL is returned on failure and a bytes object on success. This is equivalent to the Python expression bytes(o), when o is not an integer. Unlike bytes(o), a TypeError is raised when o is an integer instead of a zero-initialized bytes object.

int **PyObject_IsSubclass(PyObject *derived, PyObject *cls)**

Return 1 if the class derived is identical to or derived from the class cls, otherwise return 0. In case of an error, return -1.
If `cls` is a tuple, the check will be done against every entry in `cls`. The result will be 1 when at least one of the checks returns 1, otherwise it will be 0.

If `cls` has a `__subclasscheck__()` method, it will be called to determine the subclass status as described in PEP 3119. Otherwise, `derived` is a subclass of `cls` if it is a direct or indirect subclass, i.e. contained in `cls.__mro__`.

Normally only class objects, i.e. instances of `type` or a derived class, are considered classes. However, objects can override this by having a `__bases__` attribute (which must be a tuple of base classes).

```c
int PyObject_IsInstance(PyObject *inst, PyObject *cls)
```

Return 1 if `inst` is an instance of the class `cls` or a subclass of `cls`, or 0 if not. On error, returns -1 and sets an exception.

If `cls` is a tuple, the check will be done against every entry in `cls`. The result will be 1 when at least one of the checks returns 1, otherwise it will be 0.

If `cls` has a `__instancecheck__()` method, it will be called to determine the subclass status as described in PEP 3119. Otherwise, `inst` is an instance of `cls` if its class is a subclass of `cls`.

An instance `inst` can override what is considered its class by having a `__class__` attribute.

An object `cls` can override if it is considered a class, and what its base classes are, by having a `__bases__` attribute (which must be a tuple of base classes).
int PyCallable_Check(PyObject *o)

Determine if the object o is callable. Return 1 if the object is callable and 0 otherwise. This function always succeeds.

PyObject* PyObject_Call(PyObject *callable_object, PyObject *args, PyObject *kw)

Call a callable Python object callable_object, with arguments given by the tuple args, and named arguments given by the dictionary kw. If no named arguments are needed, kw may be NULL. args must not be NULL, use an empty tuple if no arguments are needed. Returns the result of the call on success, or NULL on failure. This is the equivalent of the Python expression callable_object(*args, **kw).

PyObject* PyObject_CallObject(PyObject *callable_object, PyObject *args)

Call a callable Python object callable_object, with arguments given by the tuple args. If no arguments are needed, then args may be NULL. Returns the result of the call on success, or NULL on failure. This is the equivalent of the Python expression callable_object(*args).

PyObject* PyObject_CallFunction(PyObject *callable, const char *format, ...)

Call a callable Python object callable, with a variable number of C arguments. The C arguments are described using a Py_BuildValue() style format string. The format may be NULL, indicating that no arguments are provided. Returns the result of the call on success, or NULL on failure. This is the equivalent of the
Python expression `callable(*args)`. Note that if you only pass `PyObject * args`, `PyObject_CallFunctionObjArgs()` is a faster alternative.

*Changed in version 3.4:* The type of `format` was changed from `char *`.

```c
PyObject* PyObject_CallMethod(PyObject *o, const char *method, const char *format, ...)
```

*Return value: New reference.*

Call the method named `method` of object `o` with a variable number of C arguments. The C arguments are described by a `Py_BuildValue()` format string that should produce a tuple. The format may be `NULL`, indicating that no arguments are provided. Returns the result of the call on success, or `NULL` on failure. This is the equivalent of the Python expression `o.method(args)`. Note that if you only pass `PyObject * args`, `PyObject_CallMethodObjArgs()` is a faster alternative.

*Changed in version 3.4:* The types of `method` and `format` were changed from `char *`.

```c
PyObject* PyObject_CallFunctionObjArgs(PyObject *callable, ..., NULL)
```

*Return value: New reference.*

Call a callable Python object `callable`, with a variable number of `PyObject*` arguments. The arguments are provided as a variable number of parameters followed by `NULL`. Returns the result of the call on success, or `NULL` on failure.

```c
PyObject* PyObject_CallMethodObjArgs(PyObject *o, PyObject *name, ..., NULL)
```
Calls a method of the object o, where the name of the method is given as a Python string object in name. It is called with a variable number of PyObject* arguments. The arguments are provided as a variable number of parameters followed by NULL. Returns the result of the call on success, or NULL on failure.

Py_hash_t PyObject_Hash(PyObject *o)
Compute and return the hash value of an object o. On failure, return -1. This is the equivalent of the Python expression hash(o).

Changed in version 3.2: The return type is now Py_hash_t. This is a signed integer the same size as Py_ssize_t.

Py_hash_t PyObject_HashNotImplemented(PyObject *o)
Set a TypeError indicating that type(o) is not hashable and return -1. This function receives special treatment when stored in a tp_hash slot, allowing a type to explicitly indicate to the interpreter that it is not hashable.

int PyObject_IsTrue(PyObject *o)
Returns 1 if the object o is considered to be true, and 0 otherwise. This is equivalent to the Python expression not not o. On failure, return -1.

int PyObject_Not(PyObject *o)
Returns 0 if the object o is considered to be true, and 1 otherwise. This is equivalent to the Python expression not o. On failure, return -1.

PyObject* PyObject_Type(PyObject *o)
When o is non-NULL, returns a type object corresponding to the object type of object o. On failure, raises SystemError and returns NULL. This is equivalent to the Python expression type(o). This function increments the reference count of the return value. There's really no reason to use this function instead of the common expression o->ob_type, which returns a pointer of type PyTypeObject*, except when the incremented reference count is needed.

int PyObject_TypeCheck(PyObject *o, PyTypeObject *type)

Return true if the object o is of type type or a subtype of type. Both parameters must be non-NULL.

Py_ssize_t PyObject_Length(PyObject *o)
Py_ssize_t PyObject_Size(PyObject *o)

Return the length of object o. If the object o provides either the sequence and mapping protocols, the sequence length is returned. On error, -1 is returned. This is the equivalent to the Python expression len(o).

Py_ssize_t PyObject_LengthHint(PyObject *o, Py_ssize_t default)

Return an estimated length for the object o. First try to return its actual length, then an estimate using __length_hint__(), and finally return the default value. On error return -1. This is the equivalent to the Python expression operator.length_hint(o, default).

New in version 3.4.

PyObject* PyObject_GetItem(PyObject *o, PyObject *key)
Return element of o corresponding to the object key or NULL on failure. This is the equivalent of the Python expression o[key].

int PyObject_SetItem(PyObject *o, PyObject *key, PyObject *v)
Map the object key to the value v. Returns -1 on failure. This is the equivalent of the Python statement o[key] = v.

int PyObject_DelItem(PyObject *o, PyObject *key)
Delete the mapping for key from o. Returns -1 on failure. This is the equivalent of the Python statement del o[key].

PyObject* PyObject_Dir(PyObject *o)
This is equivalent to the Python expression dir(o), returning a (possibly empty) list of strings appropriate for the object argument, or NULL if there was an error. If the argument is NULL, this is like the Python dir(), returning the names of the current locals; in this case, if no execution frame is active then NULL is returned but PyErr_Occurred() will return false.

PyObject* PyObject_GetIter(PyObject *o)
This is equivalent to the Python expression iter(o). It returns a new iterator for the object argument, or the object itself if the object is already an iterator. Raises TypeError and returns NULL if the object cannot be iterated.
Number Protocol

int **PyNumber_Check**(*PyObject* *o*)

Returns 1 if the object o provides numeric protocols, and false otherwise. This function always succeeds.

**PyObject** *PyNumber_Add*(PyObject *o1, PyObject *o2)

*Return value: New reference.*

Returns the result of adding o1 and o2, or NULL on failure. This is the equivalent of the Python expression o1 + o2.

**PyObject** *PyNumber_Subtract*(PyObject *o1, PyObject *o2)

*Return value: New reference.*

Returns the result of subtracting o2 from o1, or NULL on failure. This is the equivalent of the Python expression o1 - o2.

**PyObject** *PyNumber_Multiply*(PyObject *o1, PyObject *o2)

*Return value: New reference.*

Returns the result of multiplying o1 and o2, or NULL on failure. This is the equivalent of the Python expression o1 * o2.

**PyObject** *PyNumber_MatrixMultiply*(PyObject *o1, PyObject *o2)

Returns the result of matrix multiplication on o1 and o2, or NULL on failure. This is the equivalent of the Python expression o1 @ o2.

*New in version 3.5.*

**PyObject** *PyNumber_FloorDivide*(PyObject *o1, PyObject *o2)
Return the floor of o1 divided by o2, or NULL on failure. This is equivalent to the “classic” division of integers.

PyObject* **PyNumber_TrueDivide**(PyObject *o1, PyObject *o2)

Return a reasonable approximation for the mathematical value of o1 divided by o2, or NULL on failure. The return value is “approximate” because binary floating point numbers are approximate; it is not possible to represent all real numbers in base two. This function can return a floating point value when passed two integers.

PyObject* **PyNumber_Remainder**(PyObject *o1, PyObject *o2)

Returns the remainder of dividing o1 by o2, or NULL on failure. This is the equivalent of the Python expression o1 \% o2.

PyObject* **PyNumber_Divmod**(PyObject *o1, PyObject *o2)

See the built-in function divmod(). Returns NULL on failure. This is the equivalent of the Python expression divmod(o1, o2).

PyObject* **PyNumber_Power**(PyObject *o1, PyObject *o2, PyObject *o3)

See the built-in function pow(). Returns NULL on failure. This is the equivalent of the Python expression pow(o1, o2, o3), where o3 is optional. If o3 is to be ignored, pass Py_None in its place (passing NULL for o3 would cause an illegal memory access).
PyObject* PyNumber_Negative(PyObject *o)

_Return value: New reference._
Returns the negation of o on success, or NULL on failure. This is the equivalent of the Python expression -o.

PyObject* PyNumber_Positive(PyObject *o)

_Return value: New reference._
Returns o on success, or NULL on failure. This is the equivalent of the Python expression +o.

PyObject* PyNumber_Absolute(PyObject *o)

_Return value: New reference._
Returns the absolute value of o, or NULL on failure. This is the equivalent of the Python expression abs(o).

PyObject* PyNumber_Invert(PyObject *o)

_Return value: New reference._
Returns the bitwise negation of o on success, or NULL on failure. This is the equivalent of the Python expression ~o.

PyObject* PyNumber_Lshift(PyObject *o1, PyObject *o2)

_Return value: New reference._
Returns the result of left shifting o1 by o2 on success, or NULL on failure. This is the equivalent of the Python expression o1 << o2.

PyObject* PyNumber_Rshift(PyObject *o1, PyObject *o2)

_Return value: New reference._
Returns the result of right shifting o1 by o2 on success, or NULL on failure. This is the equivalent of the Python expression o1 >> o2.

PyObject* PyNumber_And(PyObject *o1, PyObject *o2)

_Return value: New reference._
Returns the “bitwise and” of o1 and o2 on success and NULL on failure. This is the equivalent of the Python expression o1 & o2.

PyObject* PyNumber_Xor(PyObject *o1, PyObject *o2)

Returns the “bitwise exclusive or” of o1 by o2 on success, or NULL on failure. This is the equivalent of the Python expression o1 ^ o2.

PyObject* PyNumber_Or(PyObject *o1, PyObject *o2)

Returns the “bitwise or” of o1 and o2 on success, or NULL on failure. This is the equivalent of the Python expression o1 | o2.

PyObject* PyNumber_InPlaceAdd(PyObject *o1, PyObject *o2)

Returns the result of adding o1 and o2, or NULL on failure. The operation is done in-place when o1 supports it. This is the equivalent of the Python statement o1 += o2.

PyObject* PyNumber_InPlaceSubtract(PyObject *o1, PyObject *o2)

Returns the result of subtracting o2 from o1, or NULL on failure. The operation is done in-place when o1 supports it. This is the equivalent of the Python statement o1 -= o2.

PyObject* PyNumber_InPlaceMultiply(PyObject *o1, PyObject *o2)

Returns the result of multiplying o1 and o2, or NULL on failure. The operation is done in-place when o1 supports it. This is the
equivalent of the Python statement `o1 *= o2`.

```c
PyObject* PyNumber_InPlaceMatrixMultiply(PyObject *o1, PyObject *o2)
```

Returns the result of matrix multiplication on `o1` and `o2`, or `NULL` on failure. The operation is done in-place when `o1` supports it. This is the equivalent of the Python statement `o1 @= o2`.

New in version 3.5.

```c
PyObject* PyNumber_InPlaceFloorDivide(PyObject *o1, PyObject *o2)
```


Returns the mathematical floor of dividing `o1` by `o2`, or `NULL` on failure. The operation is done in-place when `o1` supports it. This is the equivalent of the Python statement `o1 //= o2`.

```c
PyObject* PyNumber_InPlaceTrueDivide(PyObject *o1, PyObject *o2)
```


Return a reasonable approximation for the mathematical value of `o1` divided by `o2`, or `NULL` on failure. The return value is “approximate” because binary floating point numbers are approximate; it is not possible to represent all real numbers in base two. This function can return a floating point value when passed two integers. The operation is done in-place when `o1` supports it.

```c
PyObject* PyNumber_InPlaceRemainder(PyObject *o1, PyObject *o2)
```


Returns the remainder of dividing `o1` by `o2`, or `NULL` on failure. The operation is done in-place when `o1` supports it. This is the
equivalent of the Python statement \( o_1 \ %= \ o_2 \).

\[\textbf{PyObject}^* \textbf{PyNumber\_InPlacePower}(\textbf{PyObject} \ o_1, \textbf{PyObject} \ o_2, \textbf{PyObject} \ o_3)\]

*Return value: New reference.*

See the built-in function \texttt{pow()}. Returns \texttt{NULL} on failure. The operation is done *in-place* when \( o_1 \) supports it. This is the equivalent of the Python statement \( o_1 \ \ast\ast= \ o_2 \) when \( o_3 \) is \texttt{Py\_None}, or an in-place variant of \texttt{pow(o1, \ o2, \ o3)} otherwise. If \( o_3 \) is to be ignored, pass \texttt{Py\_None} in its place (passing \texttt{NULL} for \( o_3 \) would cause an illegal memory access).

\[\textbf{PyObject}^* \textbf{PyNumber\_InPlaceLshift}(\textbf{PyObject} \ o_1, \textbf{PyObject} \ o_2)\]

*Return value: New reference.*

Returns the result of left shifting \( o_1 \) by \( o_2 \) on success, or \texttt{NULL} on failure. The operation is done *in-place* when \( o_1 \) supports it. This is the equivalent of the Python statement \( o_1 \ \ll= \ o_2 \).

\[\textbf{PyObject}^* \textbf{PyNumber\_InPlaceRshift}(\textbf{PyObject} \ o_1, \textbf{PyObject} \ o_2)\]

*Return value: New reference.*

Returns the result of right shifting \( o_1 \) by \( o_2 \) on success, or \texttt{NULL} on failure. The operation is done *in-place* when \( o_1 \) supports it. This is the equivalent of the Python statement \( o_1 \ \gg= \ o_2 \).

\[\textbf{PyObject}^* \textbf{PyNumber\_InPlaceAnd}(\textbf{PyObject} \ o_1, \textbf{PyObject} \ o_2)\]

*Return value: New reference.*

Returns the “bitwise and” of \( o_1 \) and \( o_2 \) on success and \texttt{NULL} on failure. The operation is done *in-place* when \( o_1 \) supports it. This is the equivalent of the Python statement \( o_1 \ \&= \ o_2 \).
PyObject* PyNumber_InPlaceXor(PyObject *o1, PyObject *o2)

Returns the “bitwise exclusive or” of o1 by o2 on success, or NULL on failure. The operation is done in-place when o1 supports it. This is the equivalent of the Python statement o1 ^= o2.

PyObject* PyNumber_InPlaceOr(PyObject *o1, PyObject *o2)

Returns the “bitwise or” of o1 and o2 on success, or NULL on failure. The operation is done in-place when o1 supports it. This is the equivalent of the Python statement o1 |= o2.

PyObject* PyNumber_Long(PyObject *o)

Returns the o converted to an integer object on success, or NULL on failure. This is the equivalent of the Python expression int(o).

PyObject* PyNumber_Float(PyObject *o)

Returns the o converted to a float object on success, or NULL on failure. This is the equivalent of the Python expression float(o).

PyObject* PyNumber_Index(PyObject *o)

Returns the o converted to a Python int on success or NULL with a TypeError exception raised on failure.

PyObject* PyNumber_ToBase(PyObject *n, int base)

Returns the integer n converted to base base as a string. The base argument must be one of 2, 8, 10, or 16. For base 2, 8, or 16, the returned string is prefixed with a base marker of '0b', '0o', or '0x', respectively. If n is not a Python int, it is converted with PyNumber_Index() first.
Py_ssize_t **PyNumber_AsSsize_t**(PyObject *o, PyObject *exc)

Returns `o` converted to a Py_ssize_t value if `o` can be interpreted as an integer. If the call fails, an exception is raised and -1 is returned.

If `o` can be converted to a Python int but the attempt to convert to a Py_ssize_t value would raise an `OverflowError`, then the `exc` argument is the type of exception that will be raised (usually `IndexError` or `OverflowError`). If `exc` is `NULL`, then the exception is cleared and the value is clipped to `PY_SSIZE_T_MIN` for a negative integer or `PY_SSIZE_T_MAX` for a positive integer.

```c
int **PyIndex_Check**(PyObject *o)
```

Returns `True` if `o` is an index integer (has the nb_index slot of the `tp_as_number` structure filled in).
Sequence Protocol

```c
int PySequence_Check(PyObject *o)

Return 1 if the object provides sequence protocol, and 0 otherwise. This function always succeeds.
```

```c
Py_ssize_t PySequence_Size(PyObject *o)
Py_ssize_t PySequence_Length(PyObject *o)

Returns the number of objects in sequence o on success, and -1 on failure. For objects that do not provide sequence protocol, this is equivalent to the Python expression `len(o)`.
```

```c
PyObject* PySequence_Concat(PyObject *o1, PyObject *o2)

Return the concatenation of o1 and o2 on success, and NULL on failure. This is the equivalent of the Python expression `o1 + o2`.
```

```c
PyObject* PySequence_Repeat(PyObject *o, Py_ssize_t count)

Return the result of repeating sequence object o count times, or NULL on failure. This is the equivalent of the Python expression `o * count`.
```

```c
PyObject* PySequence_InPlaceConcat(PyObject *o1, PyObject *o2)

Return the concatenation of o1 and o2 on success, and NULL on failure. The operation is done *in-place* when o1 supports it. This is the equivalent of the Python expression `o1 += o2`.
```

```c
PyObject* PySequence_InPlaceRepeat(PyObject *o,
```
Py_ssize_t count)

  Return the result of repeating sequence object o count times, or NULL on failure. The operation is done in-place when o supports it. This is the equivalent of the Python expression o *= count.

PyObject* PySequence_GetItem(PyObject *o, Py_ssize_t i)

  Return the i\(^{th}\) element of o, or NULL on failure. This is the equivalent of the Python expression o[i].

PyObject* PySequence_GetSlice(PyObject *o, Py_ssize_t i1, Py_ssize_t i2)

  Return the slice of sequence object o between i1 and i2, or NULL on failure. This is the equivalent of the Python expression o[i1:i2].

int PySequence_SetItem(PyObject *o, Py_ssize_t i, PyObject *v)

  Assign object v to the i\(^{th}\) element of o. Returns -1 on failure. This is the equivalent of the Python statement o[i] = v. This function does not steal a reference to v.

int PySequence_DelItem(PyObject *o, Py_ssize_t i)

  Delete the i\(^{th}\) element of object o. Returns -1 on failure. This is the equivalent of the Python statement del o[i].

int PySequence_SetSlice(PyObject *o, Py_ssize_t i1, Py_ssize_t i2, PyObject *v)

  Assign the sequence object v to the slice in sequence object o from i1 to i2. This is the equivalent of the Python statement o[i1:i2]
int PySequence_DelSlice(PyObject *o, Py_ssize_t i1, Py_ssize_t i2)
    Delete the slice in sequence object o from i1 to i2. Returns -1 on failure. This is the equivalent of the Python statement del o[i1:i2].

Py_ssize_t PySequence_Count(PyObject *o, PyObject *value)
    Return the number of occurrences of value in o, that is, return the number of keys for which o[key] == value. On failure, return -1. This is equivalent to the Python expression o.count(value).

int PySequence_Contains(PyObject *o, PyObject *value)
    Determine if o contains value. If an item in o is equal to value, return 1, otherwise return 0. On error, return -1. This is equivalent to the Python expression value in o.

Py_ssize_t PySequence_Index(PyObject *o, PyObject *value)
    Return the first index i for which o[i] == value. On error, return -1. This is equivalent to the Python expression o.index(value).

PyObject* PySequence_List(PyObject *o)
    Return a list object with the same contents as the sequence or iterable o, or NULL on failure. The returned list is guaranteed to be new. This is equivalent to the Python expression list(o).

PyObject* PySequence_Tuple(PyObject *o)
    Return a tuple object with the same contents as the arbitrary sequence o or NULL on failure. If o is a tuple, a new reference will
be returned, otherwise a tuple will be constructed with the appropriate contents. This is equivalent to the Python expression `tuple(o).

PyObject* PySequence_Fast(PyObject *o, const char *m)

*Return value: New reference.*
Return the sequence `o` as a list, unless it is already a tuple or list, in which case `o` is returned. Use `PySequence_Fast_GET_ITEM()` to access the members of the result. Returns `NULL` on failure. If the object is not a sequence, raises `TypeError` with `m` as the message text.

PyObject* PySequence_Fast_GET_ITEM(PyObject *o, Py_ssize_t i)

*Return value: Borrowed reference.*
Return the `i`th element of `o`, assuming that `o` was returned by `PySequence_Fast()`, `o` is not `NULL`, and that `i` is within bounds.

PyObject** PySequence_Fast_ITEMS(PyObject *o)

Return the underlying array of PyObject pointers. Assumes that `o` was returned by `PySequence_Fast()` and `o` is not `NULL`.

Note, if a list gets resized, the reallocation may relocate the items array. So, only use the underlying array pointer in contexts where the sequence cannot change.

PyObject* PySequence_ITEM(PyObject *o, Py_ssize_t i)

*Return value: New reference.*
Return the `i`th element of `o` or `NULL` on failure. Macro form of `PySequence_GetItem()` but without checking that `PySequence_Check()` on `o` is true and without adjustment for negative indices.
Pyssize_t PySequence_Fast_GET_SIZE(PyObject *o)

Returns the length of o, assuming that o was returned by PySequence_Fast() and that o is not NULL. The size can also be gotten by calling PySequence_Size() on o, but PySequence_Fast_GET_SIZE() is faster because it can assume o is a list or tuple.
Mapping Protocol

int \texttt{PyMapping\_Check}(:text\begin{command}{ Zukunft BASIC}{PyObject}*\texttt{o})

Return 1 if the object provides mapping protocol, and 0 otherwise. This function always succeeds.

\begin{command}{ Zukunft BASIC}{Py\_ssize\_t}\texttt{PyMapping\_Size}(:text\begin{command}{ Zukunft BASIC}{PyObject}*\texttt{o})

\begin{command}{ Zukunft BASIC}{Py\_ssize\_t}\texttt{PyMapping\_Length}(:text\begin{command}{ Zukunft BASIC}{PyObject}*\texttt{o})

Returns the number of keys in object \texttt{o} on success, and -1 on failure. For objects that do not provide mapping protocol, this is equivalent to the Python expression \texttt{len(o)}.

int \texttt{PyMapping\_DelItemString}(:text\begin{command}{ Zukunft BASIC}{PyObject}*\texttt{o}, \begin{command}{ Zukunft BASIC}{const}\begin{command}{ Zukunft BASIC}{char}*\texttt{key})

Remove the mapping for object \texttt{key} from the object \texttt{o}. Return -1 on failure. This is equivalent to the Python statement \texttt{del o[key]}.

int \texttt{PyMapping\_DelItem}(:text\begin{command}{ Zukunft BASIC}{PyObject}*\texttt{o, PyObject}*\texttt{key})

Remove the mapping for object \texttt{key} from the object \texttt{o}. Return -1 on failure. This is equivalent to the Python statement \texttt{del o[key]}.

int \texttt{PyMapping\_HasKeyString}(:text\begin{command}{ Zukunft BASIC}{PyObject}*\texttt{o, const char}*\texttt{key})

On success, return 1 if the mapping object has the key \texttt{key} and 0 otherwise. This is equivalent to the Python expression \texttt{key in o}. This function always succeeds.

int \texttt{PyMapping\_HasKey}(:text\begin{command}{ Zukunft BASIC}{PyObject}*\texttt{o, PyObject}*\texttt{key})

Return 1 if the mapping object has the key \texttt{key} and 0 otherwise. This is equivalent to the Python expression \texttt{key in o}. This function always succeeds.
PyObject* PyMapping_Keys(PyObject *o)

*Return value: New reference.*
On success, return a list of the keys in object o. On failure, return NULL. This is equivalent to the Python expression list(o.keys()).

PyObject* PyMapping_Values(PyObject *o)

*Return value: New reference.*
On success, return a list of the values in object o. On failure, return NULL. This is equivalent to the Python expression list(o.values()).

PyObject* PyMapping_Items(PyObject *o)

*Return value: New reference.*
On success, return a list of the items in object o, where each item is a tuple containing a key-value pair. On failure, return NULL. This is equivalent to the Python expression list(o.items()).

PyObject* PyMapping_GetItemString(PyObject *o, const char *key)

*Return value: New reference.*
Return element of o corresponding to the object key or NULL on failure. This is the equivalent of the Python expression o[key].

int PyMapping_SetItemString(PyObject *o, const char *key, PyObject *v)

Map the object key to the value v in object o. Returns -1 on failure. This is the equivalent of the Python statement o[key] = v.
Iterator Protocol

There are two functions specifically for working with iterators.

```c
int PyIter_Check(PyObject *o)
```

Return true if the object o supports the iterator protocol.

```c
PyObject* PyIter_Next(PyObject *o)
```


Return the next value from the iteration o. The object must be an iterator (it is up to the caller to check this). If there are no remaining values, returns NULL with no exception set. If an error occurs while retrieving the item, returns NULL and passes along the exception.

To write a loop which iterates over an iterator, the C code should look something like this:

```c
PyObject *iterator = PyObject_GetIter(obj);
PyObject *item;

if (iterator == NULL) {
    /* propagate error */
}

while (item = PyIter_Next(iterator)) {
    /* do something with item */
    ...  /* release reference when done */
    Py_DECREF(item);
}

Py_DECREF(iterator);

if (PyErr_Occurred()) {
```
/* propagate error */
}
else {
    /* continue doing useful work */
}
Buffer Protocol

Certain objects available in Python wrap access to an underlying memory array or buffer. Such objects include the built-in bytes and bytearray, and some extension types like array.array. Third-party libraries may define their own types for special purposes, such as image processing or numeric analysis.

While each of these types have their own semantics, they share the common characteristic of being backed by a possibly large memory buffer. It is then desirable, in some situations, to access that buffer directly and without intermediate copying.

Python provides such a facility at the C level in the form of the buffer protocol. This protocol has two sides:

- on the producer side, a type can export a “buffer interface” which allows objects of that type to expose information about their underlying buffer. This interface is described in the section Buffer Object Structures;
- on the consumer side, several means are available to obtain a pointer to the raw underlying data of an object (for example a method parameter).

Simple objects such as bytes and bytearray expose their underlying buffer in byte-oriented form. Other forms are possible; for example, the elements exposed by an array.array can be multi-byte values.

An example consumer of the buffer interface is the write() method of file objects: any object that can export a series of bytes through the buffer interface can be written to a file. While write() only needs
read-only access to the internal contents of the object passed to it, other methods such as `readinto()` need write access to the contents of their argument. The buffer interface allows objects to selectively allow or reject exporting of read-write and read-only buffers.

There are two ways for a consumer of the buffer interface to acquire a buffer over a target object:

- call `PyObject_GetBuffer()` with the right parameters;
- call `PyArg_ParseTuple()` (or one of its siblings) with one of the `y*`, `w*` or `s*` format codes.

In both cases, `PyBuffer_Release()` must be called when the buffer isn’t needed anymore. Failure to do so could lead to various issues such as resource leaks.
Buffer structure

Buffer structures (or simply “buffers”) are useful as a way to expose the binary data from another object to the Python programmer. They can also be used as a zero-copy slicing mechanism. Using their ability to reference a block of memory, it is possible to expose any data to the Python programmer quite easily. The memory could be a large, constant array in a C extension, it could be a raw block of memory for manipulation before passing to an operating system library, or it could be used to pass around structured data in its native, in-memory format.

Contrary to most data types exposed by the Python interpreter, buffers are not PyObject pointers but rather simple C structures. This allows them to be created and copied very simply. When a generic wrapper around a buffer is needed, a memoryview object can be created.

For short instructions how to write an exporting object, see Buffer Object Structures. For obtaining a buffer, see PyObject_GetBuffer().

**Py_buffer**

```c
void *buf
```

A pointer to the start of the logical structure described by the buffer fields. This can be any location within the underlying physical memory block of the exporter. For example, with negative strides the value may point to the end of the memory block.

For contiguous arrays, the value points to the beginning of the memory block.
void *obj
A new reference to the exporting object. The reference is owned by the consumer and automatically decremented and set to NULL by PyBuffer_Release(). The field is the equivalent of the return value of any standard C-API function.

As a special case, for temporary buffers that are wrapped by PyMemoryView_FromBuffer() or PyBuffer_FillInfo() this field is NULL. In general, exporting objects MUST NOT use this scheme.

Py_ssize_t len
product(shape) * itemsize. For contiguous arrays, this is the length of the underlying memory block. For non-contiguous arrays, it is the length that the logical structure would have if it were copied to a contiguous representation.

Accessing ((char *)buf)[0] up to ((char *)buf)[len-1] is only valid if the buffer has been obtained by a request that guarantees contiguity. In most cases such a request will be PyBUF_SIMPLE or PyBUF_WRITABLE.

int readonly
An indicator of whether the buffer is read-only. This field is controlled by the PyBUF_WRITABLE flag.

Py_ssize_t itemsize
Item size in bytes of a single element. Same as the value of struct.calcsize() called on non-NULL format values.

Important exception: If a consumer requests a buffer without the PyBUF_FORMAT flag, format will be set to NULL, but
itemsizes still has the value for the original format.

If shape is present, the equality product(shape) * itemsize == len still holds and the consumer can use itemsize to navigate the buffer.

If shape is NULL as a result of a PyBUF_SIMPLE or a PyBUF_WRITABLE request, the consumer must disregard itemsize and assume itemsize == 1.

const char *format
A NULL terminated string in struct module style syntax describing the contents of a single item. If this is NULL, "B" (unsigned bytes) is assumed.

This field is controlled by the PyBUF_FORMAT flag.

int ndim
The number of dimensions the memory represents as an n-dimensional array. If it is 0, buf points to a single item representing a scalar. In this case, shape, strides and suboffsets MUST be NULL.

The macro PyBUF_MAX_NDIM limits the maximum number of dimensions to 64. Exporters MUST respect this limit, consumers of multi-dimensional buffers SHOULD be able to handle up to PyBUF_MAX_NDIM dimensions.

Py_ssize_t *shape
An array of Py_ssize_t of length ndim indicating the shape of the memory as an n-dimensional array. Note that shape[0] * ... * shape[ndim-1] * itemsize MUST be equal to
Shape values are restricted to shape[n] >= 0. The case shape[n] == 0 requires special attention. See complex arrays for further information.

The shape array is read-only for the consumer.

**Py_ssize_t** *strides*

An array of Py_ssize_t of length ndim giving the number of bytes to skip to get to a new element in each dimension.

Stride values can be any integer. For regular arrays, strides are usually positive, but a consumer MUST be able to handle the case strides[n] <= 0. See complex arrays for further information.

The strides array is read-only for the consumer.

**Py_ssize_t** *suboffsets*

An array of Py_ssize_t of length ndim. If suboffsets[n] >= 0, the values stored along the nth dimension are pointers and the suboffset value dictates how many bytes to add to each pointer after de-referencing. A suboffset value that is negative indicates that no de-referencing should occur (striding in a contiguous memory block).

If all suboffsets are negative (i.e. no de-referencing is needed, then this field must be NULL (the default value).

This type of array representation is used by the Python Imaging Library (PIL). See complex arrays for further information how to access elements of such an array.
The suboffsets array is read-only for the consumer.

void *internal

This is for use internally by the exporting object. For example, this might be re-cast as an integer by the exporter and used to store flags about whether or not the shape, strides, and suboffsets arrays must be freed when the buffer is released. The consumer MUST NOT alter this value.
Buffer request types

Buffers are usually obtained by sending a buffer request to an exporting object via `PyObject_GetBuffer()`. Since the complexity of the logical structure of the memory can vary drastically, the consumer uses the `flags` argument to specify the exact buffer type it can handle.

All `Py_buffer` fields are unambiguously defined by the request type.

request-independent fields

The following fields are not influenced by `flags` and must always be filled in with the correct values: `obj, buf, len, itemsize, ndim`.

readonly, format

**PyBUF_WRITABLE**

Controls the `readonly` field. If set, the exporter MUST provide a writable buffer or else report failure. Otherwise, the exporter MAY provide either a read-only or writable buffer, but the choice MUST be consistent for all consumers.

**PyBUF_FORMAT**

Controls the `format` field. If set, this field MUST be filled in correctly. Otherwise, this field MUST be `NULL`.

`PyBUF_WRITABLE` can be |'d to any of the flags in the next section. Since `PyBUF_SIMPLE` is defined as 0, `PyBUF_WRITABLE` can be used as a stand-alone flag to request a simple writable buffer.
PyBUF_FORMAT can be |'d to any of the flags except PyBUF_SIMPLE. The latter already implies format B (unsigned bytes).

shape, strides, suboffsets

The flags that control the logical structure of the memory are listed in decreasing order of complexity. Note that each flag contains all bits of the flags below it.

<table>
<thead>
<tr>
<th>Request</th>
<th>shape</th>
<th>strides</th>
<th>suboffsets</th>
</tr>
</thead>
<tbody>
<tr>
<td>PyBUF_INDIRECT</td>
<td>yes</td>
<td>yes</td>
<td>if needed</td>
</tr>
<tr>
<td>PyBUF_STRIDES</td>
<td>yes</td>
<td>yes</td>
<td>NULL</td>
</tr>
<tr>
<td>PyBUF_ND</td>
<td>yes</td>
<td>NULL</td>
<td>NULL</td>
</tr>
<tr>
<td>PyBUF_SIMPLE</td>
<td>NULL</td>
<td>NULL</td>
<td>NULL</td>
</tr>
</tbody>
</table>

contiguity requests

C or Fortran contiguity can be explicitly requested, with and without stride information. Without stride information, the buffer must be C-contiguous.

<table>
<thead>
<tr>
<th>Request</th>
<th>shape</th>
<th>strides</th>
<th>suboffsets</th>
<th>cor</th>
</tr>
</thead>
<tbody>
<tr>
<td>PyBUF_C_CONTIGUOUS</td>
<td>yes</td>
<td>yes</td>
<td>NULL</td>
<td>C</td>
</tr>
<tr>
<td>PyBUF_F_CONTIGUOUS</td>
<td>yes</td>
<td>yes</td>
<td>NULL</td>
<td>F</td>
</tr>
<tr>
<td>PyBUF_ANY_CONTIGUOUS</td>
<td>yes</td>
<td>yes</td>
<td>NULL</td>
<td>C o</td>
</tr>
</tbody>
</table>
compound requests

All possible requests are fully defined by some combination of the flags in the previous section. For convenience, the buffer protocol provides frequently used combinations as single flags.

In the following table \( U \) stands for undefined contiguity. The consumer would have to call \texttt{PyBuffer\_IsContiguous()} to determine contiguity.

<table>
<thead>
<tr>
<th>Request</th>
<th>shape</th>
<th>strides</th>
<th>suboffsets</th>
<th>contig</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>PyBUF_FULL</td>
<td>yes</td>
<td>yes</td>
<td>if needed</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>PyBUF_FULL_RO</td>
<td>yes</td>
<td>yes</td>
<td>if needed</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>PyBUF_RECORDS</td>
<td>yes</td>
<td>yes</td>
<td>NULL</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>PyBUF_RECORDS_RO</td>
<td>yes</td>
<td>yes</td>
<td>NULL</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>PyBUF_STRIDED</td>
<td>yes</td>
<td>yes</td>
<td>NULL</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>PyBUF_STRIDED_RO</td>
<td>yes</td>
<td>yes</td>
<td>NULL</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>PyBUF_CONTIG</td>
<td>yes</td>
<td>NULL</td>
<td>NULL</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>PyBUF_CONTIG_RO</td>
<td>yes</td>
<td>NULL</td>
<td>NULL</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>
Complex arrays

NumPy-style: shape and strides

The logical structure of NumPy-style arrays is defined by *itemsize*, *ndim*, *shape* and *strides*.

If *ndim* == 0, the memory location pointed to by *buf* is interpreted as a scalar of size *itemsize*. In that case, both *shape* and *strides* are *NULL*.

If *strides* is *NULL*, the array is interpreted as a standard n-dimensional C-array. Otherwise, the consumer must access an n-dimensional array as follows:

```c
ptr = (char *)buf + indices[0] * strides[0] + ...
    + indices[n-1] * strides[n-1]
item = *(typeof(item) *)ptr;
```

As noted above, *buf* can point to any location within the actual memory block. An exporter can check the validity of a buffer with this function:

```python
def verify_structure(memlen, itemsize, ndim, shape,
                      """Verify that the parameters represent a valid
                       the bounds of the allocated memory:
                       char *mem: start of the physical memory block
                       memlen: length of the physical memory block
                       offset: (char *)buf - mem"
                      
                      if offset % itemsize:
                        return False
                      if offset < 0 or offset+itemsize > memlen:
                        return False
```

if any(v % itemsize for v in strides):
    return False

if ndim <= 0:
    return ndim == 0 and not shape and not strides
if 0 in shape:
    return True

imin = sum(strides[j]*(shape[j]-1) for j in range(len(strides)) if strides[j] <= 0)
imax = sum(strides[j]*(shape[j]-1) for j in range(len(strides)) if strides[j] > 0)

return 0 <= offset+imin and offset+imax+itemsize

PIL-style: shape, strides and suboffsets

In addition to the regular items, PIL-style arrays can contain pointers that must be followed in order to get to the next element in a dimension. For example, the regular three-dimensional C-array char v[2][2][3] can also be viewed as an array of 2 pointers to 2 two-dimensional arrays: char (*v[2])[2][3]. In suboffsets representation, those two pointers can be embedded at the start of buf, pointing to two char x[2][3] arrays that can be located anywhere in memory.

Here is a function that returns a pointer to the element in an N-D array pointed to by an N-dimensional index when there are both non-NULL strides and suboffsets:

```c
void *get_item_pointer(int ndim, void *buf, Py_ssize_t *suboffsets, Py_ssize_t itemsize)
char *pointer = (char*)buf;
```
int i;
for (i = 0; i < ndim; i++) {
    pointer += strides[i] * indices[i];
    if (suboffsets[i] >= 0) {
        pointer = *((char**)pointer) + suboffsets[i];
    }
}
return (void*)pointer;
Buffer-related functions

int **PyObject** CheckBuffer**(PyObject *obj)**

Return 1 if obj supports the buffer interface otherwise 0. When 1 is returned, it doesn’t guarantee that **PyObject_GetBuffer()** will succeed.

int **PyObject_GetBuffer**(PyObject *exporter, Py_buffer *view, int flags)

Send a request to exporter to fill in view as specified by flags. If the exporter cannot provide a buffer of the exact type, it MUST raise PyExc_BufferError, set view->obj to NULL and return -1.

On success, fill in view, set view->obj to a new reference to exporter and return 0. In the case of chained buffer providers that redirect requests to a single object, view->obj MAY refer to this object instead of exporter (See Buffer Object Structures).

Successful calls to **PyObject_GetBuffer()** must be paired with calls to **PyBuffer_Release()**, similar to malloc() and free(). Thus, after the consumer is done with the buffer, **PyBuffer_Release()** must be called exactly once.

void **PyBuffer_Release**(Py_buffer *view)

Release the buffer view and decrement the reference count for view->obj. This function MUST be called when the buffer is no longer being used, otherwise reference leaks may occur.

It is an error to call this function on a buffer that was not obtained via **PyObject_GetBuffer()**.
Py_ssize_t **PyBuffer_SizeFromFormat** (const char *)

Return the implied *itemsize* from *format*. This function is not yet implemented.

int **PyBuffer_IsContiguous** (Py_buffer *view, char *order)

Return 1 if the memory defined by the *view* is C-style (*order* is 'C') or Fortran-style (*order* is 'F') *contiguous* or either one (*order* is 'A'). Return 0 otherwise.

void **PyBuffer_FillContiguousStrides** (int *ndim, Py_ssize_t *shape, Py_ssize_t *strides, Py_ssize_t *itemsize, char *order)

Fill the *strides* array with byte-strides of a *contiguous* (C-style if *order* is 'C' or Fortran-style if *order* is 'F') array of the given shape with the given number of bytes per element.

int **PyBuffer_FillInfo** (Py_buffer *view, PyObject *exporter, void *buf, Py_ssize_t *len, int *readonly, int *flags)

Handle buffer requests for an exporter that wants to expose *buf* of size *len* with writability set according to *readonly*. *buf* is interpreted as a sequence of unsigned bytes.

The *flags* argument indicates the request type. This function always fills in *view* as specified by *flags*, unless *buf* has been designated as read-only and **PyBUF_WRITABLE** is set in *flags*.

On success, set *view-* >obj to a new reference to *exporter* and return 0. Otherwise, raise PyExc_BufferError, set *view-* >obj to *NULL* and return -1;

If this function is used as part of a **getbufferproc**, *exporter* MUST be set to the exporting object and *flags* must be passed unmodified.
Otherwise, exporter MUST be NULL.
Old Buffer Protocol

*Deprecated since version 3.0.*

These functions were part of the “old buffer protocol” API in Python 2. In Python 3, this protocol doesn’t exist anymore but the functions are still exposed to ease porting 2.x code. They act as a compatibility wrapper around the new buffer protocol, but they don’t give you control over the lifetime of the resources acquired when a buffer is exported.

Therefore, it is recommended that you call `PyObject_GetBuffer()` (or the y* or w* format codes with the `PyArg_ParseTuple()` family of functions) to get a buffer view over an object, and `PyBuffer_Release()` when the buffer view can be released.

```c
int PyObject_AsCharBuffer(PyObject *obj, const char **buffer, Py_ssize_t *buffer_len)
```

Returns a pointer to a read-only memory location usable as character-based input. The `obj` argument must support the single-segment character buffer interface. On success, returns 0, sets `buffer` to the memory location and `buffer_len` to the buffer length. Returns -1 and sets a `TypeError` on error.

```c
int PyObject_AsReadBuffer(PyObject *obj, const void **buffer, Py_ssize_t *buffer_len)
```

Returns a pointer to a read-only memory location containing arbitrary data. The `obj` argument must support the single-segment readable buffer interface. On success, returns 0, sets `buffer` to the memory location and `buffer_len` to the buffer length. Returns -1 and sets a `TypeError` on error.
int **PyObject_CheckReadBuffer(PyObject *o)

Returns 1 if o supports the single-segment readable buffer interface. Otherwise returns 0.

int PyObject_AsWriteBuffer(PyObject *obj, void **buffer, Py_ssize_t *buffer_len)

Returns a pointer to a writable memory location. The obj argument must support the single-segment, character buffer interface. On success, returns 0, sets buffer to the memory location and buffer_len to the buffer length. Returns -1 and sets a TypeError on error.
Concrete Objects Layer

The functions in this chapter are specific to certain Python object types. Passing them an object of the wrong type is not a good idea; if you receive an object from a Python program and you are not sure that it has the right type, you must perform a type check first; for example, to check that an object is a dictionary, use `PyDict_Check()`. The chapter is structured like the “family tree” of Python object types.

**Warning:** While the functions described in this chapter carefully check the type of the objects which are passed in, many of them do not check for *NULL* being passed instead of a valid object. Allowing *NULL* to be passed in can cause memory access violations and immediate termination of the interpreter.
Fundamental Objects

This section describes Python type objects and the singleton object None.

- Type Objects
- The None Object
Numeric Objects

- Integer Objects
- Boolean Objects
- Floating Point Objects
- Complex Number Objects
  - Complex Numbers as C Structures
  - Complex Numbers as Python Objects
Sequence Objects

Generic operations on sequence objects were discussed in the previous chapter; this section deals with the specific kinds of sequence objects that are intrinsic to the Python language.

- **Bytes Objects**
- **Byte Array Objects**
  - Type check macros
  - Direct API functions
  - Macros
- **Unicode Objects and Codecs**
  - Unicode Objects
    - Unicode Type
    - Unicode Character Properties
    - Creating and accessing Unicode strings
    - Deprecated Py_UNICODE APIs
    - Locale Encoding
    - File System Encoding
    - wchar_t Support
    - UCS4 Support
  - Built-in Codecs
    - Generic Codecs
    - UTF-8 Codecs
    - UTF-32 Codecs
    - UTF-16 Codecs
    - UTF-7 Codecs
    - Unicode-Escape Codecs
    - Raw-Unicode-Escape Codecs
    - Latin-1 Codecs
    - ASCII Codecs
    - Character Map Codecs
    - MBCS codecs for Windows
- Methods & Slots
  - Methods and Slot Functions
- Tuple Objects
- Struct Sequence Objects
- List Objects
Container Objects

- Dictionary Objects
- Set Objects
Function Objects

- Function Objects
- Instance Method Objects
- Method Objects
- Cell Objects
- Code Objects
Other Objects

- File Objects
- Module Objects
  - Initializing C modules
    - Single-phase initialization
    - Multi-phase initialization
    - Low-level module creation functions
    - Support functions
  - Module lookup
- Iterator Objects
- Descriptor Objects
- Slice Objects
- MemoryView objects
- Weak Reference Objects
- Capsules
- Generator Objects
- Coroutine Objects
- DateTime Objects
Type Objects

PyTypeObject

The C structure of the objects used to describe built-in types.

PyObject* PyType_Type

This is the type object for type objects; it is the same object as type in the Python layer.

int PyType_Check(PyObject *o)

Return true if the object o is a type object, including instances of types derived from the standard type object. Return false in all other cases.

int PyType_CheckExact(PyObject *o)

Return true if the object o is a type object, but not a subtype of the standard type object. Return false in all other cases.

unsigned int PyType_ClearCache()

Clear the internal lookup cache. Return the current version tag.

long PyType_GetFlags(PyTypeObject* type)

Return the tp_flags member of type. This function is primarily meant for use with Py_LIMITED_API; the individual flag bits are guaranteed to be stable across Python releases, but access to tp_flags itself is not part of the limited API.

New in version 3.2.

void PyType_Modified(PyTypeObject *type)

Invalidate the internal lookup cache for the type and all of its
subtypes. This function must be called after any manual modification of the attributes or base classes of the type.

```c
int PyType_HasFeature(PyTypeObject *o, int feature)
```

Return true if the type object `o` sets the feature `feature`. Type features are denoted by single bit flags.

```c
int PyType_IS_GC(PyTypeObject *o)
```

Return true if the type object includes support for the cycle detector; this tests the type flag `Py_TPFLAGS_HAVE_GC`.

```c
int PyType_IsSubtype(PyTypeObject *a, PyTypeObject *b)
```

Return true if `a` is a subtype of `b`.

This function only checks for actual subtypes, which means that `__subclasscheck__()` is not called on `b`. Call `PyObject_IsSubclass()` to do the same check that `issubclass()` would do.

```c
PyObject* PyType_GenericAlloc(PyTypeObject *type, Py_ssize_t nitems)
```

*Return value: New reference.*

Generic handler for the `tp_alloc` slot of a type object. Use Python’s default memory allocation mechanism to allocate a new instance and initialize all its contents to `NULL`.

```c
PyObject* PyType_GenericNew(PyTypeObject *type, PyObject *args, PyObject *kwds)
```

*Return value: New reference.*

Generic handler for the `tp_new` slot of a type object. Create a new instance using the type’s `tp_alloc` slot.

```c
int PyType_Ready(PyTypeObject *type)
```
Finalize a type object. This should be called on all type objects to finish their initialization. This function is responsible for adding inherited slots from a type’s base class. Return 0 on success, or return -1 and sets an exception on error.

PyObject* **PyType_FromSpec**(PyType_Spec *spec)

Creates and returns a heap type object from the spec passed to the function.

PyObject* **PyType_FromSpecWithBases**(PyType_Spec *spec, PyObject *bases)

Creates and returns a heap type object from the spec. In addition to that, the created heap type contains all types contained by the bases tuple as base types. This allows the caller to reference other heap types as base types.

*New in version 3.3.*

void* **PyType_GetSlot**(PyTypeObject *type, int slot)

Return the function pointer stored in the given slot. If the result is NULL, this indicates that either the slot is NULL, or that the function was called with invalid parameters. Callers will typically cast the result pointer into the appropriate function type.

*New in version 3.4.*
The None Object

Note that the `PyTypeObject` for None is not directly exposed in the Python/C API. Since None is a singleton, testing for object identity (using `==` in C) is sufficient. There is no `PyNone_Check()` function for the same reason.

**PyObject* Py_None**

The Python None object, denoting lack of value. This object has no methods. It needs to be treated just like any other object with respect to reference counts.

**Py_RETURN_NONE**

Properly handle returning `Py_None` from within a C function (that is, increment the reference count of None and return it.)
Integer Objects

All integers are implemented as “long” integer objects of arbitrary size.

**PyLongObject**

This subtype of *PyObject* represents a Python integer object.

**PyTypeObject PyLong_Type**

This instance of *PyTypeObject* represents the Python integer type. This is the same object as *int* in the Python layer.

```c
int PyLong_Check(PyObject *p)
Return true if its argument is a PyLongObject or a subtype of PyLongObject.
```

```c
int PyLong_CheckExact(PyObject *p)
Return true if its argument is a PyLongObject, but not a subtype of PyLongObject.
```

```c
PyObject* PyLong_FromLong(long v)
Return a new PyLongObject object from v, or NULL on failure.
```

The current implementation keeps an array of integer objects for all integers between -5 and 256, when you create an int in that range you actually just get back a reference to the existing object. So it should be possible to change the value of 1. I suspect the behaviour of Python in this case is undefined. :-)

```c
PyObject* PyLong_FromUnsignedLong(unsigned long v)
```
Return a new `PyLongObject` object from a C `unsigned long`, or `NULL` on failure.

```c
PyObject* PyLong_FromSsize_t(Py_ssize_t v)
```
Return a new `PyLongObject` object from a C `Py_ssize_t`, or `NULL` on failure.

```c
PyObject* PyLong_FromSize_t(size_t v)
```
Return a new `PyLongObject` object from a C `size_t`, or `NULL` on failure.

```c
PyObject* PyLong_FromLongLong(PY_LONG_LONG v)
```
*Return value: New reference.*
Return a new `PyLongObject` object from a C `long long`, or `NULL` on failure.

```c
PyObject* PyLong_FromUnsignedLongLong(unsigned PY_LONG_LONG v)
```
*Return value: New reference.*
Return a new `PyLongObject` object from a C `unsigned long long`, or `NULL` on failure.

```c
PyObject* PyLong_FromDouble(double v)
```
*Return value: New reference.*
Return a new `PyLongObject` object from the integer part of `v`, or `NULL` on failure.

```c
PyObject* PyLong_FromString(const char *str, char **pend, int base)
```
*Return value: New reference.*
Return a new `PyLongObject` based on the string value in `str`, which is interpreted according to the radix in `base`. If `pend` is non-
NULL, *pend will point to the first character in str which follows the representation of the number. If base is 0, the radix will be determined based on the leading characters of str: if str starts with '0x' or '0X', radix 16 will be used; if str starts with '0o' or '00', radix 8 will be used; if str starts with '0b' or '0B', radix 2 will be used; otherwise radix 10 will be used. If base is not 0, it must be between 2 and 36, inclusive. Leading spaces are ignored. If there are no digits, ValueError will be raised.

PyObject* PyLong_FromUnicode(Py_UNICODE *u, Py_ssize_t length, int base)

Convert a sequence of Unicode digits to a Python integer value. The Unicode string is first encoded to a byte string using PyUnicode_EncodeDecimal() and then converted using PyLong_FromString().

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style Py_UNICODE API; please migrate to using PyLong_FromUnicodeObject().

PyObject* PyLong_FromUnicodeObject(PyObject *u, int base)

Convert a sequence of Unicode digits in the string u to a Python integer value. The Unicode string is first encoded to a byte string using PyUnicode_EncodeDecimal() and then converted using PyLong_FromString().

New in version 3.3.

PyObject* PyLong_FromVoidPtr(void *p)

Create a Python integer from the pointer \( p \). The pointer value can be retrieved from the resulting value using \( \text{PyLong_AsVoidPtr()} \).

long \( \text{PyLong_AsLong}(\text{PyObject } *\text{obj}) \)
Return a C long representation of \( \text{obj} \). If \( \text{obj} \) is not an instance of \( \text{PyLongObject} \), first call its \( \text{__int__()} \) method (if present) to convert it to a \( \text{PyLongObject} \).

Raise \( \text{OverflowError} \) if the value of \( \text{obj} \) is out of range for a long.

long \( \text{PyLong_AsLongAndOverflow}(\text{PyObject } *\text{obj}, \text{int } *\text{overflow}) \)
Return a C long representation of \( \text{obj} \). If \( \text{obj} \) is not an instance of \( \text{PyLongObject} \), first call its \( \text{__int__()} \) method (if present) to convert it to a \( \text{PyLongObject} \).

If the value of \( \text{obj} \) is greater than \( \text{LONG_MAX} \) or less than \( \text{LONG_MIN} \), set \( *\text{overflow} \) to 1 or -1, respectively, and return -1; otherwise, set \( *\text{overflow} \) to 0. If any other exception occurs set \( *\text{overflow} \) to 0 and return -1 as usual.

PY_LONG_LONG \( \text{PyLong_AsLongLong}(\text{PyObject } *\text{obj}) \)
Return a C long long representation of \( \text{obj} \). If \( \text{obj} \) is not an instance of \( \text{PyLongObject} \), first call its \( \text{__int__()} \) method (if present) to convert it to a \( \text{PyLongObject} \).

Raise \( \text{OverflowError} \) if the value of \( \text{obj} \) is out of range for a long.

PY_LONG_LONG
**PyLong_AsLongLongAndOverflow**(*PyObject* *obj*, int *overflow*)

Return a C long long representation of *obj*. If *obj* is not an instance of *PyLongObject*, first call its `__int__()` method (if present) to convert it to a *PyLongObject*.

If the value of *obj* is greater than PY_LLONG_MAX or less than PY_LLONG_MIN, set *overflow* to 1 or -1, respectively, and return -1; otherwise, set *overflow* to 0. If any other exception occurs set *overflow* to 0 and return -1 as usual.

*New in version 3.2.*

**Py_ssize_t PyLong_AsSsize_t**(*PyObject* *pylong*)

Return a C Py_ssize_t representation of *pylong*. *pylong* must be an instance of *PyLongObject*.

Raise *OverflowError* if the value of *pylong* is out of range for a *Py_ssize_t*.

**unsigned long PyLong_AsUnsignedLong**(*PyObject* *pylong*)

Return a C unsigned long representation of *pylong*. *pylong* must be an instance of *PyLongObject*.

Raise *OverflowError* if the value of *pylong* is out of range for an unsigned long.

**size_t PyLong_AsSize_t**(*PyObject* *pylong*)

Return a C size_t representation of *pylong*. *pylong* must be an instance of *PyLongObject*.

Raise *OverflowError* if the value of *pylong* is out of range for a
size_t.

unsigned PY_LONG_LONG
PyLong_AsUnsignedLongLong(PyObject *pylong)

Return a C unsigned PY_LONG_LONG representation of pylong. pylong must be an instance of PyLongObject.

Raise OverflowError if the value of pylong is out of range for an unsigned PY_LONG_LONG.

Changed in version 3.1: A negative pylong now raises OverflowError, not TypeError.

unsigned long PyLong_AsUnsignedLongMask(PyObject *obj)

Return a C unsigned long representation of obj. If obj is not an instance of PyLongObject, first call its __int__() method (if present) to convert it to a PyLongObject.

If the value of obj is out of range for an unsigned long, return the reduction of that value modulo ULONG_MAX + 1.

unsigned PY_LONG_LONG
PyLong_AsUnsignedLongLongMask(PyObject *obj)

Return a C unsigned long long representation of obj. If obj is not an instance of PyLongObject, first call its __int__() method (if present) to convert it to a PyLongObject.

If the value of obj is out of range for an unsigned long long, return the reduction of that value modulo PY_ULLONG_MAX + 1.

double PyLong_AsDouble(PyObject *pylong)

Return a C double representation of pylong. pylong must be an
instance of `PyLongObject`.

Raise `OverflowError` if the value of `pylong` is out of range for a double.

```c
void* PyLong_AsVoidPtr(PyObject *pylong)
```

Convert a Python integer `pylong` to a C void pointer. If `pylong` cannot be converted, an `OverflowError` will be raised. This is only assured to produce a usable void pointer for values created with `PyLong_FromVoidPtr()`.
Boolean Objects

Booleans in Python are implemented as a subclass of integers. There are only two booleans, Py_False and Py_True. As such, the normal creation and deletion functions don’t apply to booleans. The following macros are available, however.

```c
int PyBool_Check(PyObject *o)
    Return true if o is of type PyBool_Type.
```

```c
PyObject* Py_False
    The Python False object. This object has no methods. It needs to
    be treated just like any other object with respect to reference
    counts.
```

```c
PyObject* Py_True
    The Python True object. This object has no methods. It needs to
    be treated just like any other object with respect to reference
    counts.
```

```c
Py_RETURN_FALSE
    Return Py_False from a function, properly incrementing its
    reference count.
```

```c
Py_RETURN_TRUE
    Return Py_True from a function, properly incrementing its
    reference count.
```

```c
PyObject* PyBool_FromLong(long v)
    Return a new reference to Py_True or Py_False depending on
the truth value of \( v \).
Floating Point Objects

**PyFloatObject**
This subtype of `PyObject` represents a Python floating point object.

**PyTypeObject PyFloat_Type**
This instance of `PyTypeObject` represents the Python floating point type. This is the same object as `float` in the Python layer.

```c
int PyFloat_Check(PyObject *p)
```

Return true if its argument is a `PyFloatObject` or a subtype of `PyFloatObject`.

```c
int PyFloat_CheckExact(PyObject *p)
```

Return true if its argument is a `PyFloatObject`, but not a subtype of `PyFloatObject`.

```c
PyObject* PyFloat_FromString(PyObject *str)
```

*Return value: New reference.*
Create a `PyFloatObject` object based on the string value in `str`, or `NULL` on failure.

```c
PyObject* PyFloat_FromDouble(double v)
```

*Return value: New reference.*
Create a `PyFloatObject` object from `v`, or `NULL` on failure.

```c
double PyFloat_AsDouble(PyObject *pyfloat)
```

Return a C double representation of the contents of `pyfloat`. If `pyfloat` is not a Python floating point object but has a `__float__()` method, this method will first be called to convert
pyfloat into a float. This method returns -1.0 upon failure, so one should call PyErr_Occurred() to check for errors.

double PyFloat_AS_DOUBLE(PyObject *pyfloat)
    Return a C double representation of the contents of pyfloat, but without error checking.

PyObject* PyFloat_GetInfo(void)
    Return a structseq instance which contains information about the precision, minimum and maximum values of a float. It's a thin wrapper around the header file float.h.

double PyFloat_GetMax()
    Return the maximum representable finite float DBL_MAX as C double.

double PyFloat_GetMin()
    Return the minimum normalized positive float DBL_MIN as C double.

int PyFloat_ClearFreeList()
    Clear the float free list. Return the number of items that could not be freed.
Complex Number Objects

Python’s complex number objects are implemented as two distinct types when viewed from the C API: one is the Python object exposed to Python programs, and the other is a C structure which represents the actual complex number value. The API provides functions for working with both.
Complex Numbers as C Structures

Note that the functions which accept these structures as parameters and return them as results do so by value rather than dereferencing them through pointers. This is consistent throughout the API.

Py_complex
The C structure which corresponds to the value portion of a Python complex number object. Most of the functions for dealing with complex number objects use structures of this type as input or output values, as appropriate. It is defined as:

```
typedef struct {
    double real;
    double imag;
} Py_complex;
```

Py_complex _Py_c_sum(Py_complex left, Py_complex right)
Return the sum of two complex numbers, using the C Py_complex representation.

Py_complex _Py_c_diff(Py_complex left, Py_complex right)
Return the difference between two complex numbers, using the C Py_complex representation.

Py_complex _Py_c_neg(Py_complex complex)
Return the negation of the complex number complex, using the C Py_complex representation.

Py_complex _Py_c_prod(Py_complex left, Py_complex right)
Return the product of two complex numbers, using the C Py_complex representation.
**Py_complex _Py_c_quot(Py_complex dividend, Py_complex divisor)**

Return the quotient of two complex numbers, using the C Py_complex representation.

If *divisor* is null, this method returns zero and sets errno to EDOM.

**Py_complex _Py_c_pow(Py_complex num, Py_complex exp)**

Return the exponentiation of *num* by *exp*, using the C Py_complex representation.

If *num* is null and *exp* is not a positive real number, this method returns zero and sets errno to EDOM.
Complex Numbers as Python Objects

**PyComplexObject**
This subtype of *PyObject* represents a Python complex number object.

**PyTypeObject PyComplex_Type**
This instance of *PyTypeObject* represents the Python complex number type. It is the same object as *complex* in the Python layer.

`int PyComplex_Check(PyObject *p)`
Return true if its argument is a *PyComplexObject* or a subtype of *PyComplexObject*.

`int PyComplex_CheckExact(PyObject *p)`
Return true if its argument is a *PyComplexObject*, but not a subtype of *PyComplexObject*.

`PyObject* PyComplex_FromCComplex(Py_complex v)`
*Return value: New reference.*
Create a new Python complex number object from a C Py_complex value.

`PyObject* PyComplex_FromDoubles(double real, double imag)`
*Return value: New reference.*
Return a new *PyComplexObject* object from real and imag.

`double PyComplex_RealAsDouble(PyObject *op)`
Return the real part of op as a C double.

`double PyComplex_ImagAsDouble(PyObject *op)`
Return the imaginary part of \textit{op} as a C double.

\texttt{Py\_complex PyComplex\_AsCComplex(PyObject *op)}

Return the \texttt{Py\_complex} value of the complex number \textit{op}.

If \textit{op} is not a Python complex number object but has a \texttt{\_\_complex\_\_()} method, this method will first be called to convert \textit{op} to a Python complex number object. Upon failure, this method returns -1.0 as a real value.
Bytes Objects

These functions raise TypeError when expecting a bytes parameter and are called with a non-bytes parameter.

PyBytesObject
This subtype of PyObject represents a Python bytes object.

PyTypeObject PyBytes_Type
This instance of PyTypeObject represents the Python bytes type; it is the same object as bytes in the Python layer.

int PyBytes_Check(PyObject *o)
Return true if the object o is a bytes object or an instance of a subtype of the bytes type.

int PyBytes_CheckExact(PyObject *o)
Return true if the object o is a bytes object, but not an instance of a subtype of the bytes type.

PyObject* PyBytes_FromString(const char *v)
Return a new bytes object with a copy of the string v as value on success, and NULL on failure. The parameter v must not be NULL; it will not be checked.

PyObject* PyBytes_FromStringAndSize(const char *v, Py_ssize_t len)
Return a new bytes object with a copy of the string v as value and length len on success, and NULL on failure. If v is NULL, the contents of the bytes object are uninitialized.
PyObject* PyBytes_FromFormat(const char *format, ...)  
Take a C printf()-style format string and a variable number of arguments, calculate the size of the resulting Python bytes object and return a bytes object with the values formatted into it. The variable arguments must be C types and must correspond exactly to the format characters in the format string. The following format characters are allowed:

<table>
<thead>
<tr>
<th>Format Characters</th>
<th>Type</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>%%%</td>
<td>n/a</td>
<td>The literal % character.</td>
</tr>
<tr>
<td>%c</td>
<td>int</td>
<td>A single byte, represented as a C int.</td>
</tr>
<tr>
<td>%d</td>
<td>int</td>
<td>Exactly equivalent to printf(&quot;%d&quot;).</td>
</tr>
<tr>
<td>%u</td>
<td>unsigned int</td>
<td>Exactly equivalent to printf(&quot;%u&quot;).</td>
</tr>
<tr>
<td>%ld</td>
<td>long</td>
<td>Exactly equivalent to printf(&quot;%ld&quot;).</td>
</tr>
<tr>
<td>%lu</td>
<td>unsigned long</td>
<td>Exactly equivalent to printf(&quot;%lu&quot;).</td>
</tr>
<tr>
<td>%zd</td>
<td>Py_ssize_t</td>
<td>Exactly equivalent to printf(&quot;%zd&quot;).</td>
</tr>
<tr>
<td>%zu</td>
<td>size_t</td>
<td>Exactly equivalent to printf(&quot;%zu&quot;).</td>
</tr>
<tr>
<td>%i</td>
<td>int</td>
<td>Exactly equivalent to printf(&quot;%i&quot;).</td>
</tr>
<tr>
<td>%x</td>
<td>int</td>
<td>Exactly equivalent to printf(&quot;%x&quot;).</td>
</tr>
<tr>
<td>%s</td>
<td>char*</td>
<td>A null-terminated C character</td>
</tr>
</tbody>
</table>
The hex representation of a C pointer. Mostly equivalent to `printf("%p")` except that it is guaranteed to start with the literal 0x regardless of what the platform’s `printf` yields.

An unrecognized format character causes all the rest of the format string to be copied as-is to the result object, and any extra arguments discarded.

```
PyObject* PyBytes_FromFormatV(const char *format,
va_list vargs)
```
Identical to `PyBytes_FromFormat()` except that it takes exactly two arguments.

```
PyObject* PyBytes_FromObject(PyObject *o)
```
Return the bytes representation of object o that implements the buffer protocol.

```
Py_ssize_t PyBytes_Size(PyObject *o)
```
Return the length of the bytes in bytes object o.

```
Py_ssize_t PyBytes_GET_SIZE(PyObject *o)
```
Macro form of `PyBytes_Size()` but without error checking.

```
char* PyBytes_AsString(PyObject *o)
```
Return a pointer to the contents of o. The pointer refers to the internal buffer of o, which consists of `len(o) + 1` bytes. The last byte in the buffer is always null, regardless of whether there are any other null bytes. The data must not be modified in any way,
unless the object was just created using PyBytes_FromStringAndSize(NULL, size). It must not be deallocated. If o is not a bytes object at all, PyBytes_AsString() returns NULL and raises TypeError.

char* PyBytes_AS_STRING(PyObject *string)
Macro form of PyBytes_AsString() but without error checking.

int PyBytes_AsStringAndSize(PyObject *obj, char **buffer, Py_ssize_t *length)
Return the null-terminated contents of the object obj through the output variables buffer and length.

If length is NULL, the bytes object may not contain embedded null bytes; if it does, the function returns -1 and a TypeError is raised.

The buffer refers to an internal buffer of obj, which includes an additional null byte at the end (not counted in length). The data must not be modified in any way, unless the object was just created using PyBytes_FromStringAndSize(NULL, size). It must not be deallocated. If obj is not a bytes object at all, PyBytes_AsStringAndSize() returns -1 and raises TypeError.

void PyBytes_Concat(PyObject **bytes, PyObject *newpart)
Create a new bytes object in *bytes containing the contents of newpart appended to bytes; the caller will own the new reference. The reference to the old value of bytes will be stolen. If the new object cannot be created, the old reference to bytes will still be discarded and the value of *bytes will be set to NULL; the appropriate exception will be set.
void **PyBytes_ConcatAndDel**(*PyObject bytes, PyObject *newpart*)

Create a new bytes object in `bytes` containing the contents of `newpart` appended to `bytes`. This version decrements the reference count of `newpart`.

int **_PyBytes_Resize**(*PyObject **bytes, Py_ssize_t newsize*)

A way to resize a bytes object even though it is “immutable”. Only use this to build up a brand new bytes object; don’t use this if the bytes may already be known in other parts of the code. It is an error to call this function if the refcount on the input bytes object is not one. Pass the address of an existing bytes object as an lvalue (it may be written into), and the new size desired. On success, `bytes` holds the resized bytes object and 0 is returned; the address in `bytes` may differ from its input value. If the reallocation fails, the original bytes object at `bytes` is deallocated, `bytes` is set to `NULL`, a memory exception is set, and -1 is returned.
Byte Array Objects

**PyByteArrayObject**
This subtype of *PyObject* represents a Python bytearray object.

**PyTypeObject** *PyByteArray_Type*
This instance of *PyTypeObject* represents the Python bytearray type; it is the same object as *bytearray* in the Python layer.
Type check macros

int PyByteArray_Check(PyObject *o)
    Return true if the object o is a bytearray object or an instance of a subtype of the bytearray type.

int PyByteArray_CheckExact(PyObject *o)
    Return true if the object o is a bytearray object, but not an instance of a subtype of the bytearray type.
Direct API functions

**PyObject**\* **PyByteArray_FromObject**(PyObject *o)

Return a new bytearray object from any object, \( o \), that implements the buffer protocol.

**PyObject**\* **PyByteArray_FromStringAndSize**(const char *string, Py_ssize_t len)

Create a new bytearray object from \( string \) and its length, \( len \). On failure, \( NULL \) is returned.

**PyObject**\* **PyByteArray_Concat**(PyObject *a, PyObject *b)

Concat bytearrays \( a \) and \( b \) and return a new bytearray with the result.

**Py_ssize_t** **PyByteArray_Size**(PyObject *bytearray)

Return the size of \( bytearray \) after checking for a \( NULL \) pointer.

**char**\* **PyByteArray_AsString**(PyObject *bytearray)

Return the contents of \( bytearray \) as a char array after checking for a \( NULL \) pointer. The returned array always has an extra null byte appended.

**int** **PyByteArray_Resize**(PyObject \*bytearray, Py_ssize_t len)

Resize the internal buffer of \( bytearray \) to \( len \).
Macros

These macros trade safety for speed and they don’t check pointers.

```c
char* PyByteArray_AS_STRING(PyObject *bytearray)
Macro version of PyByteArray_AsString().
```

```c
Py_ssize_t PyByteArray_GET_SIZE(PyObject *bytearray)
Macro version of PyByteArray_Size().
```
Unicode Objects and Codecs
Unicode Objects

Since the implementation of PEP 393 in Python 3.3, Unicode objects internally use a variety of representations, in order to allow handling the complete range of Unicode characters while staying memory efficient. There are special cases for strings where all code points are below 128, 256, or 65536; otherwise, code points must be below 1114112 (which is the full Unicode range).

Py_UNICODE* and UTF-8 representations are created on demand and cached in the Unicode object. The Py_UNICODE* representation is deprecated and inefficient; it should be avoided in performance- or memory-sensitive situations.

Due to the transition between the old APIs and the new APIs, unicode objects can internally be in two states depending on how they were created:

- “canonical” unicode objects are all objects created by a non-deprecated unicode API. They use the most efficient representation allowed by the implementation.
- “legacy” unicode objects have been created through one of the deprecated APIs (typically PyUnicode_FromUnicode()) and only bear the Py_UNICODE* representation; you will have to call PyUnicode_READY() on them before calling any other API.

Unicode Type

These are the basic Unicode object types used for the Unicode implementation in Python:

Py_UCS4
**Py_UCS2**
**Py_UCS1**

These types are typedefs for unsigned integer types wide enough to contain characters of 32 bits, 16 bits and 8 bits, respectively. When dealing with single Unicode characters, use `Py_UCS4`.

*New in version 3.3.*

**Py_UNICODE**

This is a typedef of `wchar_t`, which is a 16-bit type or 32-bit type depending on the platform.

*Changed in version 3.3:* In previous versions, this was a 16-bit type or a 32-bit type depending on whether you selected a “narrow” or “wide” Unicode version of Python at build time.

**PyASCIIObject**
**PyCompactUnicodeObject**
**PyUnicodeObject**

These subtypes of `PyObject` represent a Python Unicode object. In almost all cases, they shouldn’t be used directly, since all API functions that deal with Unicode objects take and return `PyObject` pointers.

*New in version 3.3.*

**PyTypeObject** **PyUnicode_Type**

This instance of `PyTypeObject` represents the Python Unicode type. It is exposed to Python code as `str`.

The following APIs are really C macros and can be used to do fast checks and to access internal read-only data of Unicode objects:
int PyUnicode_Check(PyObject *o)

Return true if the object o is a Unicode object or an instance of a Unicode subtype.

int PyUnicode_CheckExact(PyObject *o)

Return true if the object o is a Unicode object, but not an instance of a subtype.

int PyUnicode_READY(PyObject *o)

Ensure the string object o is in the “canonical” representation. This is required before using any of the access macros described below.

Returns 0 on success and -1 with an exception set on failure, which in particular happens if memory allocation fails.

New in version 3.3.

Py_ssize_t PyUnicode_GET_LENGTH(PyObject *o)

Return the length of the Unicode string, in code points. o has to be a Unicode object in the “canonical” representation (not checked).

New in version 3.3.

Py_UCS1* PyUnicode_1BYTE_DATA(PyObject *o)
Py_UCS2* PyUnicode_2BYTE_DATA(PyObject *o)
Py_UCS4* PyUnicode_4BYTE_DATA(PyObject *o)

Return a pointer to the canonical representation cast to UCS1, UCS2 or UCS4 integer types for direct character access. No checks are performed if the canonical representation has the correct character size; use PyUnicode_KIND() to select the right macro. Make sure PyUnicode_READY() has been called before accessing this.
New in version 3.3.

PyUnicode WCHAR_KIND
PyUnicode 1BYTE_KIND
PyUnicode 2BYTE_KIND
PyUnicode 4BYTE_KIND

Return values of the PyUnicode_KIND() macro.

New in version 3.3.

int PyUnicode_KIND(PyObject *o)

Return one of the PyUnicode kind constants (see above) that indicate how many bytes per character this Unicode object uses to store its data. o has to be a Unicode object in the “canonical” representation (not checked).

New in version 3.3.

void* PyUnicode_DATA(PyObject *o)

Return a void pointer to the raw unicode buffer. o has to be a Unicode object in the “canonical” representation (not checked).

New in version 3.3.

void PyUnicode_WRITE(int kind, void *data, Py_ssize_t index, Py_UCS4 value)

Write into a canonical representation data (as obtained with PyUnicode_DATA()). This macro does not do any sanity checks and is intended for usage in loops. The caller should cache the kind value and data pointer as obtained from other macro calls. index is the index in the string (starts at 0) and value is the new code point value which should be written to that location.
New in version 3.3.

**Py_UNICODE** `PyUnicode_READ(int kind, void *data, Py_ssize_t index)`
Read a code point from a canonical representation `data` (as obtained with `PyUnicode_DATA()`). No checks or ready calls are performed.

New in version 3.3.

**Py_UNICODE** `PyUnicode_READ_CHAR(PyObject *o, Py_ssize_t index)`
Read a character from a Unicode object `o`, which must be in the "canonical" representation. This is less efficient than `PyUnicode_READ()` if you do multiple consecutive reads.

New in version 3.3.

**Py_UNICODE** `PyUnicode_MAX_CHAR_VALUE(PyObject *o)`
Return the maximum code point that is suitable for creating another string based on `o`, which must be in the "canonical" representation. This is always an approximation but more efficient than iterating over the string.

New in version 3.3.

`int PyUnicode_ClearFreeList()`
Clear the free list. Return the total number of freed items.

`Py_ssize_t PyUnicode_GET_SIZE(PyObject *o)`
Return the size of the deprecated `Py_UNICODE` representation, in code units (this includes surrogate pairs as 2 units). `o` has to be a Unicode object (not checked).
Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style Unicode API, please migrate to using PyUnicode_GET_LENGTH().

Py_ssize_t **PyUnicode_GET_DATA_SIZE**(PyObject *o)
Return the size of the deprecated Py_UNICODE representation in bytes. o has to be a Unicode object (not checked).

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style Unicode API, please migrate to using PyUnicode_GET_LENGTH().

Py_UNICODE* **PyUnicode_AS_UNICODE**(PyObject *o)
const char* **PyUnicode_AS_DATA**(PyObject *o)
Return a pointer to a Py_UNICODE representation of the object. The returned buffer is always terminated with an extra null code point. It may also contain embedded null code points, which would cause the string to be truncated when used in most C functions. The AS_DATA form casts the pointer to const char *. The o argument has to be a Unicode object (not checked).

Changed in version 3.3: This macro is now inefficient – because in many cases the Py_UNICODE representation does not exist and needs to be created – and can fail (return NULL with an exception set). Try to port the code to use the new PyUnicode_nBYTE_DATA() macros or use PyUnicode_WRITE() or PyUnicode_READ().

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style Unicode API, please migrate to using the PyUnicode_nBYTE_DATA() family of macros.
Unicode Character Properties

Unicode provides many different character properties. The most often needed ones are available through these macros which are mapped to C functions depending on the Python configuration.

```c
int Py_UNICODE_ISSPACE(Py_UNICODE ch)
    Return 1 or 0 depending on whether `ch` is a whitespace character.

int Py_UNICODE_ISLOWER(Py_UNICODE ch)
    Return 1 or 0 depending on whether `ch` is a lowercase character.

int Py_UNICODE_ISUPPER(Py_UNICODE ch)
    Return 1 or 0 depending on whether `ch` is an uppercase character.

int Py_UNICODE_ISTITLE(Py_UNICODE ch)
    Return 1 or 0 depending on whether `ch` is a titlecase character.

int Py_UNICODE_ISLINEBREAK(Py_UNICODE ch)
    Return 1 or 0 depending on whether `ch` is a linebreak character.

int Py_UNICODE_ISDECIMAL(Py_UNICODE ch)
    Return 1 or 0 depending on whether `ch` is a decimal character.

int Py_UNICODE_ISDIGIT(Py_UNICODE ch)
    Return 1 or 0 depending on whether `ch` is a digit character.

int Py_UNICODE_ISNUMERIC(Py_UNICODE ch)
    Return 1 or 0 depending on whether `ch` is a numeric character.

int Py_UNICODE_ISALPHA(Py_UNICODE ch)
    Return 1 or 0 depending on whether `ch` is an alphabetic character.
int Py_UNICODE_ISALNUM(Py_UNICODE ch)
    Return 1 or 0 depending on whether ch is an alphanumeric character.

int Py_UNICODE_ISPRINTABLE(Py_UNICODE ch)
    Return 1 or 0 depending on whether ch is a printable character. Nonprintable characters are those characters defined in the Unicode character database as “Other” or “Separator”, excepting the ASCII space (0x20) which is considered printable. (Note that printable characters in this context are those which should not be escaped when repr() is invoked on a string. It has no bearing on the handling of strings written to sys.stdout or sys.stderr.)

These APIs can be used for fast direct character conversions:

Py_UNICODE Py_UNICODE_TOLOWER(Py_UNICODE ch)
    Return the character ch converted to lower case.

      Deprecated since version 3.3: This function uses simple case mappings.

Py_UNICODE Py_UNICODE_TOUPPER(Py_UNICODE ch)
    Return the character ch converted to upper case.

      Deprecated since version 3.3: This function uses simple case mappings.

Py_UNICODE Py_UNICODE_TOTITLE(Py_UNICODE ch)
    Return the character ch converted to title case.

      Deprecated since version 3.3: This function uses simple case mappings.
int **Py_UNICODE_TODECIMAL**(Py_UNICODE ch)

Return the character **ch** converted to a decimal positive integer. Return -1 if this is not possible. This macro does not raise exceptions.

int **Py_UNICODE_TODIGIT**(Py_UNICODE ch)

Return the character **ch** converted to a single digit integer. Return -1 if this is not possible. This macro does not raise exceptions.

double **Py_UNICODE_TONUMERIC**(Py_UNICODE ch)

Return the character **ch** converted to a double. Return -1.0 if this is not possible. This macro does not raise exceptions.

These APIs can be used to work with surrogates:

**Py_UNICODE_IS_SURROGATE**(ch)

Check if **ch** is a surrogate (0xD800 <= **ch** <= 0xDBFF).

**Py_UNICODE_IS_HIGH_SURROGATE**(ch)

Check if **ch** is an high surrogate (0xD800 <= **ch** <= 0xDBFF).

**Py_UNICODE_IS_LOW_SURROGATE**(ch)

Check if **ch** is a low surrogate (0xDC00 <= **ch** <= 0xDFFF).

**Py_UNICODE_JOIN_SURROGATES**(high, low)

Join two surrogate characters and return a single Py_UCS4 value. **high** and **low** are respectively the leading and trailing surrogates in a surrogate pair.

Creating and accessing Unicode strings

To create Unicode objects and access their basic sequence properties,
use these APIs:

**PyObject* PyUnicode_New**(Py_ssize_t size, Py_UCS4 maxchar)

Create a new Unicode object. `maxchar` should be the true maximum code point to be placed in the string. As an approximation, it can be rounded up to the nearest value in the sequence 127, 255, 65535, 1114111.

This is the recommended way to allocate a new Unicode object. Objects created using this function are not resizable.

*New in version 3.3.*

**PyObject* PyUnicode_FromKindAndData**(int kind, const void *buffer, Py_ssize_t size)

Create a new Unicode object with the given `kind` (possible values are `PyUnicode_1BYTE_KIND` etc., as returned by `PyUnicode_KIND()`). The `buffer` must point to an array of `size` units of 1, 2 or 4 bytes per character, as given by the kind.

*New in version 3.3.*

**PyObject* PyUnicode_FromStringAndSize**(const char *u, Py_ssize_t size)

Create a Unicode object from the char buffer `u`. The bytes will be interpreted as being UTF-8 encoded. The buffer is copied into the new object. If the buffer is not `NULL`, the return value might be a shared object, i.e. modification of the data is not allowed.

If `u` is `NULL`, this function behaves like `PyUnicode_FromUnicode()` with the buffer set to `NULL`. This usage is deprecated in favor of `PyUnicode_New()`.
**PyObject** *PyUnicode_FromString*(const char *u)

Create a Unicode object from an UTF-8 encoded null-terminated char buffer u.

**PyObject** *PyUnicode_FromFormat*(const char *format, ...)

Take a C printf()-style format string and a variable number of arguments, calculate the size of the resulting Python unicode string and return a string with the values formatted into it. The variable arguments must be C types and must correspond exactly to the format characters in the format ASCII-encoded string. The following format characters are allowed:

<table>
<thead>
<tr>
<th>Format Characters</th>
<th>Type</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>n/a</td>
<td>The literal % character.</td>
</tr>
<tr>
<td>%c</td>
<td>int</td>
<td>A single character, represented as an C int.</td>
</tr>
<tr>
<td>%d</td>
<td>int</td>
<td>Exactly equivalent to printf(&quot;%d&quot;).</td>
</tr>
<tr>
<td>%u</td>
<td>unsigned int</td>
<td>Exactly equivalent to printf(&quot;%u&quot;).</td>
</tr>
<tr>
<td>%ld</td>
<td>long</td>
<td>Exactly equivalent to printf(&quot;%ld&quot;).</td>
</tr>
<tr>
<td>%li</td>
<td>long</td>
<td>Exactly equivalent to printf(&quot;%li&quot;).</td>
</tr>
<tr>
<td>%lu</td>
<td>unsigned long</td>
<td>Exactly equivalent to printf(&quot;%lu&quot;).</td>
</tr>
<tr>
<td>%lld</td>
<td>long long</td>
<td>Exactly equivalent to printf(&quot;%lld&quot;).</td>
</tr>
<tr>
<td>%lli</td>
<td>long long</td>
<td>Exactly equivalent to printf(&quot;%lli&quot;).</td>
</tr>
<tr>
<td>Format Code</td>
<td>Data Type</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>%llu</td>
<td>unsigned long long</td>
<td>Exactly equivalent to printf(&quot;%llu&quot;).</td>
</tr>
<tr>
<td>%zd</td>
<td>Py_ssize_t</td>
<td>Exactly equivalent to printf(&quot;%zd&quot;).</td>
</tr>
<tr>
<td>%zi</td>
<td>Py_ssize_t</td>
<td>Exactly equivalent to printf(&quot;%zi&quot;).</td>
</tr>
<tr>
<td>%zu</td>
<td>size_t</td>
<td>Exactly equivalent to printf(&quot;%zu&quot;).</td>
</tr>
<tr>
<td>%i</td>
<td>int</td>
<td>Exactly equivalent to printf(&quot;%i&quot;).</td>
</tr>
<tr>
<td>%x</td>
<td>int</td>
<td>Exactly equivalent to printf(&quot;%x&quot;).</td>
</tr>
<tr>
<td>%s</td>
<td>char*</td>
<td>A null-terminated C character array.</td>
</tr>
<tr>
<td>%p</td>
<td>void*</td>
<td>The hex representation of a C pointer. Mostly equivalent to printf(&quot;%p&quot;) except that it is guaranteed to start with the literal 0x regardless of what the platform’s printf yields.</td>
</tr>
<tr>
<td>%A</td>
<td>PyObject*</td>
<td>The result of calling ascii().</td>
</tr>
<tr>
<td>%U</td>
<td>PyObject*</td>
<td>A unicode object.</td>
</tr>
<tr>
<td>%V</td>
<td>PyObject*, char*</td>
<td>A unicode object (which may be NULL) and a null-terminated C character array as a second parameter (which will be used, if the first parameter is NULL).</td>
</tr>
<tr>
<td>%S</td>
<td>PyObject*</td>
<td>The result of calling PyObject_Str().</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>%R</td>
<td>PyObject*</td>
<td>The result of calling PyObject_Repr().</td>
</tr>
</tbody>
</table>

An unrecognized format character causes all the rest of the format string to be copied as-is to the result string, and any extra arguments discarded.

**Note:** The “%lld” and “%llu” format specifiers are only available when HAVE_LONG_LONG is defined.

**Note:** The width formatter unit is number of characters rather than bytes. The precision formatter unit is number of bytes for "%s" and "%V" (if the PyObject* argument is NULL), and a number of characters for "%A", "%U", "%S", "%R" and "%V" (if the PyObject* argument is not NULL).

*Changed in version 3.2:* Support for "%lld" and "%llu" added.

*Changed in version 3.3:* Support for "%li", "%lli" and "%zi" added.

*Changed in version 3.4:* Support width and precision formatter for "%s", "%A", "%U", "%V", "%S", "%R" added.

```c
PyObject* PyUnicode_FromFormatV(const char *format, va_list vars)

Identical to PyUnicode_FromFormat() except that it takes exactly two arguments.
```

```c
PyObject* PyUnicode_FromEncodedObject(PyObject *obj, const char *encoding, const char *errors)
```
Coerce an encoded object `obj` to an Unicode object and return a reference with incremented refcount.

`bytes`, `bytearray` and other `bytes-like objects` are decoded according to the given `encoding` and using the error handling defined by `errors`. Both can be `NULL` to have the interface use the default values (see the next section for details).

All other objects, including Unicode objects, cause a `TypeError` to be set.

The API returns `NULL` if there was an error. The caller is responsible for decref'ing the returned objects.

```c
Pyssize_t PyUnicode_GetLength(PyObject *unicode)
Return the length of the Unicode object, in code points.
New in version 3.3.
```

```c
int PyUnicode_CopyCharacters(PyObject *to, Pyssize_t to_start, PyObject *from, Pyssize_t from_start, Pyssize_t how_many)
Copy characters from one Unicode object into another. This function performs character conversion when necessary and falls back to `memcpy()` if possible. Returns -1 and sets an exception on error, otherwise returns 0.
New in version 3.3.
```

```c
Pyssize_t PyUnicode_Fill(PyObject *unicode, Pyssize_t start, Pyssize_t length, Py_UCS4 fill_char)
Fill a string with a character: write `fill_char` into
```
unicode[start:start+length].

Fail if fill_char is bigger than the string maximum character, or if the string has more than 1 reference.

Return the number of written character, or return -1 and raise an exception on error.

New in version 3.3.

```c
int PyUnicode_WriteChar(PyObject *unicode,
                        Py_ssize_t index, Py_UCS4 character)
```

Write a character to a string. The string must have been created through `PyUnicode_New()`. Since Unicode strings are supposed to be immutable, the string must not be shared, or have been hashed yet.

This function checks that `unicode` is a Unicode object, that the index is not out of bounds, and that the object can be modified safely (i.e. that it its reference count is one), in contrast to the macro version `PyUnicode_WRITE_CHAR()`.

New in version 3.3.

```c
Py_UCS4 PyUnicode_ReadChar(PyObject *unicode,
                            Py_ssize_t index)
```

Read a character from a string. This function checks that `unicode` is a Unicode object and the index is not out of bounds, in contrast to the macro version `PyUnicode_READ_CHAR()`.

New in version 3.3.

```c
PyObject* PyUnicode_Substring(PyObject *str,
                               Py_ssize_t start, Py_ssize_t end)
```
Return a substring of `str`, from character index `start` (included) to character index `end` (excluded). Negative indices are not supported.

*New in version 3.3.*

```c
Py_UCS4* PyUnicode_AsUCS4(PyObject *u, Py_UCS4 *buffer, Py_ssize_t buflen, int copy_null)
```
Copy the string `u` into a UCS4 buffer, including a null character, if `copy_null` is set. Returns `NULL` and sets an exception on error (in particular, a `ValueError` if `buflen` is smaller than the length of `u`). `buffer` is returned on success.

*New in version 3.3.*

```c
Py_UCS4* PyUnicode_AsUCS4Copy(PyObject *u)
```
Copy the string `u` into a new UCS4 buffer that is allocated using `PyMem_Malloc()`. If this fails, `NULL` is returned with a `MemoryError` set. The returned buffer always has an extra null code point appended.

*New in version 3.3.*

**Deprecated Py_UNICODE APIs**

*Deprecated since version 3.3, will be removed in version 4.0.*

These API functions are deprecated with the implementation of PEP 393. Extension modules can continue using them, as they will not be removed in Python 3.x, but need to be aware that their use can now cause performance and memory hits.

```c
PyObject* PyUnicode_FromUnicode(const Py_UNICODE *u,
```


Py

size_t

size)

Create a Unicode object from the Py_UNICODE buffer \( u \) of the given size. \( u \) may be NULL which causes the contents to be undefined. It is the user's responsibility to fill in the needed data. The buffer is copied into the new object.

If the buffer is not NULL, the return value might be a shared object. Therefore, modification of the resulting Unicode object is only allowed when \( u \) is NULL.

If the buffer is NULL, PyUnicode_READY() must be called once the string content has been filled before using any of the access macros such as PyUnicode_KIND().

Please migrate to using PyUnicode_FromKindAndData() or PyUnicode_New().

Py_UNICODE* PyUnicode_AsUnicode(PyObject *unicode)

Return a read-only pointer to the Unicode object's internal Py_UNICODE buffer, or NULL on error. This will create the Py_UNICODE* representation of the object if it is not yet available. The buffer is always terminated with an extra null code point. Note that the resulting Py_UNICODE string may also contain embedded null code points, which would cause the string to be truncated when used in most C functions.

Please migrate to using PyUnicode_AsUCS4(), PyUnicode_Substring(), PyUnicode_ReadChar() or similar new APIs.

PyObject*

PyUnicode_TransformDecimalToASCII(Py_UNICODE*s,
Py_ssize_t size)
    Create a Unicode object by replacing all decimal digits in
    Py_UNICODE buffer of the given size by ASCII digits 0–9 according
to their decimal value. Return NULL if an exception occurs.

Py_UNICODE*
PyUnicode_AsUnicodeAndSize(PyObject *unicode,
Py_ssize_t *size)
    Like PyUnicode_AsUnicode(), but also saves the
    Py_UNICODE() array length (excluding the extra null terminator) in
    size. Note that the resulting Py_UNICODE* string may contain
    embedded null code points, which would cause the string to be
    truncated when used in most C functions.

    New in version 3.3.

Py_UNICODE*
PyUnicode_AsUnicodeCopy(PyObject *unicode)
    Create a copy of a Unicode string ending with a null code point.
    Return NULL and raise a MemoryError exception on memory
    allocation failure, otherwise return a new allocated buffer (use
    PyMem_Free() to free the buffer). Note that the resulting
    Py_UNICODE* string may contain embedded null code points,
    which would cause the string to be truncated when used in most C
    functions.

    New in version 3.2.

    Please migrate to using PyUnicode_AsUCS4Copy() or similar
    new APIs.

Py_ssize_t PyUnicode_GetSize(PyObject *unicode)
    Return the size of the deprecated Py_UNICODE representation, in
code units (this includes surrogate pairs as 2 units).

Please migrate to using `PyUnicode_GetLength()`.

**PyObject**\* **PyUnicode_FromObject**(**PyObject** \*obj)

*Return value: New reference.*
Shortcut for `PyUnicode_FromEncodedObject(obj, NULL, "strict")` which is used throughout the interpreter whenever coercion to Unicode is needed.

**Locale Encoding**

The current locale encoding can be used to decode text from the operating system.

**PyObject**\* **PyUnicode_DecodeLocaleAndSize**(const char \*str, Py_ssize_t \*len, const char \*errors)

Decode a string from the current locale encoding. The supported error handlers are "strict" and "surrogateescape" (PEP 383). The decoder uses "strict" error handler if `errors` is NULL. `str` must end with a null character but cannot contain embedded null characters.

Use `PyUnicode_DecodeFSDefaultAndSize()` to decode a string from `Py_FileSystemDefaultEncoding` (the locale encoding read at Python startup).

**See also:** The `Py_DecodeLocale()` function.

*New in version 3.3.*

**PyObject**\* **PyUnicode_DecodeLocale**(const char \*str, const
char *errors)

Similar to `PyUnicode_DecodeLocaleAndSize()`, but compute the string length using `strlen()`.

*New in version 3.3.*

**PyObject** * PyUnicode_EncodeLocale**(PyObject *unicode, const char *errors)**

Encode a Unicode object to the current locale encoding. The supported error handlers are "strict" and "surrogateescape" (PEP 383). The encoder uses "strict" error handler if `errors` is NULL. Return a `bytes` object. `str` cannot contain embedded null characters.

Use `PyUnicode_EncodeFSDefault()` to encode a string to `Py_FileSystemDefaultEncoding` (the locale encoding read at Python startup).

*See also:* The `Py_EncodeLocale()` function.

*New in version 3.3.*

**File System Encoding**

To encode and decode file names and other environment strings, `Py_FileSystemEncoding` should be used as the encoding, and "surrogateescape" should be used as the error handler (PEP 383). To encode file names during argument parsing, the "0&" converter should be used, passing `PyUnicode_FSCConverter()` as the conversion function:

```c
int PyUnicode_FSCConverter(PyObject* obj, void* result)
```
ParseTuple converter: encode `str` objects to `bytes` using `PyUnicode_EncodeFSDefault()`; `bytes` objects are output as-is. `result` must be a `PyBytesObject*` which must be released when it is no longer used.

*New in version 3.1.*

To decode file names during argument parsing, the "0&" converter should be used, passing `PyUnicode_FSDecoder()` as the conversion function:

```c
int PyUnicode_FSDecoder(PyObject* obj, void* result)
```

ParseTuple converter: decode `bytes` objects to `str` using `PyUnicode_DecodeFSDefaultAndSize()`; `str` objects are output as-is. `result` must be a `PyUnicodeObject*` which must be released when it is no longer used.

*New in version 3.2.*

```c
PyObject* PyUnicode_DecodeFSDefaultAndSize(const char *s, Py_ssize_t size)
```

Decode a string using `Py_FileSystemDefaultEncoding` and the "surrogateescape" error handler, or "strict" on Windows.

If `Py_FileSystemDefaultEncoding` is not set, fall back to the locale encoding.

`Py_FileSystemDefaultEncoding` is initialized at startup from the locale encoding and cannot be modified later. If you need to decode a string from the current locale encoding, use `PyUnicode_DecodeLocaleAndSize()`.
See also: The Py_DecodeLocale() function.

Changed in version 3.2: Use "strict" error handler on Windows.

PyObject* PyUnicode_DecodeFSDefault(const char *s)
Decode a null-terminated string using Py_FileSystemDefaultEncoding and the "surrogateescape" error handler, or "strict" on Windows.

If Py_FileSystemDefaultEncoding is not set, fall back to the locale encoding.

Use PyUnicode_DecodeFSDefaultAndSize() if you know the string length.

Changed in version 3.2: Use "strict" error handler on Windows.

PyObject* PyUnicode_EncodeFSDefault(PyObject *unicode)
Encode a Unicode object to Py_FileSystemDefaultEncoding with the "surrogateescape" error handler, or "strict" on Windows, and return bytes. Note that the resulting bytes object may contain null bytes.

If Py_FileSystemDefaultEncoding is not set, fall back to the locale encoding.

Py_FileSystemDefaultEncoding is initialized at startup from the locale encoding and cannot be modified later. If you need to encode a string to the current locale encoding, use PyUnicode_EncodeLocale().

See also: The Py_EncodeLocale() function.
New in version 3.2.

wchar_t Support

wchar_t support for platforms which support it:

PyObject* PyUnicode_FromWideChar(const wchar_t *w, Py_ssize_t size)

Create a Unicode object from the wchar_t buffer w of the given size. Passing -1 as the size indicates that the function must itself compute the length, using wcslen. Return NULL on failure.

Py_ssize_t
PyUnicode_AsWideChar(PyUnicodeObject *unicode, wchar_t *w, Py_ssize_t size)

Copy the Unicode object contents into the wchar_t buffer w. At most size wchar_t characters are copied (excluding a possibly trailing null termination character). Return the number of wchar_t characters copied or -1 in case of an error. Note that the resulting wchar_t* string may or may not be null-terminated. It is the responsibility of the caller to make sure that the wchar_t* string is null-terminated in case this is required by the application. Also, note that the wchar_t* string might contain null characters, which would cause the string to be truncated when used with most C functions.

wchar_t* PyUnicode_AsWideCharString(PyObject *unicode, Py_ssize_t *size)

Convert the Unicode object to a wide character string. The output string always ends with a null character. If size is not NULL, write the number of wide characters (excluding the trailing null
termination character) into *size.

Returns a buffer allocated by PyMem_Alloc() (use PyMem_Free() to free it) on success. On error, returns NULL, *size is undefined and raises a MemoryError. Note that the resulting wchar_t string might contain null characters, which would cause the string to be truncated when used with most C functions.

*New in version 3.2.*

**UCS4 Support**

*New in version 3.3.*

size_t Py_UCS4_strlen(const Py_UCS4 *u)

Py_UCS4* Py_UCS4_strcpy(Py_UCS4 *s1, const Py_UCS4 *s2)

Py_UCS4* Py_UCS4_strncpy(Py_UCS4 *s1, const Py_UCS4 *s2, size_t n)

Py_UCS4* Py_UCS4_strcat(Py_UCS4 *s1, const Py_UCS4 *s2)

int Py_UCS4_strcmp(const Py_UCS4 *s1, const Py_UCS4 *s2)

int Py_UCS4_strncmp(const Py_UCS4 *s1, const Py_UCS4 *s2, size_t n)

Py_UCS4* Py_UCS4_strchr(const Py_UCS4 *s, Py_UCS4 c)

Py_UCS4* Py_UCS4_strrchr(const Py_UCS4 *s, Py_UCS4 c)

These utility functions work on strings of Py_UCS4 characters and otherwise behave like the C standard library functions with the same name.
Built-in Codecs

Python provides a set of built-in codecs which are written in C for speed. All of these codecs are directly usable via the following functions.

Many of the following APIs take two arguments encoding and errors, and they have the same semantics as the ones of the built-in `str()` string object constructor.

Setting encoding to `NULL` causes the default encoding to be used which is ASCII. The file system calls should use `PyUnicode_FSConverter()` for encoding file names. This uses the variable `Py_FileSystemDefaultEncoding` internally. This variable should be treated as read-only: on some systems, it will be a pointer to a static string, on others, it will change at run-time (such as when the application invokes setlocale).

Error handling is set by errors which may also be set to `NULL` meaning to use the default handling defined for the codec. Default error handling for all built-in codecs is “strict” (`ValueError` is raised).

The codecs all use a similar interface. Only deviation from the following generic ones are documented for simplicity.

Generic Codecs

These are the generic codec APIs:

```c
PyObject* PyUnicode_Decode(const char *s, Py_ssize_t size, const char *encoding, const char *errors)
```

Create a Unicode object by decoding size bytes of the encoded string s. *encoding* and *errors* have the same meaning as the parameters of the same name in the *str()* built-in function. The codec to be used is looked up using the Python codec registry. Return *NULL* if an exception was raised by the codec.

`PyObject* PyUnicode_AsEncodedString(PyObject *unicode, const char *encoding, const char *errors)`

*Return value: New reference.*

Encode a Unicode object and return the result as Python bytes object. *encoding* and *errors* have the same meaning as the parameters of the same name in the Unicode *encode()* method. The codec to be used is looked up using the Python codec registry. Return *NULL* if an exception was raised by the codec.

`PyObject* PyUnicode_Encode(const Py_UNICODE *s, Py_ssize_t size, const char *encoding, const char *errors)`

*Return value: New reference.*

Encode the Py_UNICODE buffer s of the given size and return a Python bytes object. *encoding* and *errors* have the same meaning as the parameters of the same name in the Unicode *encode()* method. The codec to be used is looked up using the Python codec registry. Return *NULL* if an exception was raised by the codec.

*Deprecated since version 3.3, will be removed in version 4.0:* Part of the old-style Py_UNICODE API; please migrate to using PyUnicode_AsEncodedString().

**UTF-8 Codecs**

These are the UTF-8 codec APIs:
PyObject* PyUnicode_DecodeUTF8(const char *s,
Py_ssize_t size, const char *errors)

*Return value: New reference.*

Create a Unicode object by decoding size bytes of the UTF-8 encoded string s. Return NULL if an exception was raised by the codec.

PyObject* PyUnicode_DecodeUTF8Stateful(const char *s,
Py_ssize_t size, const char *errors, Py_ssize_t *consumed)

*Return value: New reference.*

If consumed is NULL, behave like PyUnicode_DecodeUTF8(). If consumed is not NULL, trailing incomplete UTF-8 byte sequences will not be treated as an error. Those bytes will not be decoded and the number of bytes that have been decoded will be stored in consumed.

PyObject* PyUnicode_AsUTF8String(PyObject *unicode)

*Return value: New reference.*

Encode a Unicode object using UTF-8 and return the result as Python bytes object. Error handling is “strict”. Return NULL if an exception was raised by the codec.

char* PyUnicode_AsUTF8AndSize(PyObject *unicode,
Py_ssize_t *size)

Return a pointer to the UTF-8 encoding of the Unicode object, and store the size of the encoded representation (in bytes) in size. The size argument can be NULL; in this case no size will be stored. The returned buffer always has an extra null byte appended (not included in size), regardless of whether there are any other null code points.

In the case of an error, NULL is returned with an exception set and
no size is stored.

This caches the UTF-8 representation of the string in the Unicode object, and subsequent calls will return a pointer to the same buffer. The caller is not responsible for deallocating the buffer.

*New in version 3.3.*

```c
char* PyUnicode_AsUTF8(PyObject *unicode)
    As PyUnicode_AsUTF8AndSize(), but does not store the size.

*New in version 3.3.*

```c
PyObject* PyUnicode_EncodeUTF8(const Py_UNICODE*s, Py_ssize_t size, const char *errors)
    *Return value: New reference.*
    Encode the Py_UNICODE buffer s of the given size using UTF-8 and return a Python bytes object. Return NULL if an exception was raised by the codec.

*Deprecated since version 3.3, will be removed in version 4.0:* Part of the old-style Py_UNICODE API; please migrate to using PyUnicode_AsUTF8String() or PyUnicode_AsUTF8AndSize().

**UTF-32 Codecs**

These are the UTF-32 codec APIs:

```c
PyObject* PyUnicode_DecodeUTF32(const char *s, Py_ssize_t size, const char *errors, int *byteorder)
    Decode size bytes from a UTF-32 encoded buffer string and return the corresponding Unicode object. errors (if non-NULL) defines the
error handling. It defaults to “strict”.

If `byteorder` is non-NULL, the decoder starts decoding using the given byte order:

```
*byteorder == -1: little endian
*byteorder == 0: native order
*byteorder == 1: big endian
```

If `*byteorder` is zero, and the first four bytes of the input data are a byte order mark (BOM), the decoder switches to this byte order and the BOM is not copied into the resulting Unicode string. If `*byteorder` is -1 or 1, any byte order mark is copied to the output.

After completion, `*byteorder` is set to the current byte order at the end of input data.

If `byteorder` is NULL, the codec starts in native order mode.

Return `NULL` if an exception was raised by the codec.

```python
PyObject* PyUnicode_DecodeUTF32Stateful(const char *s, Py_ssize_t size, const char *errors, int *byteorder, Py_ssize_t *consumed)
```

If `consumed` is `NULL`, behave like `PyUnicode_DecodeUTF32()`. If `consumed` is not `NULL`, `PyUnicode_DecodeUTF32Stateful()` will not treat trailing incomplete UTF-32 byte sequences (such as a number of bytes not divisible by four) as an error. Those bytes will not be decoded and the number of bytes that have been decoded will be stored in `consumed`.

```python
PyObject* PyUnicode_AsUTF32String(PyObject *unicode)
```
Return a Python byte string using the UTF-32 encoding in native byte order. The string always starts with a BOM mark. Error handling is “strict”. Return NULL if an exception was raised by the codec.

```c
PyObject* PyUnicode_EncodeUTF32(const Py_UNICODE *s, Py_ssize_t size, const char *errors, int byteorder)
```

Return a Python bytes object holding the UTF-32 encoded value of the Unicode data in s. Output is written according to the following byte order:

- `byteorder == -1`: little endian
- `byteorder == 0`: native byte order (writes a BOM mark)
- `byteorder == 1`: big endian

If byteorder is 0, the output string will always start with the Unicode BOM mark (U+FEFF). In the other two modes, no BOM mark is prepended.

If `Py_UNICODE_WIDE` is not defined, surrogate pairs will be output as a single code point.

Return NULL if an exception was raised by the codec.

*Deprecated since version 3.3, will be removed in version 4.0:* Part of the old-style `Py_UNICODE` API; please migrate to using `PyUnicode_AsUTF32String()`.

**UTF-16 Codecs**

These are the UTF-16 codec APIs:

```c
PyObject* PyUnicode_DecodeUTF16(const char *s,
```
Py_ssize_t size, const char *errors, int *byteorder)


Decode size bytes from a UTF-16 encoded buffer string and return the corresponding Unicode object. errors (if non-NULL) defines the error handling. It defaults to “strict”.

If byteorder is non-NULL, the decoder starts decoding using the given byte order:

*byteorder == -1: little endian
*byteorder == 0: native order
*byteorder == 1: big endian

If *byteorder is zero, and the first two bytes of the input data are a byte order mark (BOM), the decoder switches to this byte order and the BOM is not copied into the resulting Unicode string. If *byteorder is -1 or 1, any byte order mark is copied to the output (where it will result in either a \ufeff or a \ufffe character).

After completion, *byteorder is set to the current byte order at the end of input data.

If byteorder is NULL, the codec starts in native order mode.

Return NULL if an exception was raised by the codec.

PyObject* PyUnicode_DecodeUTF16Stateful(const char *s,
Py_ssize_t size, const char *errors, int *byteorder,
Py_ssize_t *consumed)


If consumed is NULL, behave like PyUnicode_DecodeUTF16().

If consumed is not NULL,
PyUnicode_DecodeUTF16Stateful() will not treat trailing incomplete UTF-16 byte sequences (such as an odd number of bytes or a split surrogate pair) as an error. Those bytes will not be decoded and the number of bytes that have been decoded will be stored in consumed.

PyObject* PyUnicode_AsUTF16String(PyObject *unicode)

Return a Python byte string using the UTF-16 encoding in native byte order. The string always starts with a BOM mark. Error handling is “strict”. Return NULL if an exception was raised by the codec.

PyObject* PyUnicode_EncodeUTF16(const Py_UNICODE *s, Py_ssize_t size, const char *errors, int byteorder)

Return a Python bytes object holding the UTF-16 encoded value of the Unicode data in s. Output is written according to the following byte order:

| byteorder == -1: little endian |
| byteorder == 0: native byte order (writes a BOM mark) |
| byteorder == 1: big endian |

If byteorder is 0, the output string will always start with the Unicode BOM mark (U+FEFF). In the other two modes, no BOM mark is prepended.

If Py_UNICODE_WIDE is defined, a single Py_UNICODE value may get represented as a surrogate pair. If it is not defined, each Py_UNICODE values is interpreted as an UCS-2 character.
Return *NULL* if an exception was raised by the codec.

*Deprecated since version 3.3, will be removed in version 4.0:* Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsUTF16String()*.

**UTF-7 Codecs**

These are the UTF-7 codec APIs:

**PyObject**\* **PyUnicode_DecodeUTF7** (const char \*s, Py_ssize_t size, const char \*errors)

Create a Unicode object by decoding *size* bytes of the UTF-7 encoded string *s*. Return *NULL* if an exception was raised by the codec.

**PyObject**\* **PyUnicode_DecodeUTF7Stateful** (const char \*s, Py_ssize_t size, const char \*errors, Py_ssize_t \*consumed)

If *consumed* is NULL, behave like **PyUnicode_DecodeUTF7()**. If *consumed* is not NULL, trailing incomplete UTF-7 base-64 sections will not be treated as an error. Those bytes will not be decoded and the number of bytes that have been decoded will be stored in *consumed*.

**PyObject**\* **PyUnicode_EncodeUTF7** (const Py_UNICODE \*s, Py_ssize_t size, int base64SetO, int base64WhiteSpace, const char \*errors)

Encode the *Py_UNICODE* buffer of the given size using UTF-7 and return a Python bytes object. Return *NULL* if an exception was raised by the codec.

If *base64SetO* is nonzero, “Set O” (punctuation that has no
otherwise special meaning) will be encoded in base-64. If
\texttt{base64WhiteSpace} is nonzero, whitespace will be encoded in
base-64. Both are set to zero for the Python “utf-7” codec.

\textit{Deprecated since version 3.3, will be removed in version 4.0}: Part
of the old-style \texttt{Py\_UNICODE} API.

\section*{Unicode-Escape Codecs}

These are the “Unicode Escape” codec APIs:

\begin{verbatim}
PyObject* \texttt{PyUnicode\_DecodeUnicodeEscape} (const char *s,
Py\_ssize\_t size, const char *errors)
  \textit{Return value: New reference.}
  Create a Unicode object by decoding size bytes of the Unicode-
  Escape encoded string \texttt{s}. Return NULL if an exception was
  raised by the codec.

PyObject* \texttt{PyUnicode\_AsUnicodeEscapeString} (PyObject *unicode)
  \textit{Return value: New reference.}
  Encode a Unicode object using Unicode-Escape and return the
  result as Python string object. Error handling is “strict”. Return
  NULL if an exception was raised by the codec.

PyObject* \texttt{PyUnicode\_EncodeUnicodeEscape} (const
Py\_UNICODE *s, Py\_ssize\_t size)
  \textit{Return value: New reference.}
  Encode the \texttt{Py\_UNICODE} buffer of the given size using Unicode-
  Escape and return a Python string object. Return NULL if an
  exception was raised by the codec.
\end{verbatim}

\textit{Deprecated since version 3.3, will be removed in version 4.0}: Part
of the old-style `Py_UNICODE` API; please migrate to using `PyUnicode_AsUnicodeEscapeString()`.

Raw-Unicode-Escape Codecs

These are the “Raw Unicode Escape” codec APIs:

**PyObject* `PyUnicode_DecodeRawUnicodeEscape`**(const char *s, Py_ssize_t size, const char *errors)

*Return value: New reference.*
Create a Unicode object by decoding `size` bytes of the Raw-Unicode-Escape encoded string `s`. Return `NULL` if an exception was raised by the codec.

**PyObject* `PyUnicode_AsRawUnicodeEscapeString`**(PyObject *unicode)

*Return value: New reference.*
Encode a Unicode object using Raw-Unicode-Escape and return the result as Python string object. Error handling is “strict”. Return `NULL` if an exception was raised by the codec.

**PyObject* `PyUnicode_EncodeRawUnicodeEscape`**(const Py_UNICODE *s, Py_ssize_t size, const char *errors)

*Return value: New reference.*
Encode the `Py_UNICODE` buffer of the given `size` using Raw-Unicode-Escape and return a Python string object. Return `NULL` if an exception was raised by the codec.

*Deprecated since version 3.3, will be removed in version 4.0:* Part of the old-style `Py_UNICODE` API; please migrate to using `PyUnicode_AsRawUnicodeEscapeString()`.
Latin-1 Codecs

These are the Latin-1 codec APIs: Latin-1 corresponds to the first 256 Unicode ordinals and only these are accepted by the codecs during encoding.

**PyObject** `PyUnicode_DecodeLatin1`(const char *s, Py_ssize_t size, const char *errors)

*Return value: New reference.*
Create a Unicode object by decoding size bytes of the Latin-1 encoded string s. Return `NULL` if an exception was raised by the codec.

**PyObject** `PyUnicode_AsLatin1String`(PyObject *unicode)

*Return value: New reference.*
Encode a Unicode object using Latin-1 and return the result as Python bytes object. Error handling is “strict”. Return `NULL` if an exception was raised by the codec.

**PyObject** `PyUnicode_EncodeLatin1`(const Py_UNICODE *s, Py_ssize_t size, const char *errors)

*Return value: New reference.*
Encode the Py_UNICODE buffer of the given size using Latin-1 and return a Python bytes object. Return `NULL` if an exception was raised by the codec.

*Deprecated since version 3.3, will be removed in version 4.0:* Part of the old-style Py_UNICODE API; please migrate to using `PyUnicode_AsLatin1String()`.

ASCII Codecs
These are the ASCII codec APIs. Only 7-bit ASCII data is accepted. All other codes generate errors.

**PyObject** `PyUnicode_DecodeASCII`(const char *s, Py_ssize_t size, const char *errors)

*Return value: New reference.*
Create a Unicode object by decoding size bytes of the ASCII encoded string s. Return `NULL` if an exception was raised by the codec.

**PyObject** `PyUnicode_AsASCIIString`(PyObject *unicode)

*Return value: New reference.*
Encode a Unicode object using ASCII and return the result as Python bytes object. Error handling is “strict”. Return `NULL` if an exception was raised by the codec.

**PyObject** `PyUnicode_EncodeASCII`(const Py_UNICODE *s, Py_ssize_t size, const char *errors)

*Return value: New reference.*
Encode the Py_UNICODE buffer of the given size using ASCII and return a Python bytes object. Return `NULL` if an exception was raised by the codec.

*Deprecated since version 3.3, will be removed in version 4.0:* Part of the old-style Py_UNICODE API; please migrate to using PyUnicode_AsASCIIString().

**Character Map Codecs**

This codec is special in that it can be used to implement many different codecs (and this is in fact what was done to obtain most of the standard codecs included in the encodings package). The codec
uses mapping to encode and decode characters.

Decoding mappings must map single string characters to single Unicode characters, integers (which are then interpreted as Unicode ordinals) or None (meaning “undefined mapping” and causing an error).

Encoding mappings must map single Unicode characters to single string characters, integers (which are then interpreted as Latin-1 ordinals) or None (meaning “undefined mapping” and causing an error).

The mapping objects provided must only support the __getitem__ mapping interface.

If a character lookup fails with a LookupError, the character is copied as-is meaning that its ordinal value will be interpreted as Unicode or Latin-1 ordinal resp. Because of this, mappings only need to contain those mappings which map characters to different code points.

These are the mapping codec APIs:

```c
PyObject* PyUnicode_DecodeCharmap(const char *s, Py_ssize_t size, PyObject *mapping, const char *errors)

Create a Unicode object by decoding size bytes of the encoded string s using the given mapping object. Return NULL if an exception was raised by the codec. If mapping is NULL latin-1 decoding will be done. Else it can be a dictionary mapping byte or a unicode string, which is treated as a lookup table. Byte values greater that the length of the string and U+FFFFE “characters” are treated as “undefined mapping”.

PyObject* PyUnicode_AsCharmapString(PyObject *unicode,

```

PyObject *mapping)

Encode a Unicode object using the given mapping object and return the result as Python string object. Error handling is “strict”. Return NULL if an exception was raised by the codec.

The following codec API is special in that maps Unicode to Unicode.

PyObject* PyUnicode_TranslateCharmap(const Py_UNICODE *s, Py_ssize_t size, PyObject *table, const char *errors)

Translate a Py_UNICODE buffer of the given size by applying a character mapping table to it and return the resulting Unicode object. Return NULL when an exception was raised by the codec.

The mapping table must map Unicode ordinal integers to Unicode ordinal integers or None (causing deletion of the character).

Mapping tables need only provide the __getitem__() interface; dictionaries and sequences work well. Unmapped character ordinals (ones which cause a LookupError) are left untouched and are copied as-is.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style Py_UNICODE API.

PyObject* PyUnicode_EncodeCharmap(const Py_UNICODE *s, Py_ssize_t size, PyObject *mapping, const char *errors)

Encode the Py_UNICODE buffer of the given size using the given mapping object and return a Python string object. Return NULL if an exception was raised by the codec.
**Deprecated since version 3.3, will be removed in version 4.0:** Part of the old-style `Py_UNICODE` API; please migrate to using `PyUnicode_AsCharmapString()`.

**MBCS codecs for Windows**

These are the MBCS codec APIs. They are currently only available on Windows and use the Win32 MBCS converters to implement the conversions. Note that MBCS (or DBCS) is a class of encodings, not just one. The target encoding is defined by the user settings on the machine running the codec.

**PyObject** `PyUnicode_DecodeMBCS`(const char *s, Py_ssize_t size, const char *errors)

*Return value: New reference.*
Create a Unicode object by decoding size bytes of the MBCS encoded string s. Return `NULL` if an exception was raised by the codec.

**PyObject** `PyUnicode_DecodeMBCSStrateful`(const char *s, int size, const char *errors, int *consumed)

If `consumed` is `NULL`, behave like `PyUnicode_DecodeMBCS()`. If `consumed` is not `NULL`, `PyUnicode_DecodeMBCSStrateful()` will not decode trailing lead byte and the number of bytes that have been decoded will be stored in `consumed`.

**PyObject** `PyUnicode_AsMBCSString`(PyObject *unicode)

*Return value: New reference.*
Encode a Unicode object using MBCS and return the result as Python bytes object. Error handling is “strict”. Return `NULL` if an exception was raised by the codec.
PyObject* PyUnicode_EncodeCodePage(int code_page, PyObject *unicode, const char *errors)

    Encode the Unicode object using the specified code page and return a Python bytes object. Return NULL if an exception was raised by the codec. Use CP_ACP code page to get the MBCS encoder.

    New in version 3.3.

PyObject* PyUnicode_EncodeMBCS(const Py_UNICODE *s, Py_ssize_t size, const char *errors)

    Encode the Py_UNICODE buffer of the given size using MBCS and return a Python bytes object. Return NULL if an exception was raised by the codec.

    Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style Py_UNICODE API; please migrate to using PyUnicode_AsMBCSString() or PyUnicode_EncodeCodePage().

Methods & Slots
Methods and Slot Functions

The following APIs are capable of handling Unicode objects and strings on input (we refer to them as strings in the descriptions) and return Unicode objects or integers as appropriate.

They all return NULL or -1 if an exception occurs.

PyObject* **PyUnicode_Concat** (PyObject *left, PyObject *right)

*Return value: New reference.*
Concat two strings giving a new Unicode string.

PyObject* **PyUnicode_Split** (PyObject *s, PyObject *sep, Py_ssize_t maxsplit)

*Return value: New reference.*
Split a string giving a list of Unicode strings. If sep is NULL, splitting will be done at all whitespace substrings. Otherwise, splits occur at the given separator. At most maxsplit splits will be done. If negative, no limit is set. Separators are not included in the resulting list.

PyObject* **PyUnicode_Splitlines** (PyObject *s, int keepend)

*Return value: New reference.*
Split a Unicode string at line breaks, returning a list of Unicode strings. CRLF is considered to be one line break. If keepend is 0, the Line break characters are not included in the resulting strings.

PyObject* **PyUnicode_Translate** (PyObject *str, PyObject *table, const char *errors)

*Return value: New reference.*
Translate a string by applying a character mapping table to it and return the resulting Unicode object.
The mapping table must map Unicode ordinal integers to Unicode ordinal integers or None (causing deletion of the character).

Mapping tables need only provide the `__getitem__()` interface; dictionaries and sequences work well. Unmapped character ordinals (ones which cause a `LookupError`) are left untouched and are copied as-is.

`errors` has the usual meaning for codecs. It may be `NULL` which indicates to use the default error handling.

**PyObject** `PyUnicode_Join(PyObject *separator, PyObject *seq)`

*Return value: New reference.*

Join a sequence of strings using the given `separator` and return the resulting Unicode string.

**Py_ssize_t** `PyUnicode_Tailmatch(PyObject *str, PyObject *substr, Py_ssize_t start, Py_ssize_t end, int direction)`

Return 1 if `substr` matches `str[start:end]` at the given tail end (`direction == -1` means to do a prefix match, `direction == 1` a suffix match), 0 otherwise. Return -1 if an error occurred.

**Py_ssize_t** `PyUnicode_Find(PyObject *str, PyObject *substr, Py_ssize_t start, Py_ssize_t end, int direction)`

Return the first position of `substr` in `str[start:end]` using the given `direction` (`direction == 1` means to do a forward search, `direction == -1` a backward search). The return value is the index of the first match; a value of -1 indicates that no match was found, and -2 indicates that an error occurred and an exception has been set.

**Py_ssize_t** `PyUnicode_FindChar(PyObject *str, Py_UCS4 ch, Py_ssize_t start, Py_ssize_t end, int direction)`
Return the first position of the character \textit{ch} in \texttt{str[start:end]} using the given \textit{direction} (\textit{direction} == 1 means to do a forward search, \textit{direction} == -1 a backward search). The return value is the index of the first match; a value of -1 indicates that no match was found, and -2 indicates that an error occurred and an exception has been set.

\textit{New in version 3.3.}

\begin{verbatim}
Py_ssize_t PyUnicode_Count(PyObject *str, PyObject *substr, Py_ssize_t start, Py_ssize_t end)
    Return the number of non-overlapping occurrences of \texttt{substr} in \texttt{str[start:end]}. Return -1 if an error occurred.

PyObject* PyUnicode_Replace(PyObject *str, PyObject *substr, PyObject *replstr, Py_ssize_t maxcount)
    Replace at most \texttt{maxcount} occurrences of \texttt{substr} in \texttt{str} with \texttt{replstr} and return the resulting Unicode object. \texttt{maxcount} == -1 means replace all occurrences.

int PyUnicode_Compare(PyObject *left, PyObject *right)
    Compare two strings and return -1, 0, 1 for less than, equal, and greater than, respectively.

int PyUnicode_CompareWithASCIIString(PyObject *uni, const char *string)
    Compare a unicode object, \texttt{uni}, with \texttt{string} and return -1, 0, 1 for less than, equal, and greater than, respectively. It is best to pass only ASCII-encoded strings, but the function interprets the input string as ISO-8859-1 if it contains non-ASCII characters.

PyObject* PyUnicode_RichCompare(PyObject *left,
PyObject *right, int op)
   Rich compare two unicode strings and return one of the following:
   
   - NULL in case an exception was raised
   - Py_True or Py_False for successful comparisons
   - Py_NotImplemented in case the type combination is unknown

   Note that Py_EQ and Py_NE comparisons can cause a UnicodeWarning in case the conversion of the arguments to Unicode fails with a UnicodeDecodeError.

   Possible values for op are Py_GT, Py_GE, Py_EQ, Py_NE, Py_LT, and Py_LE.

PyObject* PyUnicode_Format(PyObject *format, PyObject *args)
   Return a new string object from format and args; this is analogous to format % args.

int PyUnicode_Contains(PyObject *container, PyObject *element)
   Check whether element is contained in container and return true or false accordingly.

   element has to coerce to a one element Unicode string. -1 is returned if there was an error.

void PyUnicode_InternInPlace(PyObject **string)
   Intern the argument *string in place. The argument must be the address of a pointer variable pointing to a Python unicode string object. If there is an existing interned string that is the same as *string, it sets *string to it (decrementing the reference count of the
old string object and incrementing the reference count of the interned string object), otherwise it leaves *string alone and interns it (incrementing its reference count). (Clarification: even though there is a lot of talk about reference counts, think of this function as reference-count-neutral; you own the object after the call if and only if you owned it before the call.)

(PyObject*) **PyUnicode_InternFromString**(const char *v)

A combination of **PyUnicode_FromString()** and **PyUnicode_InternInPlace()**, returning either a new unicode string object that has been interned, or a new (“owned”) reference to an earlier interned string object with the same value.
Tuple Objects

**PyTupleObject**
This subtype of *PyObject* represents a Python tuple object.

**PyTypeObject PyTuple_Type**
This instance of *PyTypeObject* represents the Python tuple type; it is the same object as *tuple* in the Python layer.

```c
int PyTuple_Check(*p)
```
Return true if *p* is a tuple object or an instance of a subtype of the tuple type.

```c
int PyTuple_CheckExact(*p)
```
Return true if *p* is a tuple object, but not an instance of a subtype of the tuple type.

```c
PyObject* PyTuple_New(Py_ssize_t len)
```
*Return value: New reference.*
Return a new tuple object of size *len*, or *NULL* on failure.

```c
PyObject* PyTuple_Pack(Py_ssize_t n, ...)
```
*Return value: New reference.*
Return a new tuple object of size *n*, or *NULL* on failure. The tuple values are initialized to the subsequent *n* C arguments pointing to Python objects. PyTuple_Pack(2, a, b) is equivalent to PyTuple_Pack("(OO)", a, b).

```c
Py_ssize_t PyTuple_Size(*p)
```
Take a pointer to a tuple object, and return the size of that tuple.
Py_ssize_t PyTuple_GET_SIZE(PyObject *p)
    Return the size of the tuple p, which must be non-NULL and point
    to a tuple; no error checking is performed.

PyObject* PyTuple_GetItem(PyObject *p, Py_ssize_t pos)
    Return value: Borrowed reference.
    Return the object at position pos in the tuple pointed to by p. If pos
    is out of bounds, return NULL and sets an IndexError exception.

PyObject* PyTuple_GET_ITEM(PyObject *p, Py_ssize_t pos)
    Return value: Borrowed reference.
    Like PyTuple_GetItem(), but does no checking of its arguments.

PyObject* PyTuple_GetSlice(PyObject *p, Py_ssize_t low,
        Py_ssize_t high)
    Take a slice of the tuple pointed to by p from low to high and return
    it as a new tuple.

int PyTuple_SetItem(PyObject *p, Py_ssize_t pos, PyObject *o)
    Insert a reference to object o at position pos of the tuple pointed to
    by p. Return 0 on success.

    Note: This function “steals” a reference to o.

void PyTuple_SET_ITEM(PyObject *p, Py_ssize_t pos,
        PyObject *o)
    Like PyTuple_SetItem(), but does no error checking, and
    should only be used to fill in brand new tuples.

    Note: This function “steals” a reference to o.
int _PyTuple_Resize(PyObject **p, Py_ssize_t newsize)

Can be used to resize a tuple. newsize will be the new length of the tuple. Because tuples are supposed to be immutable, this should only be used if there is only one reference to the object. Do not use this if the tuple may already be known to some other part of the code. The tuple will always grow or shrink at the end. Think of this as destroying the old tuple and creating a new one, only more efficiently. Returns 0 on success. Client code should never assume that the resulting value of *p will be the same as before calling this function. If the object referenced by *p is replaced, the original *p is destroyed. On failure, returns -1 and sets *p to NULL, and raises MemoryError or SystemError.

int PyTuple_ClearFreeList()

Clear the free list. Return the total number of freed items.
Struct Sequence Objects

Struct sequence objects are the C equivalent of `namedtuple()` objects, i.e. a sequence whose items can also be accessed through attributes. To create a struct sequence, you first have to create a specific struct sequence type.

*PyTypeObject*

*PyStructSequence_NewType*(PyStructSequence_Desc *desc)

Create a new struct sequence type from the data in `desc`, described below. Instances of the resulting type can be created with `PyStructSequence_New()`.

*void PyStructSequence_InitType*(PyTypeObject *type, PyStructSequence_Desc *desc)

Initializes a struct sequence type `type` from `desc` in place.

*int PyStructSequence_InitType2*(PyTypeObject *type, PyStructSequence_Desc *desc)

The same as `PyStructSequence_InitType`, but returns 0 on success and -1 on failure.

*New in version 3.4.*

*PyStructSequence_Desc*

Contains the meta information of a struct sequence type to create.

<table>
<thead>
<tr>
<th>Field</th>
<th>C Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>char *</td>
<td>name of the struct sequence type</td>
</tr>
<tr>
<td>doc</td>
<td>char *</td>
<td>pointer to docstring for the type or NULL to omit</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>fields</td>
<td>PyStructSequence_Field *</td>
<td>pointer to NULL-terminated array with field names of the new type</td>
</tr>
<tr>
<td>n_in_sequence</td>
<td>int</td>
<td>number of fields visible to the Python side (if used as tuple)</td>
</tr>
</tbody>
</table>

**PyStructSequence_Field**

Describes a field of a struct sequence. As a struct sequence is modeled as a tuple, all fields are typed as `PyObject*`. The index in the fields array of the `PyStructSequence_Desc` determines which field of the struct sequence is described.

<table>
<thead>
<tr>
<th>Field</th>
<th>C Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>char *</td>
<td>name for the field or NULL to end the list of named fields, set to PyStructSequence_UnnamedField to leave unnamed</td>
</tr>
<tr>
<td>doc</td>
<td>char *</td>
<td>field docstring or NULL to omit</td>
</tr>
</tbody>
</table>

char* **PyStructSequence_UnnamedField**

Special value for a field name to leave it unnamed.
**PyObject**\* PyStructSequence\_New\((\text{PyTypeObject} \ *\text{type})\)

Creates an instance of \text{type}, which must have been created with \text{PyStructSequence\_NewType}().

**PyObject**\* PyStructSequence\_GetItem\((\text{PyObject} \ *\text{p}, \text{Py\_ssize\_t} \text{pos})\)

Return the object at position \text{pos} in the struct sequence pointed to by \text{p}. No bounds checking is performed.

**PyObject**\* PyStructSequence\_GET\_ITEM\((\text{PyObject} \ *\text{p}, \text{Py\_ssize\_t} \text{pos})\)

Macro equivalent of \text{PyStructSequence\_GetItem}().

void PyStructSequence\_SetItem\((\text{PyObject} \ *\text{p}, \text{Py\_ssize\_t} \text{pos}, \text{PyObject} \ *\text{o})\)

Sets the field at index \text{pos} of the struct sequence \text{p} to value \text{o}. Like \text{PyTuple\_SET\_ITEM()}, this should only be used to fill in brand new instances.

**Note:** This function “steals” a reference to \text{o}.

**PyObject**\* PyStructSequence\_SET\_ITEM\((\text{PyObject} \ *\text{p}, \text{Py\_ssize\_t} \ *\text{pos}, \text{PyObject} \ *\text{o})\)

Macro equivalent of \text{PyStructSequence\_SetItem}().

**Note:** This function “steals” a reference to \text{o}.
List Objects

**PyListObject**
This subtype of *PyObject* represents a Python list object.

**PyTypeObject PyList_Type**
This instance of *PyTypeObject* represents the Python list type. This is the same object as *list* in the Python layer.

```c
int PyList_Check(PyObject *p)
```
Return true if *p* is a list object or an instance of a subtype of the list type.

```c
int PyList_CheckExact(PyObject *p)
```
Return true if *p* is a list object, but not an instance of a subtype of the list type.

```c
PyObject* PyList_New(Py_ssize_t len)
```
*Return value: New reference.*
Return a new list of length *len* on success, or *NULL* on failure.

**Note:** If *len* is greater than zero, the returned list object’s items are set to NULL. Thus you cannot use abstract API functions such as *PySequence_SetItem()* or expose the object to Python code before setting all items to a real object with *PyList_SetItem()*.

```c
Py_ssize_t PyList_Size(PyObject *list)
```
Return the length of the list object in *list*; this is equivalent to *len(list)* on a list object.
Py_ssize_t **PyList_GET_SIZE(PyObject *list)**
Macro form of **PyList_Size()** without error checking.

PyObject* **PyList_GetItem(PyObject *list, Py_ssize_t index)**
*Return value: Borrowed reference.*
Return the object at position *index* in the list pointed to by *list*. The position must be positive, indexing from the end of the list is not supported. If *index* is out of bounds, return NULL and set an IndexError exception.

PyObject* **PyList_GET_ITEM(PyObject *list, Py_ssize_t i)**
*Return value: Borrowed reference.*
Macro form of **PyList_GetItem()** without error checking.

int **PyList_SetItem(PyObject *list, Py_ssize_t index, PyObject *item)**
Set the item at index *index* in list to *item*. Return 0 on success or -1 on failure.

**Note:** This function “steals” a reference to *item* and discards a reference to an item already in the list at the affected position.

void **PyList_SET_ITEM(PyObject *list, Py_ssize_t i, PyObject *o)**
Macro form of **PyList_SetItem()** without error checking. This is normally only used to fill in new lists where there is no previous content.

**Note:** This macro “steals” a reference to *item*, and, unlike **PyList_SetItem()**, does not discard a reference to any item that is being replaced; any reference in *list* at position *i* will be leaked.
int PyList_Insert(PyObject *list, Py_ssize_t index, PyObject *item)
    Insert the item item into list list in front of index index. Return 0 if successful; return -1 and set an exception if unsuccessful. Analogous to list.insert(index, item).

int PyList_Append(PyObject *list, PyObject *item)
    Append the object item at the end of list list. Return 0 if successful; return -1 and set an exception if unsuccessful. Analogous to list.append(item).

PyObject* PyList_GetSlice(PyObject *list, Py_ssize_t low, Py_ssize_t high)
    Return a list of the objects in list containing the objects between low and high. Return NULL and set an exception if unsuccessful. Analogous to list[low:high]. Negative indices, as when slicing from Python, are not supported.

int PyList_SetSlice(PyObject *list, Py_ssize_t low, Py_ssize_t high, PyObject *itemlist)
    Set the slice of list between low and high to the contents of itemlist. Analogous to list[low:high] = itemlist. The itemlist may be NULL, indicating the assignment of an empty list (slice deletion). Return 0 on success, -1 on failure. Negative indices, as when slicing from Python, are not supported.

int PyList_Sort(PyObject *list)
    Sort the items of list in place. Return 0 on success, -1 on failure. This is equivalent to list.sort().

int PyList_Reverse(PyObject *list)
Reverse the items of list in place. Return 0 on success, -1 on failure. This is the equivalent of list.reverse().

PyObject* PyList_AsTuple(PyObject *list)

Return a new tuple object containing the contents of list; equivalent to tuple(list).

int PyList_ClearFreeList()

Clear the free list. Return the total number of freed items.

New in version 3.3.
Dictionary Objects

**PyDictObject**
This subtype of PyObject represents a Python dictionary object.

**PyTypeObject PyDict_Type**
This instance of PyTypeObject represents the Python dictionary type. This is the same object as `dict` in the Python layer.

```c
int PyDict_Check(PyObject *p)
```
Return true if `p` is a dict object or an instance of a subtype of the dict type.

```c
int PyDict_CheckExact(PyObject *p)
```
Return true if `p` is a dict object, but not an instance of a subtype of the dict type.

```c
PyObject* PyDict_New()
```
Return a new empty dictionary, or NULL on failure.

```c
PyObject* PyDictProxy_New(PyObject *mapping)
```
Return a types.MappingProxyType object for a mapping which enforces read-only behavior. This is normally used to create a view to prevent modification of the dictionary for non-dynamic class types.

```c
void PyDict_Clear(PyObject *p)
```
Empty an existing dictionary of all key-value pairs.
int **PyDict**. **Contains**(PyObject *p, PyObject *key)
Determine if dictionary *p* contains *key*. If an item in *p* is matches *key*, return 1, otherwise return 0. On error, return -1. This is equivalent to the Python expression *key in p*.

PyObject* **PyDict**. **Copy**(PyObject *p)
*Return value: New reference.*
Return a new dictionary that contains the same key-value pairs as *p*.

int **PyDict**. **SetItem**(PyObject *p, PyObject *key, PyObject *val)
Insert *value* into the dictionary *p* with a key of *key*. *key* must be hashable; if it isn't, **TypeError** will be raised. Return 0 on success or -1 on failure.

int **PyDict**. **SetItemString**(PyObject *p, const char *key, PyObject *val)
Insert *value* into the dictionary *p* using *key* as a key. *key* should be a char*. The key object is created using PyUnicode_FromString(*key*). Return 0 on success or -1 on failure.

int **PyDict**. **DelItem**(PyObject *p, PyObject *key)
Remove the entry in dictionary *p* with key *key*. *key* must be hashable; if it isn't, **TypeError** is raised. Return 0 on success or -1 on failure.

int **PyDict**. **DelItemString**(PyObject *p, const char *key)
Remove the entry in dictionary *p* which has a key specified by the string *key*. Return 0 on success or -1 on failure.

PyObject* **PyDict**. **GetItem**(PyObject *p, PyObject *key)
Return value: Borrowed reference.
Return the object from dictionary $p$ which has a key $key$. Return NULL if the key $key$ is not present, but without setting an exception.

```c
PyObject* PyDict_GetItemWithError(PyObject *p, PyObject *key)
```

Variant of `PyDict_GetItem()` that does not suppress exceptions. Return NULL with an exception set if an exception occurred. Return NULL without an exception set if the key wasn’t present.

```c
PyObject* PyDict_GetItemString(PyObject *p, const char *key)
```

Return value: Borrowed reference.
This is the same as `PyDict_GetItem()`, but $key$ is specified as a char*, rather than a PyObject*.

```c
PyObject* PyDict_SetDefault(PyObject *p, PyObject *key, PyObject *default)
```

Return value: Borrowed reference.
This is the same as the Python-level `dict.setdefault()`. If present, it returns the value corresponding to $key$ from the dictionary $p$. If the key is not in the dict, it is inserted with value `defaultobj` and `defaultobj` is returned. This function evaluates the hash function of $key$ only once, instead of evaluating it independently for the lookup and the insertion.

```c
PyObject* PyDict_Items(PyObject *p)
```

Return a PyListObject containing all the items from the dictionary.

```c
PyObject* PyDict_Keys(PyObject *p)
```
**Return value: New reference.**

Return a `PyListObject` containing all the keys from the dictionary.

**PyObject* PyDict.Values(PyObject *p)**

**Return value: New reference.**

Return a `PyListObject` containing all the values from the dictionary `p`.

**Py_ssize_t PyDict_Size(PyObject *p)**

Return the number of items in the dictionary. This is equivalent to `len(p)` on a dictionary.

**int PyDict.Next(PyObject *p, Py_ssize_t *pos, PyObject **pkey, PyObject **pvalue)**

Iterate over all key-value pairs in the dictionary `p`. The `Py_ssize_t` referred to by `pos` must be initialized to 0 prior to the first call to this function to start the iteration; the function returns true for each pair in the dictionary, and false once all pairs have been reported. The parameters `pkey` and `pvalue` should either point to `PyObject*` variables that will be filled in with each key and value, respectively, or may be `NULL`. Any references returned through them are borrowed. `pos` should not be altered during iteration. Its value represents offsets within the internal dictionary structure, and since the structure is sparse, the offsets are not consecutive.

For example:

```c
PyObject *key, *value;
Py_ssize_t pos = 0;

while (PyDict_Next(self->dict, &pos, &key, &value
```
The dictionary $p$ should not be mutated during iteration. It is safe to modify the values of the keys as you iterate over the dictionary, but only so long as the set of keys does not change. For example:

```c
PyObject *key, *value;
Py_ssize_t pos = 0;

while (PyDict_Next(self->dict, &pos, &key, &value) == 0) {
    long i = PyLong_AsLong(value);
    if (i == -1 && PyErr_Occurred()) {
        return -1;
    }
    PyObject *o = PyLong_FromLong(i + 1);
    if (o == NULL) {
        return -1;
    }
    if (PyDict_SetItem(self->dict, key, o) < 0) {
        Py_DECREF(o);
        return -1;
    }
    Py_DECREF(o);
}
```

The function `PyDict_Merge(PyObject *a, PyObject *b, int override)` iterates over mapping object $b$ adding key-value pairs to dictionary $a$. $b$ may be a dictionary, or any object supporting `PyMapping_Keys()` and `PyObject_GetItem()`. If `override` is true, existing pairs in $a$ will be replaced if a matching key is found in $b$, otherwise pairs will only be added if there is not a matching key in $a$. Return 0 on success or -1 if an exception was raised.
int `PyDict_Update(PyObject *a, PyObject *b)`

This is the same as `PyDict_Merge(a, b, 1)` in C, and is similar to `a.update(b)` in Python except that `PyDict_Update()` doesn’t fall back to the iterating over a sequence of key value pairs if the second argument has no “keys” attribute. Return 0 on success or -1 if an exception was raised.

int `PyDict_MergeFromSeq2(PyObject *a, PyObject *seq2, int override)`

Update or merge into dictionary `a`, from the key-value pairs in `seq2`. `seq2` must be an iterable object producing iterable objects of length 2, viewed as key-value pairs. In case of duplicate keys, the last wins if `override` is true, else the first wins. Return 0 on success or -1 if an exception was raised. Equivalent Python (except for the return value):

```python
def PyDict_MergeFromSeq2(a, seq2, override):
    for key, value in seq2:
        if override or key not in a:
            a[key] = value
```

int `PyDict_ClearFreeList()`

Clear the free list. Return the total number of freed items.

`New in version 3.3.`
Set Objects

This section details the public API for `set` and `frozenset` objects. Any functionality not listed below is best accessed using the either the abstract object protocol (including `PyObject_CallMethod()`, `PyObject_RichCompareBool()`, `PyObject_Hash()`, `PyObject_Repr()`, `PyObject_IsTrue()`, `PyObject_Print()`, and `PyObject_GetIter()`) or the abstract number protocol (including `PyNumber_And()`, `PyNumber_Subtract()`, `PyNumber_Or()`, `PyNumber_Xor()`, `PyNumber_InPlaceAnd()`, `PyNumber_InPlaceSubtract()`, `PyNumber_InPlaceOr()`, and `PyNumber_InPlaceXor()`).

**PySetObject**

This subtype of `PyObject` is used to hold the internal data for both `set` and `frozenset` objects. It is like a `PyDictObject` in that it is a fixed size for small sets (much like tuple storage) and will point to a separate, variable sized block of memory for medium and large sized sets (much like list storage). None of the fields of this structure should be considered public and are subject to change. All access should be done through the documented API rather than by manipulating the values in the structure.

**PyTypeObject** `PySet_Type`

This is an instance of `PyTypeObject` representing the Python `set` type.

**PyTypeObject** `PyFrozenSet_Type`

This is an instance of `PyTypeObject` representing the Python `frozenset` type.
The following type check macros work on pointers to any Python object. Likewise, the constructor functions work with any iterable Python object.

```c
int PySet_Check(PyObject *p)
    Return true if p is a set object or an instance of a subtype.
```

```c
int PyFrozenSet_Check(PyObject *p)
    Return true if p is a frozenset object or an instance of a subtype.
```

```c
int PyAnySet_Check(PyObject *p)
    Return true if p is a set object, a frozenset object, or an instance of a subtype.
```

```c
int PyAnySet_CheckExact(PyObject *p)
    Return true if p is a set object or a frozenset object but not an instance of a subtype.
```

```c
int PyFrozenSet_CheckExact(PyObject *p)
    Return true if p is a frozenset object but not an instance of a subtype.
```

```c
PyObject* PySet_New(PyObject *iterable)
    Return a new set containing objects returned by the iterable. The iterable may be NULL to create a new empty set. Return the new set on success or NULL on failure. Raise TypeError if iterable is not actually iterable. The constructor is also useful for copying a set (c=set(s)).
```

```c
PyObject* PyFrozenSet_New(PyObject *iterable)
```
Return a new `frozenset` containing objects returned by the `iterable`. The `iterable` may be `NULL` to create a new empty `frozenset`. Return the new set on success or `NULL` on failure. Raise `TypeError` if `iterable` is not actually iterable.

The following functions and macros are available for instances of `set` or `frozenset` or instances of their subtypes.

**Py_ssize_t PySet_Size(PyObject *anyset)**

Return the length of a `set` or `frozenset` object. Equivalent to `len(anyset)`. Raises a `PyExc_SystemError` if `anyset` is not a `set`, `frozenset`, or an instance of a subtype.

**Py_ssize_t PySet_GET_SIZE(PyObject *anyset)**

Macro form of `PySet_Size()` without error checking.

**int PySet_Contains(PyObject *anyset, PyObject *key)**

Return 1 if found, 0 if not found, and -1 if an error is encountered. Unlike the Python `__contains__()` method, this function does not automatically convert unhashable sets into temporary frozensets. Raise a `TypeError` if the `key` is unhashable. Raise `PyExc_SystemError` if `anyset` is not a `set`, `frozenset`, or an instance of a subtype.

**int PySet_Add(PyObject *set, PyObject *key)**

Add `key` to a `set` instance. Also works with `frozenset` instances (like `PyTuple_SetItem()` it can be used to fill-in the values of brand new frozensets before they are exposed to other code). Return 0 on success or -1 on failure. Raise a `TypeError` if the `key` is unhashable. Raise a `MemoryError` if there is no room to grow. Raise a `SystemError` if `set` is an not an instance of `set` or its
The following functions are available for instances of `set` or its subtypes but not for instances of `frozenset` or its subtypes.

`int PySet_Discard(PyObject *set, PyObject *key)`
Return 1 if found and removed, 0 if not found (no action taken), and -1 if an error is encountered. Does not raise `KeyError` for missing keys. Raise a `TypeError` if the `key` is unhashable. Unlike the Python `discard()` method, this function does not automatically convert unhashable sets into temporary frozensets. Raise `PyExc_SystemError` if `set` is an not an instance of `set` or its subtype.

`PyObject* PySet_Pop(PyObject *set)`
*Return value: New reference.*
Return a new reference to an arbitrary object in the `set`, and removes the object from the `set`. Return `NULL` on failure. Raise `KeyError` if the set is empty. Raise a `SystemError` if `set` is an not an instance of `set` or its subtype.

`int PySet_Clear(PyObject *set)`
Empty an existing set of all elements.

`int PySet_ClearFreeList()`
Clear the free list. Return the total number of freed items.

*New in version 3.3.*
Function Objects

There are a few functions specific to Python functions.

**PyFunctionObject**
The C structure used for functions.

**PyTypeObject PyFunction_Type**
This is an instance of PyTypeObject and represents the Python function type. It is exposed to Python programmers as types.FunctionType.

int **PyFunction_Check**(PyObject *o)
Return true if o is a function object (has type PyFunction_Type). The parameter must not be NULL.

PyObject* **PyFunction_New**(PyObject *code, PyObject *globals)
*Return value: New reference.*
Return a new function object associated with the code object code. globals must be a dictionary with the global variables accessible to the function.

The function's docstring, name and __module__ are retrieved from the code object, the argument defaults and closure are set to NULL.

PyObject* **PyFunction_NewWithQualName**(PyObject *code, PyObject *globals, PyObject *qualname)
*Return value: New reference.*
As PyFunction_New(), but also allows to set the function object's __qualname__ attribute. qualname should be a unicode
object or NULL; if NULL, the __qualname__ attribute is set to the same value as its __name__ attribute.

*New in version 3.3.*

**PyObject* **PyFunction_GetCode**(PyObject *op)**

*Return value: Borrowed reference.*

Return the code object associated with the function object op.

**PyObject* **PyFunction_GetGlobals**(PyObject *op)**

*Return value: Borrowed reference.*

Return the globals dictionary associated with the function object op.

**PyObject** **PyFunction_GetModule**(PyObject *op)**

*Return value: Borrowed reference.*

Return the __module__ attribute of the function object op. This is normally a string containing the module name, but can be set to any other object by Python code.

**PyObject** **PyFunction_GetDefaults**(PyObject *op)**

*Return value: Borrowed reference.*

Return the argument default values of the function object op. This can be a tuple of arguments or NULL.

**int** **PyFunction_SetDefaults**(PyObject *op, PyObject *defaults)**

Set the argument default values for the function object op. *defaults* must be Py_None or a tuple.

Raises SystemError and returns -1 on failure.

**PyObject** **PyFunction_GetClosure**(PyObject *op)**
Return value: Borrowed reference.
Return the closure associated with the function object \( op \). This can be \( NULL \) or a tuple of cell objects.

```c
int PyFunction_SetClosure(PyObject *op, PyObject *closure)
```
Set the closure associated with the function object \( op \). \( closure \) must be \( Py_None \) or a tuple of cell objects.

Raises \texttt{SystemError} and returns -1 on failure.

```c
PyObject *PyFunction_GetAnnotations(PyObject *op)
```
Return the annotations of the function object \( op \). This can be a mutable dictionary or \( NULL \).

```c
int PyFunction_SetAnnotations(PyObject *op, PyObject *annotations)
```
Set the annotations for the function object \( op \). \( annotations \) must be a dictionary or \( Py_None \).

Raises \texttt{SystemError} and returns -1 on failure.
Instance Method Objects

An instance method is a wrapper for a PyCFunction and the new way to bind a PyCFunction to a class object. It replaces the former call PyMethod_New(func, NULL, class).

PyTypeObject PyInstanceMethod_Type
This instance of PyTypeObject represents the Python instance method type. It is not exposed to Python programs.

int PyInstanceMethod_Check(PyObject *o)
Return true if o is an instance method object (has type PyInstanceMethod_Type). The parameter must not be NULL.

PyObject* PyInstanceMethod_New(PyObject *func)
Return a new instance method object, with func being any callable object func is the function that will be called when the instance method is called.

PyObject* PyInstanceMethod_Function(PyObject *im)
Return the function object associated with the instance method im.

PyObject* PyInstanceMethod_GET_FUNCTION(PyObject *im)
Macro version of PyInstanceMethod_Function() which avoids error checking.
Method Objects

Methods are bound function objects. Methods are always bound to an instance of an user-defined class. Unbound methods (methods bound to a class object) are no longer available.

PyTypeObject PyMethod_Type

This instance of PyTypeObject represents the Python method type. This is exposed to Python programs as types.MethodType.

int PyMethod_Check(PyObject *o)

Return true if o is a method object (has type PyMethod_Type). The parameter must not be NULL.

PyObject* PyMethod_New(PyObject *func, PyObject *self)

Return a new method object, with func being any callable object and self the instance the method should be bound. func is the function that will be called when the method is called. self must not be NULL.

PyObject* PyMethod_Function(PyObject *meth)

Return value: Borrowed reference.
Return the function object associated with the method meth.

PyObject* PyMethod_GET_FUNCTION(PyObject *meth)

Return value: Borrowed reference.
Macro version of PyMethod_Function() which avoids error checking.
PyObject* **PyMethod**\_**Self** (PyObject \*\*meth)

*Return value: Borrowed reference.*
Return the instance associated with the method \*meth.  

PyObject* **PyMethod**\_**GET**\_**SELF** (PyObject \*\*meth)

*Return value: Borrowed reference.*
Macro version of **PyMethod**\_**Self**() which avoids error checking.

int **PyMethod**\_**Clear**\_**Free**\_**List**()

Clear the free list. Return the total number of freed items.
Cell Objects

“Cell” objects are used to implement variables referenced by multiple scopes. For each such variable, a cell object is created to store the value; the local variables of each stack frame that references the value contains a reference to the cells from outer scopes which also use that variable. When the value is accessed, the value contained in the cell is used instead of the cell object itself. This de-referencing of the cell object requires support from the generated byte-code; these are not automatically de-referenced when accessed. Cell objects are not likely to be useful elsewhere.

**PyCellObject**

The C structure used for cell objects.

**PyTypeObject PyCell_Type**

The type object corresponding to cell objects.

```c
int PyCell_Check(ob)
Return true if ob is a cell object; ob must not be NULL.
```

```c
PyObject* PyCell_New(PyObject *ob)
Create and return a new cell object containing the value ob. The parameter may be NULL.
```

```c
PyObject* PyCell_Get(PyObject *cell)
Return the contents of the cell cell.
```

```c
PyObject* PyCell_GET(PyObject *cell)
Return value: Borrowed reference.
```
Return the contents of the cell `cell`, but without checking that `cell` is non-`NULL` and a cell object.

```c
int PyCell_Set(PyObject *cell, PyObject *value)
```

Set the contents of the cell object `cell` to `value`. This releases the reference to any current content of the cell. `value` may be `NULL`. `cell` must be non-`NULL`; if it is not a cell object, -1 will be returned. On success, 0 will be returned.

```c
void PyCell_SET(PyObject *cell, PyObject *value)
```

Sets the value of the cell object `cell` to `value`. No reference counts are adjusted, and no checks are made for safety; `cell` must be non-`NULL` and must be a cell object.
Code Objects

Code objects are a low-level detail of the CPython implementation. Each one represents a chunk of executable code that hasn’t yet been bound into a function.

**PyCodeObject**

The C structure of the objects used to describe code objects. The fields of this type are subject to change at any time.

**PyTypeObject** **PyCode_Type**

This is an instance of **PyTypeObject** representing the Python code type.

```c
int PyCode_Check(PyObject *co)

Return true if co is a code object.
```

```c
int PyCode_GetNumFree(PyCodeObject *co)

Return the number of free variables in co.
```

```c
PyCodeObject* PyCode_New(int argcount, int kwonlyargcount,
int nlocals, int stacksize, int flags, PyObject *code, PyObject *consts,
PyObject *names, PyObject *varnames, PyObject *freevars,
PyObject *cellvars, PyObject *filename, PyObject *name,
int firstlineno, PyObject *lnotab)

Return a new code object. If you need a dummy code object to create a frame, use PyCode_NewEmpty() instead. Calling PyCode_New() directly can bind you to a precise Python version since the definition of the bytecode changes often.
```

```c
PyCodeObject* PyCode_NewEmpty(const char *filename, const char *funcname, int firstlineno)
```
Return a new empty code object with the specified filename, function name, and first line number. It is illegal to `exec()` or `eval()` the resulting code object.
File Objects

These APIs are a minimal emulation of the Python 2 C API for built-in file objects, which used to rely on the buffered I/O (FILE*) support from the C standard library. In Python 3, files and streams use the new io module, which defines several layers over the low-level unbuffered I/O of the operating system. The functions described below are convenience C wrappers over these new APIs, and meant mostly for internal error reporting in the interpreter; third-party code is advised to access the io APIs instead.

PyFile_FromFd(int fd, const char *name, const char *mode,
               int buffering, const char *encoding, const char *errors, const
               char *newline, int closefd)

Create a Python file object from the file descriptor of an already opened file fd. The arguments name, encoding, errors and newline can be NULL to use the defaults; buffering can be -1 to use the default. name is ignored and kept for backward compatibility. Return NULL on failure. For a more comprehensive description of the arguments, please refer to the io.open() function documentation.

Warning: Since Python streams have their own buffering layer, mixing them with OS-level file descriptors can produce various issues (such as unexpected ordering of data).

Changed in version 3.2: Ignore name attribute.

int PyObject_AsFileDescriptor(PyObject *p)

Return the file descriptor associated with p as an int. If the object is an integer, its value is returned. If not, the object's fileno()
method is called if it exists; the method must return an integer, which is returned as the file descriptor value. Sets an exception and returns -1 on failure.

**PyObject** `PyFile_GetLine(PyObject *p, int n)`

*Return value: New reference.*

Equivalent to `p.readline()[n]`, this function reads one line from the object `p`. `p` may be a file object or any object with a `readline()` method. If `n` is 0, exactly one line is read, regardless of the length of the line. If `n` is greater than 0, no more than `n` bytes will be read from the file; a partial line can be returned. In both cases, an empty string is returned if the end of the file is reached immediately. If `n` is less than 0, however, one line is read regardless of length, but `EOFError` is raised if the end of the file is reached immediately.

```c
PyObject* PyFile_GetLine(PyObject *p, int n)
```

```c
```

```c
Equivalent to p.readline()[n], this function reads one line from the object p. p may be a file object or any object with a readline() method. If n is 0, exactly one line is read, regardless of the length of the line. If n is greater than 0, no more than n bytes will be read from the file; a partial line can be returned. In both cases, an empty string is returned if the end of the file is reached immediately. If n is less than 0, however, one line is read regardless of length, but EOFError is raised if the end of the file is reached immediately.

```c
int PyFile_WriteObject(PyObject *obj, PyObject *p, int flags)
Write object obj to file object p. The only supported flag for flags is Py_PRINT_RAW; if given, the str() of the object is written instead of the repr(). Return 0 on success or -1 on failure; the appropriate exception will be set.

```c
int PyFile_WriteString(const char *s, PyObject *p)
Write string s to file object p. Return 0 on success or -1 on failure; the appropriate exception will be set.
```
Module Objects

**PyTypeObject** **PyModule_Type**

This instance of **PyTypeObject** represents the Python module type. This is exposed to Python programs as `types.ModuleType`.

```c
int PyModule_Check(PyObject *p)

Return true if p is a module object, or a subtype of a module object.
```

```c
int PyModule_CheckExact(PyObject *p)

Return true if p is a module object, but not a subtype of PyModule_Type.
```

**PyObject** **PyModule_NewObject**(**PyObject *name**)

Return a new module object with the `__name__` attribute set to `name`. The module's `__name__`, `__doc__`, `__package__`, and `__loader__` attributes are filled in (all but `__name__` are set to None); the caller is responsible for providing a `__file__` attribute.

New in version 3.3.

Changed in version 3.4: `__package__` and `__loader__` are set to None.

**PyObject** **PyModule_New**(const char *name)

*Return value: New reference.*

Similar to `PyImport_NewObject()`, but the name is an UTF-8 encoded string instead of a Unicode object.

**PyObject** **PyModule_GetDict**(PyObject *module)

Return value: Borrowed reference.
Return the dictionary object that implements module's namespace; this object is the same as the __dict__ attribute of the module object. This function never fails. It is recommended extensions use other PyModule_*() and PyObject_*() functions rather than directly manipulate a module's __dict__.

PyObject* PyModule_GetNameObject(PyObject *module)
Return module's __name__ value. If the module does not provide one, or if it is not a string, SystemError is raised and NULL is returned.

New in version 3.3.

char* PyModule_GetName(PyObject *module)
Similar to PyModule_GetNameObject() but return the name encoded to 'utf-8'.

void* PyModule_GetState(PyObject *module)
Return the “state” of the module, that is, a pointer to the block of memory allocated at module creation time, or NULL. See PyModuleDef.m_size.

PyModuleDef* PyModule_GetDef(PyObject *module)
Return a pointer to the PyModuleDef struct from which the module was created, or NULL if the module wasn’t created from a definition.

PyObject*
PyModule_GetFilenameObject(PyObject *module)
Return the name of the file from which module was loaded using module's __file__ attribute. If this is not defined, or if it is not a
unicode string, raise `SystemError` and return `NULL`; otherwise return a reference to a Unicode object.

*New in version 3.2.*

```c
char* PyModule_GetFilename(PyObject *module)
```

Similar to `PyModule_GetFilenameObject()` but return the filename encoded to ‘utf-8’.

*Deprecated since version 3.2:* `PyModule_GetFilename()` raises `UnicodeEncodeError` on unencodable filenames, use `PyModule_GetFilenameObject()` instead.
Initializing C modules

Modules objects are usually created from extension modules (shared libraries which export an initialization function), or compiled-in modules (where the initialization function is added using PyImport_AppendInittab()). See Building C and C++ Extensions or Extending Embedded Python for details.

The initialization function can either pass a module definition instance to PyModule_Create(), and return the resulting module object, or request “multi-phase initialization” by returning the definition struct itself.

**PyModuleDef**

The module definition struct, which holds all information needed to create a module object. There is usually only one statically initialized variable of this type for each module.

PyModuleDef_Base  \texttt{m\_base}

Always initialize this member to PyModuleDef\_HEAD\_INIT.

\texttt{char* m\_name}

Name for the new module.

\texttt{char* m\_doc}

Docstring for the module; usually a docstring variable created with PyDoc\_STRVAR() is used.

\texttt{Py\_ssize\_t m\_size}

Module state may be kept in a per-module memory area that can be retrieved with PyModule\_GetState(), rather than in static globals. This makes modules safe for use in multiple sub-
interpreters.

This memory area is allocated based on \textit{m\_size} on module creation, and freed when the module object is deallocated, after the \textit{m\_free} function has been called, if present.

Setting \textit{m\_size} to -1 means that the module does not support sub-interpreters, because it has global state.

Setting it to a non-negative value means that the module can be re-initialized and specifies the additional amount of memory it requires for its state. Non-negative \textit{m\_size} is required for multi-phase initialization.

See \textbf{PEP 3121} for more details.

\textbf{PyMethodDef* \textit{m\_methods}}

A pointer to a table of module-level functions, described by \textbf{PyMethodDef} values. Can be \textit{NULL} if no functions are present.

\textbf{PyModuleDef\_Slot* \textit{m\_slots}}

An array of slot definitions for multi-phase initialization, terminated by a \{\textit{0, NULL}\} entry. When using single-phase initialization, \textit{m\_slots} must be \textit{NULL}.

\textit{Changed in version 3.5:} Prior to version 3.5, this member was always set to \textit{NULL}, and was defined as:

\textbf{inquiry \textit{m\_reload}}

\textbf{traverseproc \textit{m\_traverse}}

A traversal function to call during GC traversal of the module object, or \textit{NULL} if not needed.
inquiry **m_clear**

A clear function to call during GC clearing of the module object, or **NULL** if not needed.

freefunc **m_free**

A function to call during deallocation of the module object, or **NULL** if not needed.

**Single-phase initialization**

The module initialization function may create and return the module object directly. This is referred to as “single-phase initialization”, and uses one of the following two module creation functions:

**PyObject**\* **PyModule_Create**(**PyModuleDef** *def*)

Create a new module object, given the definition in *def*. This behaves like **PyModule_Create2()** with *module_api_version* set to PYTHON_API_VERSION.

**PyObject**\* **PyModule_Create2**(**PyModuleDef** *def*,

int *module_api_version*)

Create a new module object, given the definition in *def*, assuming the API version *module_api_version*. If that version does not match the version of the running interpreter, a **RuntimeWarning** is emitted.

**Note:** Most uses of this function should be using **PyModule_Create()** instead; only use this if you are sure you need it.

Before it is returned from in the initialization function, the resulting module object is typically populated using functions like
Multi-phase initialization

An alternate way to specify extensions is to request “multi-phase initialization”. Extension modules created this way behave more like Python modules: the initialization is split between the creation phase, when the module object is created, and the execution phase, when it is populated. The distinction is similar to the \_\_new\_\() and \_\_init\_\() methods of classes.

Unlike modules created using single-phase initialization, these modules are not singletons: if the sys.modules entry is removed and the module is re-imported, a new module object is created, and the old module is subject to normal garbage collection – as with Python modules. By default, multiple modules created from the same definition should be independent: changes to one should not affect the others. This means that all state should be specific to the module object (using e.g. using PyModule\_GetState()), or its contents (such as the module’s \_\_dict\_\_ or individual classes created with PyType\_FromSpec()).

All modules created using multi-phase initialization are expected to support sub-interpreters. Making sure multiple modules are independent is typically enough to achieve this.

To request multi-phase initialization, the initialization function (PyInit\_modulename) returns a PyModuleDef instance with non-empty m\_slots. Before it is returned, the PyModuleDef instance must be initialized with the following function:

\[
\text{PyObject* PyModuleDef\_Init(PyModuleDef *def)}
\]
Ensures a module definition is a properly initialized Python object that correctly reports its type and reference count.

Returns `def` cast to `PyObject*`, or `NULL` if an error occurred.

*New in version 3.5.*

The `m_slots` member of the module definition must point to an array of `PyModuleDef_Slot` structures:

**PyModuleDef_Slot**

- `int slot`
  - A slot ID, chosen from the available values explained below.

- `void* value`
  - Value of the slot, whose meaning depends on the slot ID.

*New in version 3.5.*

The `m_slots` array must be terminated by a slot with id 0.

The available slot types are:

**Py_mod_create**

Specifies a function that is called to create the module object itself. The `value` pointer of this slot must point to a function of the signature:

```c
PyObject* create_module(PyObject *spec, PyModuleDef *def)
```

The function receives a `ModuleSpec` instance, as defined in [PEP 451](https://www.python.org/dev/peps/pep-0451/), and the module definition. It should return a new module object, or set an error and return `NULL`. 
This function should be kept minimal. In particular, it should not call arbitrary Python code, as trying to import the same module again may result in an infinite loop.

Multiple Py_mod_create slots may not be specified in one module definition.

If Py_mod_create is not specified, the import machinery will create a normal module object using PyModule_New(). The name is taken from spec, not the definition, to allow extension modules to dynamically adjust to their place in the module hierarchy and be imported under different names through symlinks, all while sharing a single module definition.

There is no requirement for the returned object to be an instance of PyModule_Type. Any type can be used, as long as it supports setting and getting import-related attributes. However, only PyModule_Type instances may be returned if the PyModuleDef has non-NULL m_methods, m_traverse, m_clear, m_free; non-zero m_size; or slots other than Py_mod_create.

**Py_mod_exec**

Specifies a function that is called to execute the module. This is equivalent to executing the code of a Python module: typically, this function adds classes and constants to the module. The signature of the function is:

```c
int exec_module(PyObject* module)
```

If multiple Py_mod_exec slots are specified, they are processed in the order they appear in the m_slots array.

See PEP 489 for more details on multi-phase initialization.
Low-level module creation functions

The following functions are called under the hood when using multi-phase initialization. They can be used directly, for example when creating module objects dynamically. Note that both `PyModule_FromDefAndSpec` and `PyModule_ExecDef` must be called to fully initialize a module.

```c
PyObject * PyModule_FromDefAndSpec(PyModuleDef *def, PyObject *spec)
```

Create a new module object, given the definition in `module` and the `ModuleSpec spec`. This behaves like `PyModule_FromDefAndSpec2()` with `module_api_version` set to `PYTHON_API_VERSION`.

New in version 3.5.

```c
PyObject * PyModule_FromDefAndSpec2(PyModuleDef *def, PyObject *spec, int module_api_version)
```

Create a new module object, given the definition in `module` and the `ModuleSpec spec`, assuming the API version `module_api_version`. If that version does not match the version of the running interpreter, a `RuntimeWarning` is emitted.

**Note:** Most uses of this function should be using `PyModule_FromDefAndSpec()` instead; only use this if you are sure you need it.

New in version 3.5.

```c
int PyModule_ExecDef(PyObject *module, PyModuleDef *def)
```

Process any execution slots (`Py_mod_exec`) given in `def`. 
New in version 3.5.

int **PyModule_SetDocString**((PyObject *, const char *)

Set the docstring for *module* to *docstring*. This function is called automatically when creating a module from PyModuleDef, using either PyModule_Create or PyModule_FromDefAndSpec.

New in version 3.5.

int **PyModule_AddFunctions**((PyObject *, PyMethodDef *)

Add the functions from the NULL terminated *functions* array to *module*. Refer to the PyMethodDef documentation for details on individual entries (due to the lack of a shared module namespace, module level “functions” implemented in C typically receive the module as their first parameter, making them similar to instance methods on Python classes). This function is called automatically when creating a module from PyModuleDef, using either PyModule_Create or PyModule_FromDefAndSpec.

New in version 3.5.

Support functions

The module initialization function (if using single phase initialization) or a function called from a module execution slot (if using multi-phase initialization), can use the following functions to help initialize the module state:

int **PyModule_AddObject**((PyObject *, const char *, PyObject *)


Add an object to `module` as `name`. This is a convenience function which can be used from the module's initialization function. This steals a reference to `value`. Return -1 on error, 0 on success.

```c
int PyModule_AddIntConstant(PyObject *module, const char *name, long value)
```

Add an integer constant to `module` as `name`. This convenience function can be used from the module's initialization function. Return -1 on error, 0 on success.

```c
int PyModule_AddStringConstant(PyObject *module, const char *name, const char *value)
```

Add a string constant to `module` as `name`. This convenience function can be used from the module's initialization function. The string `value` must be `NULL`-terminated. Return -1 on error, 0 on success.

```c
int PyModule_AddIntMacro(PyObject *module, macro)
```

Add an int constant to `module`. The name and the value are taken from `macro`. For example `PyModule_AddIntMacro(module, AF_INET)` adds the int constant `AF_INET` with the value of `AF_INET` to `module`. Return -1 on error, 0 on success.

```c
int PyModule_AddStringMacro(PyObject *module, macro)
```

Add a string constant to `module`.
Module lookup

Single-phase initialization creates singleton modules that can be looked up in the context of the current interpreter. This allows the module object to be retrieved later with only a reference to the module definition.

These functions will not work on modules created using multi-phase initialization, since multiple such modules can be created from a single definition.

PyObject* PyState_FindModule(PyModuleDef *def)

Returns the module object that was created from def for the current interpreter. This method requires that the module object has been attached to the interpreter state with PyState_AddModule() beforehand. In case the corresponding module object is not found or has not been attached to the interpreter state yet, it returns NULL.

int PyState_AddModule(PyObject *module, PyModuleDef *def)

Attaches the module object passed to the function to the interpreter state. This allows the module object to be accessible via PyState_FindModule().

Only effective on modules created using single-phase initialization.

New in version 3.3.

int PyState_RemoveModule(PyModuleDef *def)

Removes the module object created from def from the interpreter state.
New in version 3.3.
Iterator Objects

Python provides two general-purpose iterator objects. The first, a sequence iterator, works with an arbitrary sequence supporting the __getitem__() method. The second works with a callable object and a sentinel value, calling the callable for each item in the sequence, and ending the iteration when the sentinel value is returned.

PyTypeObject PySeqIter_Type
Type object for iterator objects returned by PySeqIter_New() and the one-argument form of the iter() built-in function for built-in sequence types.

int PySeqIter_Check(op)
Return true if the type of op is PySeqIter_Type.

PyObject* PySeqIter_New(PyObject *seq)
Return an iterator that works with a general sequence object, seq. The iteration ends when the sequence raises IndexError for the subscripting operation.

PyTypeObject PyCallIter_Type
Type object for iterator objects returned by PyCallIter_New() and the two-argument form of the iter() built-in function.

int PyCallIter_Check(op)
Return true if the type of op is PyCallIter_Type.

PyObject* PyCallIter_New(PyObject *callable, PyObject *sentinel)
**Return value: New reference.**

Return a new iterator. The first parameter, `callable`, can be any Python callable object that can be called with no parameters; each call to it should return the next item in the iteration. When `callable` returns a value equal to `sentinel`, the iteration will be terminated.
Descriptor Objects

“Descriptors” are objects that describe some attribute of an object. They are found in the dictionary of type objects.

*PyTypeObject* **PyProperty_Type**
- The type object for the built-in descriptor types.

*PyObject* **PyDescr_NewGetSet**(PyTypeObject *type, struct PyGetSetDef *getset)

  *Return value: New reference.*

*PyObject* **PyDescr_NewMember**(PyTypeObject *type, struct PyMemberDef *meth)

  *Return value: New reference.*

*PyObject* **PyDescr_NewMethod**(PyTypeObject *type, struct PyMethodDef *meth)

  *Return value: New reference.*

*PyObject* **PyDescr_NewWrapper**(PyTypeObject *type, struct wrapperbase *wrapper, void *wrapped)

  *Return value: New reference.*

*PyObject* **PyDescr_NewClassMethod**(PyTypeObject *type, PyMethodDef *method)

  *Return value: New reference.*

*int* **PyDescr_IsData**(PyObject *descr)

  Return true if the descriptor objects *descr* describes a data attribute, or false if it describes a method. *descr* must be a descriptor object; there is no error checking.
PyObject* PyWrapper_New(PyObject *, PyObject *)

*Return value: New reference.*
Slice Objects

**PyTypeObject** **PySlice_Type**

The type object for slice objects. This is the same as `slice` in the Python layer.

```c
int PySlice_Check(PyObject *ob)
```

Return true if `ob` is a slice object; `ob` must not be `NULL`.

**PyObject** **PySlice_New(PyObject *start, PyObject *stop, PyObject *step)**

*Return value: New reference.*

Return a new slice object with the given values. The `start`, `stop`, and `step` parameters are used as the values of the slice object attributes of the same names. Any of the values may be `NULL`, in which case the `None` will be used for the corresponding attribute. Return `NULL` if the new object could not be allocated.

```c
int PySlice_GetIndices(PyObject *slice, Py_ssize_t length, Py_ssize_t *start, Py_ssize_t *stop, Py_ssize_t *step)
```

Retrieve the start, stop and step indices from the slice object `slice`, assuming a sequence of length `length`. Treats indices greater than `length` as errors.

Returns 0 on success and -1 on error with no exception set (unless one of the indices was not `None` and failed to be converted to an integer, in which case -1 is returned with an exception set).

You probably do not want to use this function.

*Changed in version 3.2:* The parameter type for the `slice` parameter
int **PySlice_GetIndicesEx**(**PyObject *slice, Py_ssize_t length, Py_ssize_t *start, Py_ssize_t *stop, Py_ssize_t *step, Py_ssize_t *slicelength**)

Usable replacement for **PySlice_GetIndices()**. Retrieve the start, stop, and step indices from the slice object *slice* assuming a sequence of length *length*, and store the length of the slice in *slicelength*. Out of bounds indices are clipped in a manner consistent with the handling of normal slices.

Returns 0 on success and -1 on error with exception set.

*Changed in version 3.2*: The parameter type for the *slice* parameter was **PySliceObject** before.
MemoryView objects

A memoryview object exposes the C level buffer interface as a Python object which can then be passed around like any other object.

PyObject *PyMemoryView_FromObject(PyObject *obj)

Create a memoryview object from an object that provides the buffer interface. If obj supports writable buffer exports, the memoryview object will be read/write, otherwise it may be either read-only or read/write at the discretion of the exporter.

PyObject *PyMemoryView_FromMemory(char *mem, Py_ssize_t size, int flags)

Create a memoryview object using mem as the underlying buffer. flags can be one of PyBUF_READ or PyBUF_WRITE.

New in version 3.3.

PyObject *PyMemoryView_FromBuffer(Py_buffer *view)

Create a memoryview object wrapping the given buffer structure view. For simple byte buffers, PyMemoryView_FromMemory() is the preferred function.

PyObject *PyMemoryView_GetContiguous(PyObject *obj, int buffertype, char order)

Create a memoryview object to a contiguous chunk of memory (in either ‘C’ or ‘Fortran order) from an object that defines the buffer interface. If memory is contiguous, the memoryview object points to the original memory. Otherwise, a copy is made and the memoryview points to a new bytes object.
int PyMemoryView_Check(PyObject *obj)

Return true if the object \texttt{obj} is a memoryview object. It is not currently allowed to create subclasses of \texttt{memoryview}.

\textbf{Py_buffer *}PyMemoryView\_GET\_BUFFER(PyObject *mview)

Return a pointer to the memoryview's private copy of the exporter's buffer. \texttt{mview must} be a memoryview instance; this macro doesn't check its type, you must do it yourself or you will risk crashes.

\textbf{Py_buffer *}PyMemoryView\_GET\_BASE(PyObject *mview)

Return either a pointer to the exporting object that the memoryview is based on or \texttt{NULL} if the memoryview has been created by one of the functions \texttt{PyMemoryView\_FromMemory()} or \texttt{PyMemoryView\_FromBuffer()}. \texttt{mview must} be a memoryview instance.
Weak Reference Objects

Python supports weak references as first-class objects. There are two specific object types which directly implement weak references. The first is a simple reference object, and the second acts as a proxy for the original object as much as it can.

```c
int PyWeakref_Check(ob)
    Return true if ob is either a reference or proxy object.
```

```c
int PyWeakref_CheckRef(ob)
    Return true if ob is a reference object.
```

```c
int PyWeakref_CheckProxy(ob)
    Return true if ob is a proxy object.
```

```c
PyObject* PyWeakref_NewRef(PyObject *ob, PyObject *callback)
    Return a weak reference object for the object ob. This will always return a new reference, but is not guaranteed to create a new object; an existing reference object may be returned. The second parameter, callback, can be a callable object that receives notification when ob is garbage collected; it should accept a single parameter, which will be the weak reference object itself. callback may also be None or NULL. If ob is not a weakly-referencable object, or if callback is not callable, None, or NULL, this will return NULL and raise TypeError.
```

```c
PyObject* PyWeakref_NewProxy(PyObject *ob, PyObject *callback)
```

Return a weak reference proxy object for the object \textit{ob}. This will always return a new reference, but is not guaranteed to create a new object; an existing proxy object may be returned. The second parameter, \textit{callback}, can be a callable object that receives notification when \textit{ob} is garbage collected; it should accept a single parameter, which will be the weak reference object itself. \textit{callback} may also be None or \textit{NULL}. If \textit{ob} is not a weakly-referencable object, or if \textit{callback} is not callable, None, or \textit{NULL}, this will return \textit{NULL} and raise \texttt{TypeError}.

\textbf{PyObject* \texttt{PyWeakref\_GetObject}(PyObject *\texttt{ref})}

\textit{Return value: Borrowed reference.}

Return the referenced object from a weak reference, \textit{ref}. If the referent is no longer live, returns \texttt{Py\_None}.

\begin{center}
\textbf{Note:} This function returns a \texttt{borrowed reference} to the referenced object. This means that you should always call \texttt{Py\_INCREF()} on the object except if you know that it cannot be destroyed while you are still using it.
\end{center}

\textbf{PyObject* \texttt{PyWeakref\_GET\_OBJECT}(PyObject *\texttt{ref})}

\textit{Return value: Borrowed reference.}

Similar to \texttt{PyWeakref\_GetObject()}, but implemented as a macro that does no error checking.
Capsules

Refer to Providing a C API for an Extension Module for more information on using these objects.

PyCapsule

This subtype of PyObject represents an opaque value, useful for C extension modules who need to pass an opaque value (as a void* pointer) through Python code to other C code. It is often used to make a C function pointer defined in one module available to other modules, so the regular import mechanism can be used to access C APIs defined in dynamically loaded modules.

PyCapsule_Destructor

The type of a destructor callback for a capsule. Defined as:

```c
typedef void (*PyCapsule_Destructor)(PyObject *);
```

See PyCapsule_New() for the semantics of PyCapsule_Destructor callbacks.

int PyCapsule_CheckExact(PyObject *p)

Return true if its argument is a PyCapsule.

PyObject* PyCapsule_New(void *pointer, const char *name, PyCapsule_Destructor destructor)

*Return value: New reference.*

Create a PyCapsule encapsulating the pointer. The pointer argument may not be NULL.

On failure, set an exception and return NULL.
The name string may either be NULL or a pointer to a valid C string. If non-NULL, this string must outlive the capsule. (Though it is permitted to free it inside the destructor.)

If the destructor argument is not NULL, it will be called with the capsule as its argument when it is destroyed.

If this capsule will be stored as an attribute of a module, the name should be specified as modulename.attributename. This will enable other modules to import the capsule using PyCapsule_Import().

```c
void* PyCapsule_GetPointer(PyObject *capsule, const char *name)
Retrieve the pointer stored in the capsule. On failure, set an exception and return NULL.
```

The name parameter must compare exactly to the name stored in the capsule. If the name stored in the capsule is NULL, the name passed in must also be NULL. Python uses the C function strcmp() to compare capsule names.

```c
PyCapsule_Destructor
PyCapsule_GetDestructor(PyObject *capsule)
Return the current destructor stored in the capsule. On failure, set an exception and return NULL.
```

It is legal for a capsule to have a NULL destructor. This makes a NULL return code somewhat ambiguous; use PyCapsule_IsValid() or PyErr_Occurred() to disambiguate.

```c
void* PyCapsule_GetContext(PyObject *capsule)
Return the current context stored in the capsule. On failure, set an exception and return `NULL`.

It is legal for a capsule to have a `NULL` context. This makes a `NULL` return code somewhat ambiguous; use `PyCapsule_IsValid()` or `PyErr_Occurred()` to disambiguate.

```c
const char* PyCapsule_GetName(PyObject *capsule)
```

Return the current name stored in the capsule. On failure, set an exception and return `NULL`.

It is legal for a capsule to have a `NULL` name. This makes a `NULL` return code somewhat ambiguous; use `PyCapsule_IsValid()` or `PyErr_Occurred()` to disambiguate.

```c
void* PyCapsule_Import(const char *name, int no_block)
```

Import a pointer to a C object from a capsule attribute in a module. The `name` parameter should specify the full name to the attribute, as in `module.attribute`. The `name` stored in the capsule must match this string exactly. If `no_block` is true, import the module without blocking (using `PyImport_ImportModuleNoBlock()`). If `no_block` is false, import the module conventionally (using `PyImport_ImportModule()`).

Return the capsule's internal `pointer` on success. On failure, set an exception and return `NULL`. However, if `PyCapsule_Import()` failed to import the module, and `no_block` was true, no exception is set.

```c
int PyCapsule_IsValid(PyObject *capsule, const char *name)
```

Determines whether or not `capsule` is a valid capsule. A valid
capsule is non-NULL, passes `PyCapsule_CheckExact()`, has a non-NULL pointer stored in it, and its internal name matches the name parameter. (See `PyCapsule_GetPointer()` for information on how capsule names are compared.)

In other words, if `PyCapsule_IsValid()` returns a true value, calls to any of the accessors (any function starting with `PyCapsule_Get()`) are guaranteed to succeed.

Return a nonzero value if the object is valid and matches the name passed in. Return 0 otherwise. This function will not fail.

```c
int PyCapsule_SetContext(PyObject *capsule, void *context)
```

Set the context pointer inside `capsule` to `context`.

Return 0 on success. Return nonzero and set an exception on failure.

```c
int PyCapsule_SetDestructor(PyObject *capsule, PyCapsule_Destructor destructor)
```

Set the destructor inside `capsule` to `destructor`.

Return 0 on success. Return nonzero and set an exception on failure.

```c
int PyCapsule_SetName(PyObject *capsule, const char *name)
```

Set the name inside `capsule` to `name`. If non-NULL, the name must outlive the capsule. If the previous `name` stored in the capsule was not NULL, no attempt is made to free it.

Return 0 on success. Return nonzero and set an exception on failure.

```c
int PyCapsule_SetPointer(PyObject *capsule, void *pointer)
```
Set the void pointer inside `capsule` to `pointer`. The pointer may not be `NULL`.

Return 0 on success. Return nonzero and set an exception on failure.
Generator Objects

Generator objects are what Python uses to implement generator iterators. They are normally created by iterating over a function that yields values, rather than explicitly calling `PyGen_New()` or `PyGen_NewWithQualName()`.

**PyGenObject**

The C structure used for generator objects.

**PyTypeObject** `PyGen_Type`

The type object corresponding to generator objects.

```c
int PyGen_Check(PyObject *ob)
```

Return true if `ob` is a generator object; `ob` must not be NULL.

```c
int PyGen_CheckExact(PyObject *ob)
```

Return true if `ob`'s type is `PyGen_Type`; `ob` must not be NULL.

```c
PyObject* PyGen_New(PyFrameObject *frame)
```


Create and return a new generator object based on the `frame` object. A reference to `frame` is stolen by this function. The argument must not be NULL.

```c
PyObject* PyGen_NewWithQualName(PyFrameObject *frame, PyObject *name, PyObject *qualname)
```


Create and return a new generator object based on the `frame` object, with `__name__` and `__qualname__` set to `name` and `qualname`. A reference to `frame` is stolen by this function. The
frame argument must not be NULL.
Coroutine Objects

New in version 3.5.

Coroutine objects are what functions declared with an async keyword return.

**PyCoroObject**

The C structure used for coroutine objects.

**PyTypeObject PyCoro_Type**

The type object corresponding to coroutine objects.

```c
int PyCoro_CheckExact(PyObject *ob)
```

Return true if ob's type is PyCoro_Type; ob must not be NULL.

```c
PyObject* PyCoro_New(PyFrameObject *frame, PyObject *name, PyObject *qualname)
```

*Return value: New reference.*

Create and return a new coroutine object based on the frame object, with __name__ and __qualname__ set to name and qualname. A reference to frame is stolen by this function. The frame argument must not be NULL.
DateTime Objects

Various date and time objects are supplied by the `datetime` module. Before using any of these functions, the header file `datetime.h` must be included in your source (note that this is not included by `Python.h`), and the macro `PyDateTime_IMPORT` must be invoked, usually as part of the module initialisation function. The macro puts a pointer to a C structure into a static variable, `PyDateTimeAPI`, that is used by the following macros.

Type-check macros:

```c
int PyDate_Check(PyObject *ob)
   Return true if `ob` is of type `PyDateTime_DateType` or a subtype of `PyDateTime_DateType`. `ob` must not be `NULL`.

int PyDate_CheckExact(PyObject *ob)
   Return true if `ob` is of type `PyDateTime_DateType`. `ob` must not be `NULL`.

int PyDateTime_Check(PyObject *ob)
   Return true if `ob` is of type `PyDateTime_DateTimeType` or a subtype of `PyDateTime_DateTimeType`. `ob` must not be `NULL`.

int PyDateTime_CheckExact(PyObject *ob)
   Return true if `ob` is of type `PyDateTime_DateTimeType`. `ob` must not be `NULL`.

int PyTime_Check(PyObject *ob)
   Return true if `ob` is of type `PyDateTime_TimeType` or a subtype of `PyDateTime_TimeType`. `ob` must not be `NULL`.
```
int `PyTime_CheckExact`(`PyObject *ob`)
    Return true if `ob` is of type `PyDateTime_TimeType`. `ob` must not be `NULL`.

int `PyDelta_Check`(`PyObject *ob`)
    Return true if `ob` is of type `PyDateTime_DeltaType` or a subtype of `PyDateTime_DeltaType`. `ob` must not be `NULL`.

int `PyDelta_CheckExact`(`PyObject *ob`)
    Return true if `ob` is of type `PyDateTime_DeltaType`. `ob` must not be `NULL`.

int `PyTZInfo_Check`(`PyObject *ob`)
    Return true if `ob` is of type `PyDateTime_TZInfoType` or a subtype of `PyDateTime_TZInfoType`. `ob` must not be `NULL`.

int `PyTZInfo_CheckExact`(`PyObject *ob`)
    Return true if `ob` is of type `PyDateTime_TZInfoType`. `ob` must not be `NULL`.

Macros to create objects:

`PyObject* PyDate_FromDate(int year, int month, int day)`
    Return a datetime.date object with the specified year, month and day.

`PyObject* PyDateTime_FromDateAndTime(int year, int month, int day, int hour, int minute, int second, int usecond)`
    Return a datetime.datetime object with the specified year,
month, day, hour, minute, second and microsecond.

**PyObject** *PyTime_FromTime* (int *hour*, int *minute*, int *second*, int *usecond*)

*Return value: New reference.*
Return a datetime.time object with the specified hour, minute, second and microsecond.

**PyObject** *PyDelta_FromDSU* (int *days*, int *seconds*, int *useconds*)

*Return value: New reference.*
Return a datetime.timedelta object representing the given number of days, seconds and microseconds. Normalization is performed so that the resulting number of microseconds and seconds lie in the ranges documented for datetime.timedelta objects.

Macros to extract fields from date objects. The argument must be an instance of PyDateTime_Date, including subclasses (such as PyDateTime_DateTime). The argument must not be NULL, and the type is not checked:

int *PyDateTime_GET_YEAR* (PyDateTime_Date *o*)
Return the year, as a positive int.

int *PyDateTime_GET_MONTH* (PyDateTime_Date *o*)
Return the month, as an int from 1 through 12.

int *PyDateTime_GET_DAY* (PyDateTime_Date *o*)
Return the day, as an int from 1 through 31.

Macros to extract fields from datetime objects. The argument must be an instance of PyDateTime_DateTime, including subclasses. The argument must not be NULL, and the type is not checked:
int PyDateTime_DATE_GET_HOUR(PyDateTime_DateTime *o)
    Return the hour, as an int from 0 through 23.

int PyDateTime_DATE_GET_MINUTE(PyDateTime_DateTime *o)
    Return the minute, as an int from 0 through 59.

int PyDateTime_DATE_GET_SECOND(PyDateTime_DateTime *o)
    Return the second, as an int from 0 through 59.

int PyDateTime_DATE_GET_MICROSECOND(PyDateTime_DateTime *o)
    Return the microsecond, as an int from 0 through 999999.

Macros to extract fields from time objects. The argument must be an instance of PyDateTime_Time, including subclasses. The argument must not be NULL, and the type is not checked:

int PyDateTime_TIME_GET_HOUR(PyDateTime_Time *o)
    Return the hour, as an int from 0 through 23.

int PyDateTime_TIME_GET_MINUTE(PyDateTime_Time *o)
    Return the minute, as an int from 0 through 59.

int PyDateTime_TIME_GET_SECOND(PyDateTime_Time *o)
    Return the second, as an int from 0 through 59.

int PyDateTime_TIME_GET_MICROSECOND(PyDateTime_Time *o)
    Return the microsecond, as an int from 0 through 999999.

Macros to extract fields from time delta objects. The argument must be an instance of PyDateTime_Delta, including subclasses. The
argument must not be NULL, and the type is not checked:

```c
int PyDateTime_DELTA_GET_DAYS(PyDateTime_Delta *o)
  Return the number of days, as an int from -999999999 to 999999999.

  New in version 3.3.
```

```c
int PyDateTime_DELTA_GET_SECONDS(PyDateTime_Delta *o)
  Return the number of seconds, as an int from 0 through 86399.

  New in version 3.3.
```

```c
int PyDateTime_DELTA_GET_MICROSECOND(PyDateTime_Delta *o)
  Return the number of microseconds, as an int from 0 through 999999.

  New in version 3.3.
```

Macros for the convenience of modules implementing the DB API:

```c
PyObject* PyDateTime_FromTimestamp(PyObject *args)
  Create and return a new datetime.datetime object given an argument tuple suitable for passing to datetime.datetime.fromtimestamp().
```

```c
PyObject* PyDate_FromTimestamp(PyObject *args)
  Create and return a new datetime.date object given an argument tuple suitable for passing to datetime.date.fromtimestamp().
```
Initialization, Finalization, and Threads
Initializing and finalizing the interpreter

**void Py_Initialize()**

Initialize the Python interpreter. In an application embedding Python, this should be called before using any other Python/C API functions; with the exception of `Py_SetProgramName()`, `Py_SetPythonHome()` and `Py_SetPath()`. This initializes the table of loaded modules (`sys.modules`), and creates the fundamental modules `builtins`, `__main__` and `sys`. It also initializes the module search path (`sys.path`). It does not set `sys.argv`; use `PySys_SetArgvEx()` for that. This is a no-op when called for a second time (without calling `Py_Finalize()` first). There is no return value; it is a fatal error if the initialization fails.

**void Py_InitializeEx(int initsigs)**

This function works like `Py_Initialize()` if `initsigs` is 1. If `initsigs` is 0, it skips initialization registration of signal handlers, which might be useful when Python is embedded.

**int Py_IsInitialized()**

Return true (nonzero) when the Python interpreter has been initialized, false (zero) if not. After `Py_Finalize()` is called, this returns false until `Py_Initialize()` is called again.

**void Py_Finalize()**

Undo all initializations made by `Py_Initialize()` and subsequent use of Python/C API functions, and destroy all sub-interpreters (see `Py_NewInterpreter()` below) that were created and not yet destroyed since the last call to
Py_Initialize(). Ideally, this frees all memory allocated by the Python interpreter. This is a no-op when called for a second time (without calling Py_Initialize() again first). There is no return value; errors during finalization are ignored.

This function is provided for a number of reasons. An embedding application might want to restart Python without having to restart the application itself. An application that has loaded the Python interpreter from a dynamically loadable library (or DLL) might want to free all memory allocated by Python before unloading the DLL. During a hunt for memory leaks in an application a developer might want to free all memory allocated by Python before exiting from the application.

**Bugs and caveats:** The destruction of modules and objects in modules is done in random order; this may cause destructors (__del__() methods) to fail when they depend on other objects (even functions) or modules. Dynamically loaded extension modules loaded by Python are not unloaded. Small amounts of memory allocated by the Python interpreter may not be freed (if you find a leak, please report it). Memory tied up in circular references between objects is not freed. Some memory allocated by extension modules may not be freed. Some extensions may not work properly if their initialization routine is called more than once; this can happen if an application calls Py_Initialize() and Py_Finalize() more than once.
Process-wide parameters

int Py_SetStandardStreamEncoding(const char *encoding, const char *errors)

This function should be called before Py_Initialize(), if it is called at all. It specifies which encoding and error handling to use with standard IO, with the same meanings as in str.encode().

It overrides PYTHONIOENCODING values, and allows embedding code to control IO encoding when the environment variable does not work.

encoding and/or errors may be NULL to use PYTHONIOENCODING and/or default values (depending on other settings).

Note that sys.stderr always uses the “backslashreplace” error handler, regardless of this (or any other) setting.

If Py_Finalize() is called, this function will need to be called again in order to affect subsequent calls to Py_Initialize().

Returns 0 if successful, a nonzero value on error (e.g. calling after the interpreter has already been initialized).

New in version 3.4.

void Py_SetProgramName(wchar_t *name)

This function should be called before Py_Initialize() is called for the first time, if it is called at all. It tells the interpreter the value of the argv[0] argument to the main() function of the program (converted to wide characters). This is used by Py_GetPath()
and some other functions below to find the Python run-time libraries relative to the interpreter executable. The default value is 'python'. The argument should point to a zero-terminated wide character string in static storage whose contents will not change for the duration of the program’s execution. No code in the Python interpreter will change the contents of this storage.

Use `Py_DecodeLocale()` to decode a bytes string to get a `wchar_*` string.

`wchar* Py_GetProgramName()`
Return the program name set with `Py_SetProgramName()`, or the default. The returned string points into static storage; the caller should not modify its value.

`wchar_t* Py_GetPrefix()`
Return the prefix for installed platform-independent files. This is derived through a number of complicated rules from the program name set with `Py_SetProgramName()` and some environment variables; for example, if the program name is '/usr/local/bin/python', the prefix is '/usr/local'. The returned string points into static storage; the caller should not modify its value. This corresponds to the prefix variable in the top-level Makefile and the --prefix argument to the configure script at build time. The value is available to Python code as `sys.prefix`. It is only useful on Unix. See also the next function.

`wchar_t* Py_GetExecPrefix()`
Return the exec-prefix for installed platform-dependent files. This is derived through a number of complicated rules from the program name set with `Py_SetProgramName()` and some environment variables; for example, if the program name is
'/usr/local/bin/python', the exec-prefix is '/usr/local'. The returned string points into static storage; the caller should not modify its value. This corresponds to the exec_prefix variable in the top-level Makefile and the --exec-prefix argument to the configure script at build time. The value is available to Python code as sys.exec_prefix. It is only useful on Unix.

Background: The exec-prefix differs from the prefix when platform dependent files (such as executables and shared libraries) are installed in a different directory tree. In a typical installation, platform dependent files may be installed in the /usr/local/plat subtree while platform independent may be installed in /usr/local.

Generally speaking, a platform is a combination of hardware and software families, e.g. Sparc machines running the Solaris 2.x operating system are considered the same platform, but Intel machines running Solaris 2.x are another platform, and Intel machines running Linux are yet another platform. Different major revisions of the same operating system generally also form different platforms. Non-Unix operating systems are a different story; the installation strategies on those systems are so different that the prefix and exec-prefix are meaningless, and set to the empty string. Note that compiled Python bytecode files are platform independent (but not independent from the Python version by which they were compiled!).

System administrators will know how to configure the mount or automount programs to share /usr/local between platforms while having /usr/local/plat be a different filesystem for each platform.
wchar_t* **Py_GetProgramFullPath()**

Return the full program name of the Python executable; this is computed as a side-effect of deriving the default module search path from the program name (set by **Py_SetProgramName()** above). The returned string points into static storage; the caller should not modify its value. The value is available to Python code as **sys.executable**.

wchar_t* **Py_GetPath()**

Return the default module search path; this is computed from the program name (set by **Py_SetProgramName()** above) and some environment variables. The returned string consists of a series of directory names separated by a platform dependent delimiter character. The delimiter character is ':' on Unix and Mac OS X, ';' on Windows. The returned string points into static storage; the caller should not modify its value. The list **sys.path** is initialized with this value on interpreter startup; it can be (and usually is) modified later to change the search path for loading modules.

void **Py_SetPath**(const wchar_t *)

Set the default module search path. If this function is called before **Py_Initialize()**, then **Py_GetPath()** won't attempt to compute a default search path but uses the one provided instead. This is useful if Python is embedded by an application that has full knowledge of the location of all modules. The path components should be separated by the platform dependent delimiter character, which is ':' on Unix and Mac OS X, ';' on Windows.

This also causes **sys.executable** to be set only to the raw program name (see **Py_SetProgramName()**) and for **sys.prefix** and **sys.exec_prefix** to be empty. It is up to the
caller to modify these if required after calling \texttt{Py\_Initialize()}. 

Use \texttt{Py\_DecodeLocale()} to decode a bytes string to get a \texttt{wchar\_*} string.

The path argument is copied internally, so the caller may free it after the call completes.

\texttt{const char* Py\_GetVersion()}

Return the version of this Python interpreter. This is a string that looks something like

\begin{verbatim}
"3.0a5+ (py3k:63103M, May 12 2008, 00:53:55) \n\n[G

The first word (up to the first space character) is the current Python version; the first three characters are the major and minor version separated by a period. The returned string points into static storage; the caller should not modify its value. The value is available to Python code as \texttt{sys.version}.

\texttt{const char* Py\_GetPlatform()}

Return the platform identifier for the current platform. On Unix, this is formed from the “official” name of the operating system, converted to lower case, followed by the major revision number; e.g., for Solaris 2.x, which is also known as SunOS 5.x, the value is 'sunos5'. On Mac OS X, it is 'darwin'. On Windows, it is 'win'. The returned string points into static storage; the caller should not modify its value. The value is available to Python code as \texttt{sys.platform}.

\texttt{const char* Py\_GetCopyright()}

Return the official copyright string for the current Python version,
for example

'Copyright 1991-1995 Stichting Mathematisch Centrum, Amsterdam'

The returned string points into static storage; the caller should not modify its value. The value is available to Python code as sys.copyright.

const char* Py_GetCompiler()

Return an indication of the compiler used to build the current Python version, in square brackets, for example:

"[GCC 2.7.2.2]"

The returned string points into static storage; the caller should not modify its value. The value is available to Python code as part of the variable sys.version.

const char* Py_GetBuildInfo()

Return information about the sequence number and build date and time of the current Python interpreter instance, for example:

"#67, Aug 1 1997, 22:34:28"

The returned string points into static storage; the caller should not modify its value. The value is available to Python code as part of the variable sys.version.

void PySys_SetArgvEx(int argc, wchar_t **argv, int updatepath)

Set sys.argv based on argc and argv. These parameters are similar to those passed to the program's main() function with the difference that the first entry should refer to the script file to be
executed rather than the executable hosting the Python interpreter. If there isn't a script that will be run, the first entry in *argv* can be an empty string. If this function fails to initialize *sys.argv*, a fatal condition is signalled using *Py_FatalError()*.

If *updatepath* is zero, this is all the function does. If *updatepath* is non-zero, the function also modifies *sys.path* according to the following algorithm:

- If the name of an existing script is passed in *argv*[0], the absolute path of the directory where the script is located is prepended to *sys.path*.
- Otherwise (that is, if *argc* is 0 or *argv*[0] doesn't point to an existing file name), an empty string is prepended to *sys.path*, which is the same as prepending the current working directory (".").

Use *Py_DecodeLocale()* to decode a bytes string to get a *wchar_* string.

**Note:** It is recommended that applications embedding the Python interpreter for purposes other than executing a single script pass 0 as *updatepath*, and update *sys.path* themselves if desired. See [CVE-2008-5983](CVE-2008-5983).

On versions before 3.1.3, you can achieve the same effect by manually popping the first *sys.path* element after having called *PySys_SetArgv()*, for example using:

```python
PyRun_SimpleString("import sys; sys.path.pop(0)\n")
```

*New in version 3.1.3.*
void **PySys_SetArgv**(int argc, wchar_t **argv)

This function works like `PySys_SetArgvEx()` with `updatepath` set to 1 unless the `python` interpreter was started with the `-I`.

Use `Py_DecodeLocale()` to decode a bytes string to get a `wchar_*` string.

*Changed in version 3.4:* The `updatepath` value depends on `-I`.

void **Py_SetPythonHome**(wchar_t *home)

Set the default “home” directory, that is, the location of the standard Python libraries. See `PYTHONHOME` for the meaning of the argument string.

The argument should point to a zero-terminated character string in static storage whose contents will not change for the duration of the program’s execution. No code in the Python interpreter will change the contents of this storage.

Use `Py_DecodeLocale()` to decode a bytes string to get a `wchar_*` string.

w_char* **Py_GetPythonHome**()

Return the default “home”, that is, the value set by a previous call to `Py_SetPythonHome()`, or the value of the `PYTHONHOME` environment variable if it is set.
Thread State and the Global Interpreter Lock

The Python interpreter is not fully thread-safe. In order to support multi-threaded Python programs, there's a global lock, called the global interpreter lock or GIL, that must be held by the current thread before it can safely access Python objects. Without the lock, even the simplest operations could cause problems in a multi-threaded program: for example, when two threads simultaneously increment the reference count of the same object, the reference count could end up being incremented only once instead of twice.

Therefore, the rule exists that only the thread that has acquired the GIL may operate on Python objects or call Python/C API functions. In order to emulate concurrency of execution, the interpreter regularly tries to switch threads (see `sys.setswitchinterval()`). The lock is also released around potentially blocking I/O operations like reading or writing a file, so that other Python threads can run in the meantime.

The Python interpreter keeps some thread-specific bookkeeping information inside a data structure called `PyThreadState`. There's also one global variable pointing to the current `PyThreadState`: it can be retrieved using `PyThreadState_Get()`.

Releasing the GIL from extension code

Most extension code manipulating the GIL has the following simple structure:

Save the `thread` state in a local variable.
Release the global interpreter lock.
... Do some blocking I/O operation ...  
Reacquire the global interpreter lock.  
Restore the **thread** state from the local variable.

This is so common that a pair of macros exists to simplify it:

```c
Py_BEGIN_ALLOW_THREADS  
... Do some blocking I/O operation ...  
Py_END_ALLOW_THREADS
```

The `Py_BEGIN_ALLOW_THREADS` macro opens a new block and declares a hidden local variable; the `Py_END_ALLOW_THREADS` macro closes the block. These two macros are still available when Python is compiled without thread support (they simply have an empty expansion).

When thread support is enabled, the block above expands to the following code:

```c
PyThreadState * _save;

_save = PyEval_SaveThread();  
...Do some blocking I/O operation...  
PyEval_RestoreThread(_save);
```

Here is how these functions work: the global interpreter lock is used to protect the pointer to the current thread state. When releasing the lock and saving the thread state, the current thread state pointer must be retrieved before the lock is released (since another thread could immediately acquire the lock and store its own thread state in the global variable). Conversely, when acquiring the lock and restoring the thread state, the lock must be acquired before storing the thread state pointer.
Note: Calling system I/O functions is the most common use case for releasing the GIL, but it can also be useful before calling long-running computations which don’t need access to Python objects, such as compression or cryptographic functions operating over memory buffers. For example, the standard zlib and hashlib modules release the GIL when compressing or hashing data.

Non-Python created threads

When threads are created using the dedicated Python APIs (such as the threading module), a thread state is automatically associated to them and the code showed above is therefore correct. However, when threads are created from C (for example by a third-party library with its own thread management), they don’t hold the GIL, nor is there a thread state structure for them.

If you need to call Python code from these threads (often this will be part of a callback API provided by the aforementioned third-party library), you must first register these threads with the interpreter by creating a thread state data structure, then acquiring the GIL, and finally storing their thread state pointer, before you can start using the Python/C API. When you are done, you should reset the thread state pointer, release the GIL, and finally free the thread state data structure.

The PyGILState_Ensure() and PyGILState_Release() functions do all of the above automatically. The typical idiom for calling into Python from a C thread is:

```c
PyGILState_STATE gstate;
gstate = PyGILState_Ensure();
```
Note that the PyGILState_*() functions assume there is only one global interpreter (created automatically by `Py_Initialize()`). Python supports the creation of additional interpreters (using `Py_NewInterpreter()`), but mixing multiple interpreters and the PyGILState_*() API is unsupported.

Another important thing to note about threads is their behaviour in the face of the C `fork()` call. On most systems with `fork()`, after a process forks only the thread that issued the fork will exist. That also means any locks held by other threads will never be released. Python solves this for `os.fork()` by acquiring the locks it uses internally before the fork, and releasing them afterwards. In addition, it resets any Lock Objects in the child. When extending or embedding Python, there is no way to inform Python of additional (non-Python) locks that need to be acquired before or reset after a fork. OS facilities such as `pthread_atfork()` would need to be used to accomplish the same thing. Additionally, when extending or embedding Python, calling `fork()` directly rather than through `os.fork()` (and returning to or calling into Python) may result in a deadlock by one of Python's internal locks being held by a thread that is defunct after the fork. `PyOS_AfterFork()` tries to reset the necessary locks, but is not always able to.

High-level API
These are the most commonly used types and functions when writing C extension code, or when embedding the Python interpreter:

**PyInterpreterState**

This data structure represents the state shared by a number of cooperating threads. Threads belonging to the same interpreter share their module administration and a few other internal items. There are no public members in this structure.

Threads belonging to different interpreters initially share nothing, except process state like available memory, open file descriptors and such. The global interpreter lock is also shared by all threads, regardless of to which interpreter they belong.

**PyThreadState**

This data structure represents the state of a single thread. The only public data member is `PyInterpreterState *interp`, which points to this thread's interpreter state.

```c
void PyEval_InitThreads()
```

Initialize and acquire the global interpreter lock. It should be called in the main thread before creating a second thread or engaging in any other thread operations such as `PyEval_ReleaseThread(tstate)`. It is not needed before calling `PyEval_SaveThread()` or `PyEval_RestoreThread()`.

This is a no-op when called for a second time.

*Changed in version 3.2:* This function cannot be called before `Py_Initialize()` anymore.

**Note:** When only the main thread exists, no GIL operations are needed. This is a common situation (most Python programs do
not use threads), and the lock operations slow the interpreter down a bit. Therefore, the lock is not created initially. This situation is equivalent to having acquired the lock: when there is only a single thread, all object accesses are safe. Therefore, when this function initializes the global interpreter lock, it also acquires it. Before the Python _thread module creates a new thread, knowing that either it has the lock or the lock hasn’t been created yet, it calls PyEval_InitThreads(). When this call returns, it is guaranteed that the lock has been created and that the calling thread has acquired it.

It is not safe to call this function when it is unknown which thread (if any) currently has the global interpreter lock. This function is not available when thread support is disabled at compile time.

```c
int PyEval_ThreadsInitialized()

Returns a non-zero value if PyEval_InitThreads() has been called. This function can be called without holding the GIL, and therefore can be used to avoid calls to the locking API when running single-threaded. This function is not available when thread support is disabled at compile time.

PyThreadState* PyEval_SaveThread()

Release the global interpreter lock (if it has been created and thread support is enabled) and reset the thread state to NULL, returning the previous thread state (which is not NULL). If the lock has been created, the current thread must have acquired it. (This function is available even when thread support is disabled at compile time.)

void PyEval_RestoreThread(PyThreadState *tstate)
```
Acquire the global interpreter lock (if it has been created and thread support is enabled) and set the thread state to \texttt{tstate}, which must not be \texttt{NULL}. If the lock has been created, the current thread must not have acquired it, otherwise deadlock ensues. (This function is available even when thread support is disabled at compile time.)

\textbf{PyThreadState* \texttt{PyThreadState\_Get}()}

Return the current thread state. The global interpreter lock must be held. When the current thread state is \texttt{NULL}, this issues a fatal error (so that the caller needn't check for \texttt{NULL}).

\textbf{PyThreadState* \texttt{PyThreadState\_Swap} (PyThreadState *\texttt{tstate})}

Swap the current thread state with the thread state given by the argument \texttt{tstate}, which may be \texttt{NULL}. The global interpreter lock must be held and is not released.

\textbf{void \texttt{PyEval\_ReInitThreads}()}

This function is called from \texttt{PyOS\_AfterFork()} to ensure that newly created child processes don't hold locks referring to threads which are not running in the child process.

The following functions use thread-local storage, and are not compatible with sub-interpreters:

\textbf{PyGILState\_STATE \texttt{PyGILState\_Ensure}()}

Ensure that the current thread is ready to call the Python C API regardless of the current state of Python, or of the global interpreter lock. This may be called as many times as desired by a thread as long as each call is matched with a call to \texttt{PyGILState\_Release()}. In general, other thread-related APIs may be used between \texttt{PyGILState\_Ensure()} and
PyGILState_Release() calls as long as the thread state is restored to its previous state before the Release(). For example, normal usage of the Py_BEGIN_ALLOW_THREADS and Py_END_ALLOW_THREADS macros is acceptable.

The return value is an opaque “handle” to the thread state when PyGILState_Ensure() was called, and must be passed to PyGILState_Release() to ensure Python is left in the same state. Even though recursive calls are allowed, these handles cannot be shared - each unique call to PyGILState_Ensure() must save the handle for its call to PyGILState_Release().

When the function returns, the current thread will hold the GIL and be able to call arbitrary Python code. Failure is a fatal error.

```c
void PyGILState_Release(PyGILState_STATE)
```

Release any resources previously acquired. After this call, Python’s state will be the same as it was prior to the corresponding PyGILState_Ensure() call (but generally this state will be unknown to the caller, hence the use of the GILState API).

Every call to PyGILState_Ensure() must be matched by a call to PyGILState_Release() on the same thread.

```c
PyThreadState* PyGILState_GetThisThreadState()
```

Get the current thread state for this thread. May return NULL if no GILState API has been used on the current thread. Note that the main thread always has such a thread-state, even if no auto-thread-state call has been made on the main thread. This is mainly a helper/diagnostic function.

```c
int PyGILState_Check()
```
Return 1 if the current thread is holding the GIL and 0 otherwise. This function can be called from any thread at any time. Only if it has had its Python thread state initialized and currently is holding the GIL will it return 1. This is mainly a helper/diagnostic function. It can be useful for example in callback contexts or memory allocation functions when knowing that the GIL is locked can allow the caller to perform sensitive actions or otherwise behave differently.

New in version 3.4.

The following macros are normally used without a trailing semicolon; look for example usage in the Python source distribution.

**Py_BEGIN_ALLOW_THREADS**

This macro expands to `{ PyThreadState *save; save = PyEval_SaveThread(); }`. Note that it contains an opening brace; it must be matched with a following **Py_END_ALLOW_THREADS** macro. See above for further discussion of this macro. It is a no-op when thread support is disabled at compile time.

**Py_END_ALLOW_THREADS**

This macro expands to `PyEval_RestoreThread(_save); }`. Note that it contains a closing brace; it must be matched with an earlier **Py_BEGIN_ALLOW_THREADS** macro. See above for further discussion of this macro. It is a no-op when thread support is disabled at compile time.

**Py_BLOCK_THREADS**

This macro expands to `PyEval_RestoreThread(_save);` it is equivalent to **Py_END_ALLOW_THREADS** without the closing brace. It is a no-op when thread support is disabled at compile time.
**Py_UNBLOCK_THREADS**

This macro expands to `_save = PyEval_SaveThread();`: it is equivalent to `Py_BEGIN_ALLOW_THREADS` without the opening brace and variable declaration. It is a no-op when thread support is disabled at compile time.

**Low-level API**

All of the following functions are only available when thread support is enabled at compile time, and must be called only when the global interpreter lock has been created.

**`PyInterpreterState* PyInterpreterState_New()`**

Create a new interpreter state object. The global interpreter lock need not be held, but may be held if it is necessary to serialize calls to this function.

**`void PyInterpreterState_Clear(PyInterpreterState *interp)`**

Reset all information in an interpreter state object. The global interpreter lock must be held.

**`void PyInterpreterState_Delete(PyInterpreterState *interp)`**

Destroy an interpreter state object. The global interpreter lock need not be held. The interpreter state must have been reset with a previous call to `PyInterpreterState_Clear()`.

**`PyThreadState* PyThreadState_New(PyInterpreterState *interp)`**

Create a new thread state object belonging to the given interpreter object. The global interpreter lock need not be held, but may be held if it is necessary to serialize calls to this function.
void **PyThreadState_Clear**(PyThreadState *tstate)

Reset all information in a thread state object. The global interpreter lock must be held.

void **PyThreadState_Delete**(PyThreadState *tstate)

Destroy a thread state object. The global interpreter lock need not be held. The thread state must have been reset with a previous call to **PyThreadState_Clear**().

PyObject* **PyThreadState_GetDict**()

*Return value: Borrowed reference.*

Return a dictionary in which extensions can store thread-specific state information. Each extension should use a unique key to use to store state in the dictionary. It is okay to call this function when no current thread state is available. If this function returns **NULL**, no exception has been raised and the caller should assume no current thread state is available.

int **PyThreadState_SetAsyncExc**(long id, PyObject *exc)

Asynchronously raise an exception in a thread. The *id* argument is the thread id of the target thread; *exc* is the exception object to be raised. This function does not steal any references to *exc*. To prevent naive misuse, you must write your own C extension to call this. Must be called with the GIL held. Returns the number of thread states modified; this is normally one, but will be zero if the thread id isn't found. If *exc* is **NULL**, the pending exception (if any) for the thread is cleared. This raises no exceptions.

void **PyEval_AcquireThread**(PyThreadState *tstate)

Acquire the global interpreter lock and set the current thread state to *tstate*, which should not be **NULL**. The lock must have been created earlier. If this thread already has the lock, deadlock
ensues.

**PyEval_RestoreThread()** is a higher-level function which is always available (even when thread support isn’t enabled or when threads have not been initialized).

```c
void PyEval_ReleaseThread(PyThreadState *tstate)
```

Reset the current thread state to *NULL* and release the global interpreter lock. The lock must have been created earlier and must be held by the current thread. The `tstate` argument, which must not be *NULL*, is only used to check that it represents the current thread state — if it isn’t, a fatal error is reported.

**PyEval_SaveThread()** is a higher-level function which is always available (even when thread support isn’t enabled or when threads have not been initialized).

```c
void PyEval_AcquireLock()
```

Acquire the global interpreter lock. The lock must have been created earlier. If this thread already has the lock, a deadlock ensues.

*Deprecated since version 3.2:* This function does not update the current thread state. Please use **PyEval_RestoreThread()** or **PyEval_AcquireThread()** instead.

```c
void PyEval_ReleaseLock()
```

Release the global interpreter lock. The lock must have been created earlier.

*Deprecated since version 3.2:* This function does not update the current thread state. Please use **PyEval_SaveThread()** or **PyEval_ReleaseThread()** instead.
Sub-interpreter support

While in most uses, you will only embed a single Python interpreter, there are cases where you need to create several independent interpreters in the same process and perhaps even in the same thread. Sub-interpreters allow you to do that. You can switch between sub-interpreters using the `PyThreadState_Swap()` function. You can create and destroy them using the following functions:

```c
PyThreadState* Py_NewInterpreter()
```

Create a new sub-interpreter. This is an (almost) totally separate environment for the execution of Python code. In particular, the new interpreter has separate, independent versions of all imported modules, including the fundamental modules `builtins`, `__main__` and `sys`. The table of loaded modules (`sys.modules`) and the module search path (`sys.path`) are also separate. The new environment has no `sys.argv` variable. It has new standard I/O stream file objects `sys.stdin`, `sys.stdout` and `sys.stderr` (however these refer to the same underlying file descriptors).

The return value points to the first thread state created in the new sub-interpreter. This thread state is made in the current thread state. Note that no actual thread is created; see the discussion of thread states below. If creation of the new interpreter is unsuccessful, `NULL` is returned; no exception is set since the exception state is stored in the current thread state and there may not be a current thread state. (Like all other Python/C API functions, the global interpreter lock must be held before calling this function and is still held when it returns; however, unlike most other Python/C API functions, there needn’t be a current thread
Extension modules are shared between (sub-)interpreters as follows: the first time a particular extension is imported, it is initialized normally, and a (shallow) copy of its module's dictionary is squirreled away. When the same extension is imported by another (sub-)interpreter, a new module is initialized and filled with the contents of this copy; the extension’s init function is not called. Note that this is different from what happens when an extension is imported after the interpreter has been completely re-initialized by calling `Py_Finalize()` and `Py_Initialize()`; in that case, the extension’s init function is called again.

```c
void Py_EndInterpreter(PyThreadState *tstate)
```

Destroy the (sub-)interpreter represented by the given thread state. The given thread state must be the current thread state. See the discussion of thread states below. When the call returns, the current thread state is `NULL`. All thread states associated with this interpreter are destroyed. (The global interpreter lock must be held before calling this function and is still held when it returns.) `Py_Finalize()` will destroy all sub-interpreters that haven’t been explicitly destroyed at that point.

## Bugs and caveats

Because sub-interpreters (and the main interpreter) are part of the same process, the insulation between them isn’t perfect — for example, using low-level file operations like `os.close()` they can (accidentally or maliciously) affect each other’s open files. Because of the way extensions are shared between (sub-)interpreters, some extensions may not work properly; this is especially likely when the extension makes use of (static) global variables, or when the
extension manipulates its module’s dictionary after its initialization. It is possible to insert objects created in one sub-interpreter into a namespace of another sub-interpreter; this should be done with great care to avoid sharing user-defined functions, methods, instances or classes between sub-interpreters, since import operations executed by such objects may affect the wrong (sub-)interpreter’s dictionary of loaded modules.

Also note that combining this functionality with `PyGILState_*()` APIs is delicate, because these APIs assume a bijection between Python thread states and OS-level threads, an assumption broken by the presence of sub-interpreters. It is highly recommended that you don’t switch sub-interpreters between a pair of matching `PyGILState_Ensure()` and `PyGILState_Release()` calls. Furthermore, extensions (such as `ctypes`) using these APIs to allow calling of Python code from non-Python created threads will probably be broken when using sub-interpreters.
Asynchronous Notifications

A mechanism is provided to make asynchronous notifications to the main interpreter thread. These notifications take the form of a function pointer and a void pointer argument.

```c
int Py_AddPendingCall(int (*func)(void *), void *arg)
```

Schedule a function to be called from the main interpreter thread. On success, 0 is returned and `func` is queued for being called in the main thread. On failure, -1 is returned without setting any exception.

When successfully queued, `func` will be *eventually* called from the main interpreter thread with the argument `arg`. It will be called asynchronously with respect to normally running Python code, but with both these conditions met:

- on a bytecode boundary;
- with the main thread holding the global interpreter lock (`func` can therefore use the full C API).

`func` must return 0 on success, or -1 on failure with an exception set. `func` won’t be interrupted to perform another asynchronous notification recursively, but it can still be interrupted to switch threads if the global interpreter lock is released.

This function doesn’t need a current thread state to run, and it doesn’t need the global interpreter lock.

**Warning:** This is a low-level function, only useful for very special cases. There is no guarantee that `func` will be called as quick as possible. If the main thread is busy executing a system call, `func` won’t be called before the system call returns. This
function is generally **not** suitable for calling Python code from arbitrary C threads. Instead, use the PyGILState API.

*New in version 3.1.*
Profiling and Tracing

The Python interpreter provides some low-level support for attaching profiling and execution tracing facilities. These are used for profiling, debugging, and coverage analysis tools.

This C interface allows the profiling or tracing code to avoid the overhead of calling through Python-level callable objects, making a direct C function call instead. The essential attributes of the facility have not changed; the interface allows trace functions to be installed per-thread, and the basic events reported to the trace function are the same as had been reported to the Python-level trace functions in previous versions.

```
int (*Py_tracefunc)(PyObject *obj, PyFrameObject *frame, int what, PyObject *arg)
```

The type of the trace function registered using `PyEval_SetProfile()` and `PyEval_SetTrace()`. The first parameter is the object passed to the registration function as `obj`, `frame` is the frame object to which the event pertains, `what` is one of the constants `PyTrace_CALL`, `PyTrace_EXCEPTION`, `PyTrace_LINE`, `PyTrace_RETURN`, `PyTrace_C_CALL`, `PyTrace_C_EXCEPTION`, or `PyTrace_C_RETURN`, and `arg` depends on the value of `what`:

<table>
<thead>
<tr>
<th>Value of <code>what</code></th>
<th>Meaning of <code>arg</code></th>
</tr>
</thead>
<tbody>
<tr>
<td><code>PyTrace_CALL</code></td>
<td>Always <code>NULL</code>.</td>
</tr>
<tr>
<td><code>PyTrace_EXCEPTION</code></td>
<td>Exception information as returned by <code>sys.exc_info()</code></td>
</tr>
<tr>
<td><code>PyTrace_LINE</code></td>
<td>Always <code>NULL</code>.</td>
</tr>
<tr>
<td>PyTrace_RETURN</td>
<td>Value being returned to the caller, or NULL if caused by an exception.</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>PyTrace_C_CALL</td>
<td>Function object being called.</td>
</tr>
<tr>
<td>PyTrace_C_EXCEPTION</td>
<td>Function object being called.</td>
</tr>
<tr>
<td>PyTrace_C_RETURN</td>
<td>Function object being called.</td>
</tr>
</tbody>
</table>

**int PyTrace_CALL**

The value of the *what* parameter to a `Py_tracefunc` function when a new call to a function or method is being reported, or a new entry into a generator. Note that the creation of the iterator for a generator function is not reported as there is no control transfer to the Python bytecode in the corresponding frame.

**int PyTrace_EXCEPTION**

The value of the *what* parameter to a `Py_tracefunc` function when an exception has been raised. The callback function is called with this value for *what* when after any bytecode is processed after which the exception becomes set within the frame being executed. The effect of this is that as exception propagation causes the Python stack to unwind, the callback is called upon return to each frame as the exception propagates. Only trace functions receives these events; they are not needed by the profiler.

**int PyTrace_LINE**

The value passed as the *what* parameter to a trace function (but not a profiling function) when a line-number event is being reported.

**int PyTrace_RETURN**

The value for the *what* parameter to `Py_tracefunc` functions when a call is returning without propagating an exception.
int PyTrace_C_CALL
    The value for the what parameter to Py_tracefunc functions when a C function is about to be called.

int PyTrace_C_EXCEPTION
    The value for the what parameter to Py_tracefunc functions when a C function has raised an exception.

int PyTrace_C_RETURN
    The value for the what parameter to Py_tracefunc functions when a C function has returned.

void PyEval_SetProfile(Py_tracefunc func, PyObject *obj)
    Set the profiler function to func. The obj parameter is passed to the function as its first parameter, and may be any Python object, or NULL. If the profile function needs to maintain state, using a different value for obj for each thread provides a convenient and thread-safe place to store it. The profile function is called for all monitored events except the line-number events.

void PyEval_SetTrace(Py_tracefunc func, PyObject *obj)
    Set the tracing function to func. This is similar to PyEval_SetProfile(), except the tracing function does receive line-number events.

PyObject* PyEval_GetCallStats(PyObject *self)
    Return a tuple of function call counts. There are constants defined for the positions within the tuple:

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCALL_ALL</td>
<td>0</td>
</tr>
<tr>
<td>PCALL_FUNCTION</td>
<td>1</td>
</tr>
<tr>
<td>PCALL_FAST_FUNCTION</td>
<td>2</td>
</tr>
<tr>
<td>---------------------</td>
<td>---</td>
</tr>
<tr>
<td>PCALL_FASTER_FUNCTION</td>
<td>3</td>
</tr>
<tr>
<td>PCALL_METHOD</td>
<td>4</td>
</tr>
<tr>
<td>PCALL_BOUND_METHOD</td>
<td>5</td>
</tr>
<tr>
<td>PCALL_CFUNCTION</td>
<td>6</td>
</tr>
<tr>
<td>PCALL_TYPE</td>
<td>7</td>
</tr>
<tr>
<td>PCALL_GENERATOR</td>
<td>8</td>
</tr>
<tr>
<td>PCALL_OTHER</td>
<td>9</td>
</tr>
<tr>
<td>PCALL_POP</td>
<td>10</td>
</tr>
</tbody>
</table>

PCALL_FAST_FUNCTION means no argument tuple needs to be created. PCALL_FASTER_FUNCTION means that the fast-path frame setup code is used.

If there is a method call where the call can be optimized by changing the argument tuple and calling the function directly, it gets recorded twice.

This function is only present if Python is compiled with CALLPROFILE defined.
Advanced Debugger Support

These functions are only intended to be used by advanced debugging tools.

**PyInterpreterState** *PyInterpreterState_*Head()  
Return the interpreter state object at the head of the list of all such objects.

**PyInterpreterState** *PyInterpreterState_*Next(PyInterpreterState *interp)  
Return the next interpreter state object after *interp* from the list of all such objects.

**PyThreadState** *
**PyInterpreterState**_ThreadHead(PyInterpreterState *interp)  
Return the pointer to the first **PyThreadState** object in the list of threads associated with the interpreter *interp*.

**PyThreadState** *PyThreadState_*Next(PyThreadState *tstate)  
Return the next thread state object after *tstate* from the list of all such objects belonging to the same **PyInterpreterState** object.
Memory Management
Overview

Memory management in Python involves a private heap containing all Python objects and data structures. The management of this private heap is ensured internally by the Python memory manager. The Python memory manager has different components which deal with various dynamic storage management aspects, like sharing, segmentation, preallocation or caching.

At the lowest level, a raw memory allocator ensures that there is enough room in the private heap for storing all Python-related data by interacting with the memory manager of the operating system. On top of the raw memory allocator, several object-specific allocators operate on the same heap and implement distinct memory management policies adapted to the peculiarities of every object type. For example, integer objects are managed differently within the heap than strings, tuples or dictionaries because integers imply different storage requirements and speed/space tradeoffs. The Python memory manager thus delegates some of the work to the object-specific allocators, but ensures that the latter operate within the bounds of the private heap.

It is important to understand that the management of the Python heap is performed by the interpreter itself and that the user has no control over it, even if she regularly manipulates object pointers to memory blocks inside that heap. The allocation of heap space for Python objects and other internal buffers is performed on demand by the Python memory manager through the Python/C API functions listed in this document.

To avoid memory corruption, extension writers should never try to operate on Python objects with the functions exported by the C library:
malloc(), calloc(), realloc() and free(). This will result in mixed calls between the C allocator and the Python memory manager with fatal consequences, because they implement different algorithms and operate on different heaps. However, one may safely allocate and release memory blocks with the C library allocator for individual purposes, as shown in the following example:

```c
PyObject *res;
char *buf = (char *) malloc(BUFSIZE); /* for I/O */

if (buf == NULL)
    return PyErr_NoMemory();
...
Do some I/O operation involving buf...
res = PyBytes_FromString(buf);
free(buf); /* malloc'ed */
return res;
```

In this example, the memory request for the I/O buffer is handled by the C library allocator. The Python memory manager is involved only in the allocation of the string object returned as a result.

In most situations, however, it is recommended to allocate memory from the Python heap specifically because the latter is under control of the Python memory manager. For example, this is required when the interpreter is extended with new object types written in C. Another reason for using the Python heap is the desire to inform the Python memory manager about the memory needs of the extension module. Even when the requested memory is used exclusively for internal, highly-specific purposes, delegating all memory requests to the Python memory manager causes the interpreter to have a more accurate image of its memory footprint as a whole. Consequently, under certain circumstances, the Python memory manager may or may not trigger appropriate actions, like garbage collection, memory compaction or
other preventive procedures. Note that by using the C library allocator as shown in the previous example, the allocated memory for the I/O buffer escapes completely the Python memory manager.
Raw Memory Interface

The following function sets are wrappers to the system allocator. These functions are thread-safe, the GIL does not need to be held.

The default raw memory block allocator uses the following functions: malloc(), calloc(), realloc() and free(); call malloc(1) (or calloc(1, 1)) when requesting zero bytes.

*New in version 3.4.*

**void** PyMem_RawMalloc(size_t *p, size_t *n)

Allocates *n* bytes and returns a pointer of type void* to the allocated memory, or NULL if the request fails. Requesting zero bytes returns a distinct non-NUL1 pointer if possible, as if PyMem_RawMalloc(1) had been called instead. The memory will not have been initialized in any way.

**void** PyMem_RawCalloc(size_t *nelem, size_t *elsize)

Allocates *nelem* elements each whose size in bytes is *elsize* and returns a pointer of type void* to the allocated memory, or NULL if the request fails. The memory is initialized to zeros. Requesting zero elements or elements of size zero bytes returns a distinct non-NUL1 pointer if possible, as if PyMem_RawCalloc(1, 1) had been called instead.

*New in version 3.5.*

**void** PyMem_RawRealloc(void *p, size_t *n)

Resizes the memory block pointed to by *p* to *n* bytes. The contents will be unchanged to the minimum of the old and the new sizes. If *p* is NULL, the call is equivalent to PyMem_RawMalloc(n); else if *n*
is equal to zero, the memory block is resized but is not freed, and the returned pointer is non-\texttt{NULL}. Unless \( p \) is \texttt{NULL}, it must have been returned by a previous call to \texttt{PyMem_RawMalloc()} or \texttt{PyMem_RawRealloc()}. If the request fails, \texttt{PyMem_RawRealloc()} returns \texttt{NULL} and \( p \) remains a valid pointer to the previous memory area.

\begin{verbatim}
void PyMem_RawFree(void *p)
    Frees the memory block pointed to by \( p \), which must have been returned by a previous call to \texttt{PyMem_RawMalloc()} or \texttt{PyMem_RawRealloc()}. Otherwise, or if \texttt{PyMem_Free(p)} has been called before, undefined behavior occurs. If \( p \) is \texttt{NULL}, no operation is performed.
\end{verbatim}
Memory Interface

The following function sets, modeled after the ANSI C standard, but specifying behavior when requesting zero bytes, are available for allocating and releasing memory from the Python heap.

The default memory block allocator uses the following functions: malloc(), calloc(), realloc() and free(); call malloc(1) (or calloc(1, 1)) when requesting zero bytes.

**Warning:** The GIL must be held when using these functions.

```c
void* PyMem_Malloc(size_t n)
```

Allocates \(n\) bytes and returns a pointer of type void* to the allocated memory, or NULL if the request fails. Requesting zero bytes returns a distinct non-NULL pointer if possible, as if PyMem_Malloc(1) had been called instead. The memory will not have been initialized in any way.

```c
void* PyMem_Calloc(size_t nelem, size_t elsize)
```

Allocates \(nelem\) elements each whose size in bytes is \(elsize\) and returns a pointer of type void* to the allocated memory, or NULL if the request fails. The memory is initialized to zeros. Requesting zero elements or elements of size zero bytes returns a distinct non-NULL pointer if possible, as if PyMem_Calloc(1, 1) had been called instead.

*New in version 3.5.*

```c
void* PyMem_Realloc(void *p, size_t n)
```

Resizes the memory block pointed to by \(p\) to \(n\) bytes. The contents...
will be unchanged to the minimum of the old and the new sizes. If \( p \) is \textit{NULL}, the call is equivalent to \texttt{PyMem_Malloc(n)}; else if \( n \) is equal to zero, the memory block is resized but is not freed, and the returned pointer is non-\textit{NULL}. Unless \( p \) is \textit{NULL}, it must have been returned by a previous call to \texttt{PyMem_Malloc()} or \texttt{PyMem_Realloc()}. If the request fails, \texttt{PyMem_Realloc()} returns \textit{NULL} and \( p \) remains a valid pointer to the previous memory area.

\textbf{void \texttt{PyMem_Free}(void *\( p \))}

Frees the memory block pointed to by \( p \), which must have been returned by a previous call to \texttt{PyMem_Malloc()} or \texttt{PyMem_Realloc()}. Otherwise, or if \texttt{PyMem_Free(p)} has been called before, undefined behavior occurs. If \( p \) is \textit{NULL}, no operation is performed.

The following type-oriented macros are provided for convenience. Note that \textit{TYPE} refers to any C type.

\textbf{\texttt{TYPE}* \texttt{PyMem_New}(\texttt{TYPE}, size_t \( n \))}

Same as \texttt{PyMem_Malloc()}, but allocates \((n * \text{sizeof(TYPE)})\) bytes of memory. Returns a pointer cast to \texttt{TYPE*}. The memory will not have been initialized in any way.

\textbf{\texttt{TYPE}* \texttt{PyMem_Resize}(void *\( p \), \texttt{TYPE}, size_t \( n \))}

Same as \texttt{PyMem_Realloc()}, but the memory block is resized to \((n * \text{sizeof(TYPE)})\) bytes. Returns a pointer cast to \texttt{TYPE*}. On return, \( p \) will be a pointer to the new memory area, or \textit{NULL} in the event of failure. This is a C preprocessor macro; \( p \) is always reassigned. Save the original value of \( p \) to avoid losing memory when handling errors.
void **PyMem_Del***(void *p)
    
    Same as **PyMem_Free()**.

In addition, the following macro sets are provided for calling the Python memory allocator directly, without involving the C API functions listed above. However, note that their use does not preserve binary compatibility across Python versions and is therefore deprecated in extension modules.

**PyMem_MALLOC()**, **PyMem_REALLOC()**, **PyMem_FREE()**.

**PyMem_NEW()**, **PyMem_RESIZE()**, **PyMem_DEL()**.
Customize Memory Allocators

*New in version 3.4.*

**PyMemAllocatorEx**

Structure used to describe a memory block allocator. The structure has four fields:

<table>
<thead>
<tr>
<th>Field</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>void *ctx</td>
<td>user context passed as first argument</td>
</tr>
<tr>
<td>void* malloc(void *ctx,</td>
<td>allocate a memory block</td>
</tr>
<tr>
<td>size_t size)</td>
<td></td>
</tr>
<tr>
<td>void* calloc(void *ctx,</td>
<td>allocate a memory block initialized with zeros</td>
</tr>
<tr>
<td>size_t nelem, size_t elsize)</td>
<td></td>
</tr>
<tr>
<td>void* realloc(void *ctx,</td>
<td>allocate or resize a memory block</td>
</tr>
<tr>
<td>void *ptr, size_t new_size)</td>
<td></td>
</tr>
<tr>
<td>void free(void *ctx, void</td>
<td>free a memory block</td>
</tr>
<tr>
<td>*ptr)</td>
<td></td>
</tr>
</tbody>
</table>

*Changed in version 3.5:* The PyMemAllocator structure was renamed to **PyMemAllocatorEx** and a new calloc field was added.

**PyMemAllocatorDomain**

Enum used to identify an allocator domain. Domains:

- **PYMEM_DOMAIN_RAW:** functions **PyMem_RawMalloc()**, **PyMem_RawRealloc()** and **PyMem_RawFree()**
- **PYMEM_DOMAIN_MEM:** functions **PyMem_Malloc()**, **PyMem_Realloc()** and **PyMem_Free()**
• PYMEM_DOMAIN_OBJ: functions PyObject_Malloc(), PyObject_Realloc() and PyObject_Free()

void **PyMem_GetAllocator**(PyMemAllocatorDomain *domain, PyMemAllocatorEx **allocator)

Get the memory block allocator of the specified domain.

void **PyMem_SetAllocator**(PyMemAllocatorDomain *domain, PyMemAllocatorEx **allocator)

Set the memory block allocator of the specified domain.

The new allocator must return a distinct non-NULL pointer when requesting zero bytes.

For the PYMEM_DOMAIN_RAW domain, the allocator must be thread-safe: the **GIL** is not held when the allocator is called.

If the new allocator is not a hook (does not call the previous allocator), the **PyMem_SetupDebugHooks()** function must be called to reinstall the debug hooks on top on the new allocator.

void **PyMem_SetupDebugHooks**(void)

Setup hooks to detect bugs in the following Python memory allocator functions:

• **PyMem_RawMalloc()**, **PyMem_RawRealloc()**, **PyMem_RawFree()**
• **PyMemMalloc()**, **PyMem_Realloc()**, **PyMem_Free()**
• **PyObject_Malloc()**, **PyObject_Realloc()**, **PyObject_Free()**

Newly allocated memory is filled with the byte 0xCB, freed memory is filled with the byte 0xDB. Additional checks:
• detect API violations, ex: PyObject_Free() called on a buffer allocated by PyMem_Malloc()
• detect write before the start of the buffer (buffer underflow)
• detect write after the end of the buffer (buffer overflow)

The function does nothing if Python is not compiled in debug mode.
Customize PyObject Arena Allocator

Python has a `pymalloc` allocator for allocations smaller than 512 bytes. This allocator is optimized for small objects with a short lifetime. It uses memory mappings called “arenas” with a fixed size of 256 KB. It falls back to `PyMem_RawMalloc()` and `PyMem_RawRealloc()` for allocations larger than 512 bytes. `pymalloc` is the default allocator used by `PyObject_Malloc()`.

The default arena allocator uses the following functions:

- `VirtualAlloc()` and `VirtualFree()` on Windows,
- `mmap()` and `munmap()` if available,
- `malloc()` and `free()` otherwise.

*New in version 3.4.*

**PyObjectArenaAllocator**

Structure used to describe an arena allocator. The structure has three fields:

<table>
<thead>
<tr>
<th>Field</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>void *ctx</code></td>
<td>user context passed as first argument</td>
</tr>
<tr>
<td><code>void* alloc(void *ctx, size_t size)</code></td>
<td>allocate an arena of size bytes</td>
</tr>
<tr>
<td><code>void free(void *ctx, size_t size, void *ptr)</code></td>
<td>free an arena</td>
</tr>
</tbody>
</table>

**PyObject_GetArenaAllocator**

Get the arena allocator.
PyObject_SetArenaAllocator(PyObjectArenaAllocator *allocator)
Set the arena allocator.
Examples

Here is the example from section Overview, rewritten so that the I/O buffer is allocated from the Python heap by using the first function set:

```python
PyObject *res;
char *buf = (char *) PyMem_Malloc(BUFSIZ); /* for I/O */

if (buf == NULL)
    return PyErr_NoMemory();
/* ...Do some I/O operation involving buf... */
res = PyBytes_FromString(buf);
PyMem_Free(buf); /* allocated with PyMem_Malloc */
return res;
```

The same code using the type-oriented function set:

```python
PyObject *res;
char *buf = PyMem_New(char, BUFSIZ); /* for I/O */

if (buf == NULL)
    return PyErr_NoMemory();
/* ...Do some I/O operation involving buf... */
res = PyBytes_FromString(buf);
PyMem_Del(buf); /* allocated with PyMem_New */
return res;
```

Note that in the two examples above, the buffer is always manipulated via functions belonging to the same set. Indeed, it is required to use the same memory API family for a given memory block, so that the risk of mixing different allocators is reduced to a minimum. The following code sequence contains two errors, one of which is labeled as fatal because it mixes two different allocators operating on different heaps.
In addition to the functions aimed at handling raw memory blocks from the Python heap, objects in Python are allocated and released with `PyObject_New()`, `PyObject_NewVar()` and `PyObject_Del()`.

These will be explained in the next chapter on defining and implementing new object types in C.
Object Implementation Support

This chapter describes the functions, types, and macros used when defining new object types.

- Allocating Objects on the Heap
- Common Object Structures
- Type Objects
- Number Object Structures
- Mapping Object Structures
- Sequence Object Structures
- Buffer Object Structures
- Async Object Structures
- Supporting Cyclic Garbage Collection
Allocating Objects on the Heap

PyObject*  _PyObject_New(PyTypeObject *type)

*Return value: New reference.*

PyVarObject*  _PyObject_NewVar(PyTypeObject *type, Py_ssize_t size)

*Return value: New reference.*

PyObject*  PyObject_Init(PyObject *op, PyTypeObject *type)

*Return value: Borrowed reference.*

Initialize a newly-allocated object op with its type and initial reference. Returns the initialized object. If type indicates that the object participates in the cyclic garbage detector, it is added to the detector’s set of observed objects. Other fields of the object are not affected.

PyVarObject* PyObject_InitVar(PyVarObject *op, PyTypeObject *type, Py_ssize_t size)

*Return value: Borrowed reference.*

This does everything PyObject_Init() does, and also initializes the length information for a variable-size object.

TYPE*  PyObject_New(TYPE, PyTypeObject *type)

*Return value: New reference.*

Allocate a new Python object using the C structure type TYPE and the Python type object type. Fields not defined by the Python object header are not initialized; the object’s reference count will be one. The size of the memory allocation is determined from the tp_basicsize field of the type object.
TYPE* **PyObject_NewVar**(TYPE, PyTypeObject *type, Py_ssize_t size)

*Return value: New reference.*

Allocate a new Python object using the C structure type `TYPE` and the Python type object `type`. Fields not defined by the Python object header are not initialized. The allocated memory allows for the `TYPE` structure plus size fields of the size given by the `tp_itemsize` field of `type`. This is useful for implementing objects like tuples, which are able to determine their size at construction time. Embedding the array of fields into the same allocation decreases the number of allocations, improving the memory management efficiency.

```c
void **PyObject_Del**(PyObject *op)
```

Releases memory allocated to an object using `PyObject_New()` or `PyObject_NewVar()`. This is normally called from the `tp_dealloc` handler specified in the object’s type. The fields of the object should not be accessed after this call as the memory is no longer a valid Python object.

**PyObject _Py_NoneStruct**

Object which is visible in Python as None. This should only be accessed using the `Py_None` macro, which evaluates to a pointer to this object.

**See also:**

- **PyModule_Create()**
  - To allocate and create extension modules.
Common Object Structures

There are a large number of structures which are used in the definition of object types for Python. This section describes these structures and how they are used.

All Python objects ultimately share a small number of fields at the beginning of the object's representation in memory. These are represented by the PyObject and PyVarObject types, which are defined, in turn, by the expansions of some macros also used, whether directly or indirectly, in the definition of all other Python objects.

**PyObject**
All object types are extensions of this type. This is a type which contains the information Python needs to treat a pointer to an object as an object. In a normal “release” build, it contains only the object's reference count and a pointer to the corresponding type object. Nothing is actually declared to be a PyObject, but every pointer to a Python object can be cast to a PyObject*. Access to the members must be done by using the macros Py_REFCNT and Py_TYPE.

**PyVarObject**
This is an extension of PyObject that adds the ob_size field. This is only used for objects that have some notion of length. This type does not often appear in the Python/C API. Access to the members must be done by using the macros Py_REFCNT, Py_TYPE, and Py_SIZE.

**PyObject_HEAD**
This is a macro used when declaring new types which represent
objects without a varying length. The PyObject_HEAD macro expands to:

```c
PyObject ob_base;
```

See documentation of `PyObject` above.

**PyObject_VAR_HEAD**

This is a macro used when declaring new types which represent objects with a length that varies from instance to instance. The PyObject_VAR_HEAD macro expands to:

```c
PyVarObject ob_base;
```

See documentation of `PyVarObject` above.

**Py_TYPE(o)**

This macro is used to access the ob_type member of a Python object. It expands to:

```c
(((PyObject*)(o))->ob_type)
```

**Py_REFCNT(o)**

This macro is used to access the ob_refcnt member of a Python object. It expands to:

```c
(((PyObject*)(o))->ob_refcnt)
```

**Py_SIZE(o)**

This macro is used to access the ob_size member of a Python object. It expands to:

```c
(((PyVarObject*)(o))->ob_size)
```
**PyObject** _**_HEAD**_**_**_INIT**(type)

This is a macro which expands to initialization values for a new `PyObject` type. This macro expands to:

```
(PyObject_HEAD_INIT(type)

_PyObject_EXTRA_INIT
1, type,
```

**PyVarObject** _**_HEAD**_**_**_INIT**(type, size)

This is a macro which expands to initialization values for a new `PyVarObject` type, including the `ob_size` field. This macro expands to:

```
(PyObject_HEAD_INIT(type, size)

_PyObject_EXTRA_INIT
1, type, size,
```

**PyCFunction**

Type of the functions used to implement most Python callables in C. Functions of this type take two `PyObject`* parameters and return one such value. If the return value is `NULL`, an exception shall have been set. If not `NULL`, the return value is interpreted as the return value of the function as exposed in Python. The function must return a new reference.

**PyCFunctionWithKeywords**

Type of the functions used to implement Python callables in C that take keyword arguments: they take three `PyObject`* parameters and return one such value. See **PyCFunction** above for the meaning of the return value.

**PyMethodDef**

Structure used to describe a method of an extension type. This structure has four fields:
<table>
<thead>
<tr>
<th>Field</th>
<th>C Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ml_name</td>
<td>char *</td>
<td>name of the method</td>
</tr>
<tr>
<td>ml_meth</td>
<td>PyCFunction</td>
<td>pointer to the C implementation</td>
</tr>
<tr>
<td>ml_flags</td>
<td>int</td>
<td>flag bits indicating how the call should be constructed</td>
</tr>
<tr>
<td>ml_doc</td>
<td>char *</td>
<td>points to the contents of the docstring</td>
</tr>
</tbody>
</table>

The `ml_meth` is a C function pointer. The functions may be of different types, but they always return `PyObject*`. If the function is not of the `PyCFunction`, the compiler will require a cast in the method table. Even though `PyCFunction` defines the first parameter as `PyObject*`, it is common that the method implementation uses the specific C type of the `self` object.

The `ml_flags` field is a bitfield which can include the following flags. The individual flags indicate either a calling convention or a binding convention. Of the calling convention flags, only `METH_VARARGS` and `METH_KEYWORDS` can be combined (but note that `METH_KEYWORDS` alone is equivalent to `METH_VARARGS | METH_KEYWORDS`). Any of the calling convention flags can be combined with a binding flag.

**METH_VARARGS**

This is the typical calling convention, where the methods have the type `PyCFunction`. The function expects two `PyObject*` values. The first one is the `self` object for methods; for module functions, it is the module object. The second parameter (often called `args`) is a tuple object representing all arguments. This parameter is typically processed using `PyArg_ParseTuple()` or
PyArg_UnpackTuple().

**METH_KEYWORDS**
Methods with these flags must be of type *PyCFunctionWithKeywords*. The function expects three parameters: *self, args*, and a dictionary of all the keyword arguments. The flag is typically combined with METH_VARARGS, and the parameters are typically processed using *PyArg_ParseTupleAndKeywords()*.

**METH_NOARGS**
Methods without parameters don’t need to check whether arguments are given if they are listed with the METH_NOARGS flag. They need to be of type *PyCFunction*. The first parameter is typically named *self* and will hold a reference to the module or object instance. In all cases the second parameter will be *NULL*.

**METH_O**
Methods with a single object argument can be listed with the METH_O flag, instead of invoking *PyArg_ParseTuple()* with a "O" argument. They have the type *PyCFunction*, with the *self* parameter, and a *PyObject* parameter representing the single argument.

These two constants are not used to indicate the calling convention but the binding when use with methods of classes. These may not be used for functions defined for modules. At most one of these flags may be set for any given method.

**METH_CLASS**
The method will be passed the type object as the first parameter rather than an instance of the type. This is used to create *class*
methods, similar to what is created when using the `classmethod()` built-in function.

**METH_STATIC**

The method will be passed `NULL` as the first parameter rather than an instance of the type. This is used to create static methods, similar to what is created when using the `staticmethod()` built-in function.

One other constant controls whether a method is loaded in place of another definition with the same method name.

**METH_COEXIST**

The method will be loaded in place of existing definitions. Without `METH_COEXIST`, the default is to skip repeated definitions. Since slot wrappers are loaded before the method table, the existence of a `sq_contains` slot, for example, would generate a wrapped method named `__contains__()` and preclude the loading of a corresponding PyCFunction with the same name. With the flag defined, the PyCFunction will be loaded in place of the wrapper object and will co-exist with the slot. This is helpful because calls to PyCFunctions are optimized more than wrapper object calls.

**PyMemberDef**

Structure which describes an attribute of a type which corresponds to a C struct member. Its fields are:

<table>
<thead>
<tr>
<th>Field</th>
<th>C Type</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>char *</td>
<td>name of the member</td>
</tr>
<tr>
<td>type</td>
<td>int</td>
<td>the type of the member in the C struct</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the offset in bytes that the</td>
</tr>
<tr>
<td>offset</td>
<td>Py_ssize_t</td>
<td>member is located on the type's object struct</td>
</tr>
<tr>
<td>-------------</td>
<td>------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>flags</td>
<td>int</td>
<td>flag bits indicating if the field should be read-only or writable</td>
</tr>
<tr>
<td>doc</td>
<td>char *</td>
<td>points to the contents of the docstring</td>
</tr>
</tbody>
</table>

**type** can be one of many T_ macros corresponding to various C types. When the member is accessed in Python, it will be converted to the equivalent Python type.

<table>
<thead>
<tr>
<th>Macro name</th>
<th>C type</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_SHORT</td>
<td>short</td>
</tr>
<tr>
<td>T_INT</td>
<td>int</td>
</tr>
<tr>
<td>T_LONG</td>
<td>long</td>
</tr>
<tr>
<td>T_FLOAT</td>
<td>float</td>
</tr>
<tr>
<td>T_DOUBLE</td>
<td>double</td>
</tr>
<tr>
<td>T_STRING</td>
<td>char *</td>
</tr>
<tr>
<td>T_OBJECT</td>
<td>PyObject *</td>
</tr>
<tr>
<td>T_OBJECT_EX</td>
<td>PyObject *</td>
</tr>
<tr>
<td>T_CHAR</td>
<td>char</td>
</tr>
<tr>
<td>T_BYTE</td>
<td>char</td>
</tr>
<tr>
<td>T_UBYTE</td>
<td>unsigned char</td>
</tr>
<tr>
<td>T_UINT</td>
<td>unsigned int</td>
</tr>
<tr>
<td>T_USHORT</td>
<td>unsigned short</td>
</tr>
<tr>
<td>T_ULONG</td>
<td>unsigned long</td>
</tr>
<tr>
<td>T_BOOL</td>
<td>char</td>
</tr>
<tr>
<td>T_LONGLONG</td>
<td>long long</td>
</tr>
<tr>
<td>T_ULONGLONG</td>
<td>unsigned long long</td>
</tr>
<tr>
<td>-------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>T_PYSSIZET</td>
<td>Py_ssize_t</td>
</tr>
</tbody>
</table>

T_OBJECT and T_OBJECT_EX differ in that T_OBJECT returns None if the member is NULL and T_OBJECT_EX raises an AttributeError. Try to use T_OBJECT_EX over T_OBJECT because T_OBJECT_EX handles use of the del statement on that attribute more correctly than T_OBJECT.

Flags can be 0 for write and read access or READONLY for read-only access. Using T_STRING for type implies READONLY. Only T_OBJECT and T_OBJECT_EX members can be deleted. (They are set to NULL).
Type Objects

Perhaps one of the most important structures of the Python object system is the structure that defines a new type: the `PyTypeObject` structure. Type objects can be handled using any of the `PyObject_*` or `PyType_*()` functions, but do not offer much that's interesting to most Python applications. These objects are fundamental to how objects behave, so they are very important to the interpreter itself and to any extension module that implements new types.

Type objects are fairly large compared to most of the standard types. The reason for the size is that each type object stores a large number of values, mostly C function pointers, each of which implements a small part of the type's functionality. The fields of the type object are examined in detail in this section. The fields will be described in the order in which they occur in the structure.

Typedefs: unaryfunc, binaryfunc, ternaryfunc, inquiry, intargfunc, intintargfunc, intobjargproc, intintobjargproc, objobjargproc, destructor, freefunc, printfunc, getattrofunc, getattrfunc, setattrofunc, setattrfunc, reprfunc, hashfunc

The structure definition for `PyTypeObject` can be found in `Include/object.h`. For convenience of reference, this repeats the definition found there:

```c
typedef struct _typeobject {
    PyObject_VAR_HEAD
    const char *tp_name; /* For printing, in format "<module>.<name>" */
    Py_ssize_t tp_basicsize, tp_itemsize; /* For all */
    /* Methods to implement standard operations */
```
destructor tp_dealloc;
printfunc tp_print;
getattrfunc tp_getattr;
setattrfunc tp_setattr;
PyAsyncMethods *tp_as_async; /* formerly known as tp_compare (Python 2)
or tp_reserved (Python 3) */

reprfunc tp_repr;

/* Method suites for standard classes */

PyNumberMethods *tp_as_number;
PySequenceMethods *tp_as_sequence;
PyMappingMethods *tp_as_mapping;

/* More standard operations (here for binary compatibility) */

hashfunc tp_hash;
ternaryfunc tp_call;
reprfunc tp_str;
getattrofunc tp_getattro;
setattrofunc tp_setattro;

/* Functions to access object as input/output buffer */
PyBufferProcs *tp_as_buffer;

/* Flags to define presence of optional/expanded features */
unsigned long tp_flags;

const char *tp_doc; /* Documentation string */

/* call function for all accessible objects */
traverseproc tp_traverse;

/* delete references to contained objects */
inquiry tp_clear;
/* rich comparisons */
richcmpfunc tp_richcompare;

/* weak reference enabler */
Py_ssize_t tp_weaklistoffset;

/* Iterators */
getiterfunc tp_iter;
iternextfunc tp_iternext;

/* Attribute descriptor and subclassing stuff */
struct PyMethodDef *tp_methods;
struct PyMemberDef *tp_members;
struct PyGetSetDef *tp_getset;
struct _typeobject *tp_base;
PyObject *tp_dict;
descrgetfunc tp_descr_get;
descrsetfunc tp_descr_set;
Py_ssize_t tp_dictoffset;
initproc tp_init;
allocfunc tp_alloc;
newfunc tp_new;
freefunc tp_free; /* Low-level free-memory routine */
inquiry tp_is_gc; /* For PyObject_IS_GC */
PyObject *tp_bases;
PyObject *tp_mro; /* method resolution order */
PyObject *tp_cache;
PyObject *tp_subclasses;
PyObject *tp_weaklist;
destructor tp_del;

/* Type attribute cache version tag. Added in version 2.6 */
unsigned int tp_version_tag;

destructor tp_finalize;

} PyTypeObject;
The type object structure extends the PyVarObject structure. The ob_size field is used for dynamic types (created by type_new(), usually called from a class statement). Note that PyType_Type (the metatype) initializes tp_itemsize, which means that its instances (i.e. type objects) must have the ob_size field.

PyObject* PyObject._ob_next
PyObject* PyObject._ob_prev
These fields are only present when the macro Py_TRACE_REFS is defined. Their initialization to NULL is taken care of by the PyObject_HEAD_INIT macro. For statically allocated objects, these fields always remain NULL. For dynamically allocated objects, these two fields are used to link the object into a doubly-linked list of all live objects on the heap. This could be used for various debugging purposes; currently the only use is to print the objects that are still alive at the end of a run when the environment variable PYTHONDUMPREFS is set.

These fields are not inherited by subtypes.

Py_ssize_t PyObject.ob_refcnt
This is the type object's reference count, initialized to 1 by the PyObject_HEAD_INIT macro. Note that for statically allocated type objects, the type's instances (objects whose ob_type points back to the type) do not count as references. But for dynamically allocated type objects, the instances do count as references.

This field is not inherited by subtypes.

PyTypeObject* PyObject.ob_type
This is the type's type, in other words its metatype. It is initialized
by the argument to the PyObject_HEAD_INIT macro, and its value should normally be &PyType_Type. However, for dynamically loadable extension modules that must be usable on Windows (at least), the compiler complains that this is not a valid initializer. Therefore, the convention is to pass NULL to the PyObject_HEAD_INIT macro and to initialize this field explicitly at the start of the module’s initialization function, before doing anything else. This is typically done like this:

```c
Foo_Type.ob_type = &PyType_Type;
```

This should be done before any instances of the type are created. PyType_Ready() checks if ob_type is NULL, and if so, initializes it to the ob_type field of the base class. PyType_Ready() will not change this field if it is non-zero.

This field is inherited by subtypes.

**Py_ssize_t** PyVarObject.ob_size

For statically allocated type objects, this should be initialized to zero. For dynamically allocated type objects, this field has a special internal meaning.

This field is not inherited by subtypes.

**const char** PyTypeObject.tp_name

Pointer to a NUL-terminated string containing the name of the type. For types that are accessible as module globals, the string should be the full module name, followed by a dot, followed by the type name; for built-in types, it should be just the type name. If the module is a submodule of a package, the full package name is part of the full module name. For example, a type named T defined in
module M in subpackage Q in package P should have the `tp_name` initializer "P.Q.M.T".

For dynamically allocated type objects, this should just be the type name, and the module name explicitly stored in the type dict as the value for key '__module__'.

For statically allocated type objects, the `tp_name` field should contain a dot. Everything before the last dot is made accessible as the __module__ attribute, and everything after the last dot is made accessible as the __name__ attribute.

If no dot is present, the entire `tp_name` field is made accessible as the __name__ attribute, and the __module__ attribute is undefined (unless explicitly set in the dictionary, as explained above). This means your type will be impossible to pickle.

This field is not inherited by subtypes.

```
Py_ssize_t PyTypeObject.tp_basicsize
Py_ssize_t PyTypeObject.tp_itemsize
```

These fields allow calculating the size in bytes of instances of the type.

There are two kinds of types: types with fixed-length instances have a zero `tp_itemsize` field, types with variable-length instances have a non-zero `tp_itemsize` field. For a type with fixed-length instances, all instances have the same size, given in `tp_basicsize`.

For a type with variable-length instances, the instances must have an ob_size field, and the instance size is `tp_basicsize` plus N times `tp_itemsize`, where N is the "length" of the object. The
value of N is typically stored in the instance's ob_size field. There are exceptions: for example, ints use a negative ob_size to indicate a negative number, and N is abs(ob_size) there. Also, the presence of an ob_size field in the instance layout doesn't mean that the instance structure is variable-length (for example, the structure for the list type has fixed-length instances, yet those instances have a meaningful ob_size field).

The basic size includes the fields in the instance declared by the macro PyObject_HEAD or PyObject_VAR_HEAD (whichever is used to declare the instance struct) and this in turn includes the _ob_prev and _ob_next fields if they are present. This means that the only correct way to get an initializer for the tp_basicsize is to use the sizeof operator on the struct used to declare the instance layout. The basic size does not include the GC header size.

These fields are inherited separately by subtypes. If the base type has a non-zero tp_itemsize, it is generally not safe to set tp_itemsize to a different non-zero value in a subtype (though this depends on the implementation of the base type).

A note about alignment: if the variable items require a particular alignment, this should be taken care of by the value of tp_basicsize. Example: suppose a type implements an array of double. tp_itemsize is sizeof(double). It is the programmer's responsibility that tp_basicsize is a multiple of sizeof(double) (assuming this is the alignment requirement for double).

**Destructor** `PyTypeObject.tp_dealloc`

A pointer to the instance destructor function. This function must be
defined unless the type guarantees that its instances will never be deallocated (as is the case for the singletons None and Ellipsis).

The destructor function is called by the Py_DECREF() and Py_XDECREF() macros when the new reference count is zero. At this point, the instance is still in existence, but there are no references to it. The destructor function should free all references which the instance owns, free all memory buffers owned by the instance (using the freeing function corresponding to the allocation function used to allocate the buffer), and finally (as its last action) call the type's tp_free function. If the type is not subtypable (doesn't have the Py_TPFLAGS_BASETYPE flag bit set), it is permissible to call the object deallocator directly instead of via tp_free. The object deallocator should be the one used to allocate the instance; this is normally PyObject_Del() if the instance was allocated using PyObject_New() or PyObject_VarNew(), or PyObject_GC_Del() if the instance was allocated using PyObject_GC_New() or PyObject_GC_NewVar().

This field is inherited by subtypes.

printfunc PyTypeObject.tp_print

Reserved slot, formerly used for print formatting in Python 2.x.

getattrfunc PyTypeObject.tp_getattr

An optional pointer to the get-attribute-string function.

This field is deprecated. When it is defined, it should point to a function that acts the same as the tp_getattro function, but taking a C string instead of a Python string object to give the
attribute name. The signature is the same as for PyObject_GetAttrString().

This field is inherited by subtypes together with tp_getattro: a subtype inherits both tp_getattr and tp_getattro from its base type when the subtype's tp_getattr and tp_getattro are both NULL.

setattrfunc PyTypeObject.tp_setattr
An optional pointer to the set-attribute-string function.

This field is deprecated. When it is defined, it should point to a function that acts the same as the tp_setattro function, but taking a C string instead of a Python string object to give the attribute name. The signature is the same as for PyObject_SetAttrString().

This field is inherited by subtypes together with tp_setattro: a subtype inherits both tp_setattr and tp_setattro from its base type when the subtype's tp_setattr and tp_setattro are both NULL.

PyAsyncMethods* tp_as_async
Pointer to an additional structure that contains fields relevant only to objects which implement awaitable and asynchronous iterator protocols at the C-level. See Async Object Structures for details.

New in version 3.5: Formerly known as tp_compare and tp_reserved.

reprfunc PyTypeObject.tp_repr
An optional pointer to a function that implements the built-in function repr().
The signature is the same as for `PyObject_Repr()`; it must return a string or a Unicode object. Ideally, this function should return a string that, when passed to `eval()`, given a suitable environment, returns an object with the same value. If this is not feasible, it should return a string starting with '<' and ending with '>' from which both the type and the value of the object can be deduced.

When this field is not set, a string of the form `<%s object at %p>` is returned, where `%s` is replaced by the type name, and `%p` by the object's memory address.

This field is inherited by subtypes.

**PyNumberMethods** `* tp_as_number`  
Pointer to an additional structure that contains fields relevant only to objects which implement the number protocol. These fields are documented in [Number Object Structures](#).

The `tp_as_number` field is not inherited, but the contained fields are inherited individually.

**PySequenceMethods** `* tp_as_sequence`  
Pointer to an additional structure that contains fields relevant only to objects which implement the sequence protocol. These fields are documented in [Sequence Object Structures](#).

The `tp_as_sequence` field is not inherited, but the contained fields are inherited individually.

**PyMappingMethods** `* tp_as_mapping`  
Pointer to an additional structure that contains fields relevant only to objects which implement the mapping protocol. These fields are
documented in *Mapping Object Structures*.

The `tp_as_mapping` field is not inherited, but the contained fields are inherited individually.

**hashfunc** `PyTypeObject.tp_hash`

An optional pointer to a function that implements the built-in function `hash()`.

The signature is the same as for `PyObject_Hash()`; it must return a value of the type `Py_hash_t`. The value `-1` should not be returned as a normal return value; when an error occurs during the computation of the hash value, the function should set an exception and return `-1`.

This field can be set explicitly to `PyObject_HashNotImplemented()` to block inheritance of the hash method from a parent type. This is interpreted as the equivalent of `__hash__ = None` at the Python level, causing `isinstance(o, collections.Hashable)` to correctly return `False`. Note that the converse is also true - setting `__hash__ = None` on a class at the Python level will result in the `tp_hash` slot being set to `PyObject_HashNotImplemented()`.

When this field is not set, an attempt to take the hash of the object raises `TypeError`.

This field is inherited by subtypes together with `tp_richcompare`: a subtype inherits both of `tp_richcompare` and `tp_hash`, when the subtype’s `tp_richcompare` and `tp_hash` are both `NULL`.

**ternaryfunc** `PyTypeObject.tp_call`
An optional pointer to a function that implements calling the object. This should be *NULL* if the object is not callable. The signature is the same as for *PyObject_Call()*. 

This field is inherited by subtypes.

**reprfunc** *PyTypeObject.tp_str*

An optional pointer to a function that implements the built-in operation *str()* (Note that *str* is a type now, and *str()* calls the constructor for that type. This constructor calls *PyObject_Str()* to do the actual work, and *PyObject_Str()* will call this handler.)

The signature is the same as for *PyObject_Str()*; it must return a string or a Unicode object. This function should return a “friendly” string representation of the object, as this is the representation that will be used, among other things, by the *print()* function.

When this field is not set, *PyObject_Repr()* is called to return a string representation.

This field is inherited by subtypes.

**getattrofunc** *PyTypeObject.tp_getattro*

An optional pointer to the get-attribute function.

The signature is the same as for *PyObject_GetAttr()* . It is usually convenient to set this field to *PyObject_GenericGetAttr()* , which implements the normal way of looking for object attributes.

This field is inherited by subtypes together with *tp_getattr*: a subtype inherits both *tp_getattr* and *tp_getattro* from its
base type when the subtype’s `tp_getattr` and `tp_getattro` are both `NULL`.

`setattrofunc PyTypeObject.tp_setattro`

An optional pointer to the set-attribute function.

The signature is the same as for `PyObject_SetAttr()`. It is usually convenient to set this field to `PyObject_GenericSetAttr()`, which implements the normal way of setting object attributes.

This field is inherited by subtypes together with `tp_setattr`: a subtype inherits both `tp_setattr` and `tp_setattro` from its base type when the subtype’s `tp_setattr` and `tp_setattro` are both `NULL`.

`PyBufferProcs* PyTypeObject.tp_as_buffer`

Pointer to an additional structure that contains fields relevant only to objects which implement the buffer interface. These fields are documented in `Buffer Object Structures`.

The `tp_as_buffer` field is not inherited, but the contained fields are inherited individually.

`unsigned long PyTypeObject.tp_flags`

This field is a bit mask of various flags. Some flags indicate variant semantics for certain situations; others are used to indicate that certain fields in the type object (or in the extension structures referenced via `tp_as_number`, `tp_as_sequence`, `tp_as_mapping`, and `tp_as_buffer`) that were historically not always present are valid; if such a flag bit is clear, the type fields it guards must not be accessed and must be considered to have a zero or `NULL` value instead.
Inheritance of this field is complicated. Most flag bits are inherited individually, i.e. if the base type has a flag bit set, the subtype inherits this flag bit. The flag bits that pertain to extension structures are strictly inherited if the extension structure is inherited, i.e. the base type's value of the flag bit is copied into the subtype together with a pointer to the extension structure. The `Py_TPFLAGS_HAVE_GC` flag bit is inherited together with the `tp_traverse` and `tp_clear` fields, i.e. if the `Py_TPFLAGS_HAVE_GC` flag bit is clear in the subtype and the `tp_traverse` and `tp_clear` fields in the subtype exist and have `NULL` values.

The following bit masks are currently defined; these can be ORed together using the `|` operator to form the value of the `tp_flags` field. The macro `PyType_HasFeature()` takes a type and a flags value, `tp` and `f`, and checks whether `tp->tp_flags & f` is non-zero.

**Py_TPFLAGS_HAVE_GC**
This bit is set when the type object itself is allocated on the heap. In this case, the `ob_type` field of its instances is considered a reference to the type, and the type object is INCREF'ed when a new instance is created, and DECREF'ed when an instance is destroyed (this does not apply to instances of subtypes; only the type referenced by the instance's `ob_type` gets INCREF'ed or DECREF'ed).

**Py_TPFLAGS_BASETYPE**
This bit is set when the type can be used as the base type of another type. If this bit is clear, the type cannot be subtyped (similar to a “final” class in Java).
**Py_TPFLAGS_READY**

This bit is set when the type object has been fully initialized by `PyType_Ready()`.

**Py_TPFLAGS_READING**

This bit is set while `PyType_Ready()` is in the process of initializing the type object.

**Py_TPFLAGS_HAVE_GC**

This bit is set when the object supports garbage collection. If this bit is set, instances must be created using `PyObject_GC_New()` and destroyed using `PyObject_GC_Del()`. More information in section **Supporting Cyclic Garbage Collection**. This bit also implies that the GC-related fields `tp_traverse` and `tp_clear` are present in the type object.

**Py_TPFLAGS_DEFAULT**

This is a bitmask of all the bits that pertain to the existence of certain fields in the type object and its extension structures. Currently, it includes the following bits: `Py_TPFLAGS_HAVE_STACKLESS_EXTENSION`, `Py_TPFLAGS_HAVE_VERSION_TAG`.

**Py_TPFLAGS_LONG_SUBCLASS**

**Py_TPFLAGS_LIST_SUBCLASS**

**Py_TPFLAGS_TUPLE_SUBCLASS**

**Py_TPFLAGS_BYTES_SUBCLASS**

**Py_TPFLAGS_UNICODE_SUBCLASS**

**Py_TPFLAGS_DICT_SUBCLASS**
**Py_TPFLAGS_BASE_EXC_SUBCLASS**

**Py_TPFLAGS_TYPE_SUBCLASS**

These flags are used by functions such as `PyLong_Check()` to quickly determine if a type is a subclass of a built-in type; such specific checks are faster than a generic check, like `PyObject_IsInstance()`. Custom types that inherit from built-ins should have their `tp_flags` set appropriately, or the code that interacts with such types will behave differently depending on what kind of check is used.

**Py_TPFLAGS_HAVE_FINALIZE**

This bit is set when the `tp_finalize` slot is present in the type structure.

*New in version 3.4.*

*const char* `PyTypeObject.tp_doc`

An optional pointer to a NUL-terminated C string giving the docstring for this type object. This is exposed as the `__doc__` attribute on the type and instances of the type.

This field is *not* inherited by subtypes.

**traverseproc PyTypeObject.tp_traverse**

An optional pointer to a traversal function for the garbage collector. This is only used if the `Py_TPFLAGS_HAVE_GC` flag bit is set. More information about Python's garbage collection scheme can be found in section *Supporting Cyclic Garbage Collection*.

The `tp_traverse` pointer is used by the garbage collector to detect reference cycles. A typical implementation of a `tp_traverse` function simply calls `Py_VISIT()` on each of the
instance's members that are Python objects. For example, this is function `local_traverse()` from the `_thread` extension module:

```c
static int
local_traverse(localobject *self, visitproc visit
{
  Py_VISIT(self->args);
  Py_VISIT(self->kw);
  Py_VISIT(self->dict);
  return 0;
}
```

Note that `Py_VISIT()` is called only on those members that can participate in reference cycles. Although there is also a `self->key` member, it can only be `NULL` or a Python string and therefore cannot be part of a reference cycle.

On the other hand, even if you know a member can never be part of a cycle, as a debugging aid you may want to visit it anyway just so the `gc` module's `get_referents()` function will include it.

Note that `Py_VISIT()` requires the `visit` and `arg` parameters to `local_traverse()` to have these specific names; don’t name them just anything.

This field is inherited by subtypes together with `tp_clear` and the `Py_TPFLAGS_HAVE_GC` flag bit: the flag bit, `tp_traverse`, and `tp_clear` are all inherited from the base type if they are all zero in the subtype.

**inquiry** `PyTypeObject.tp_clear`

An optional pointer to a clear function for the garbage collector.
This is only used if the `Py_TPFLAGS_HAVE_GC` flag bit is set.

The `tp_clear` member function is used to break reference cycles in cyclic garbage detected by the garbage collector. Taken together, all `tp_clear` functions in the system must combine to break all reference cycles. This is subtle, and if in any doubt supply a `tp_clear` function. For example, the tuple type does not implement a `tp_clear` function, because it’s possible to prove that no reference cycle can be composed entirely of tuples. Therefore the `tp_clear` functions of other types must be sufficient to break any cycle containing a tuple. This isn’t immediately obvious, and there’s rarely a good reason to avoid implementing `tp_clear`.

Implementations of `tp_clear` should drop the instance’s references to those of its members that may be Python objects, and set its pointers to those members to `NULL`, as in the following example:

```c
static int
local_clear(localobject *self)
{
    Py_CLEAR(self->key);
    Py_CLEAR(self->args);
    Py_CLEAR(self->kw);
    Py_CLEAR(self->dict);
    return 0;
}
```

The `Py_CLEAR()` macro should be used, because clearing references is delicate: the reference to the contained object must not be decremented until after the pointer to the contained object is set to `NULL`. This is because decrementing the reference count
may cause the contained object to become trash, triggering a chain of reclamation activity that may include invoking arbitrary Python code (due to finalizers, or weakref callbacks, associated with the contained object). If it’s possible for such code to reference self again, it’s important that the pointer to the contained object be NULL at that time, so that self knows the contained object can no longer be used. The Py_CLEAR() macro performs the operations in a safe order.

Because the goal of tp_clear functions is to break reference cycles, it's not necessary to clear contained objects like Python strings or Python integers, which can’t participate in reference cycles. On the other hand, it may be convenient to clear all contained Python objects, and write the type’s tp_dealloc function to invoke tp_clear.

More information about Python’s garbage collection scheme can be found in section Supporting Cyclic Garbage Collection.

This field is inherited by subtypes together with tp_traverse and the Py_TPFLAGS_HAVE_GC flag bit: the flag bit, tp_traverse, and tp_clear are all inherited from the base type if they are all zero in the subtype.

richcmpfunc PyTypeObject.tp_richcompare

An optional pointer to the rich comparison function, whose signature is PyObject *tp_richcompare(PyObject *a, PyObject *b, int op). The first parameter is guaranteed to be an instance of the type that is defined by PyTypeObject.

The function should return the result of the comparison (usually Py_True or Py_False). If the comparison is undefined, it must
return Py_NotImplemented, if another error occurred it must return NULL and set an exception condition.

**Note:** If you want to implement a type for which only a limited set of comparisons makes sense (e.g. `==` and `!=`, but not `<` and friends), directly raise `TypeError` in the rich comparison function.

This field is inherited by subtypes together with `tp_hash`: a subtype inherits `tp_richcompare` and `tp_hash` when the subtype’s `tp_richcompare` and `tp_hash` are both `NULL`.

The following constants are defined to be used as the third argument for `tp_richcompare` and for `PyObject_RichCompare()`:

<table>
<thead>
<tr>
<th>Constant</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Py_LT</td>
<td><code>&lt;</code></td>
</tr>
<tr>
<td>Py_LE</td>
<td><code>&lt;=</code></td>
</tr>
<tr>
<td>Py_EQ</td>
<td><code>==</code></td>
</tr>
<tr>
<td>Py_NE</td>
<td><code>!=</code></td>
</tr>
<tr>
<td>Py_GT</td>
<td><code>&gt;</code></td>
</tr>
<tr>
<td>Py_GE</td>
<td><code>&gt;=</code></td>
</tr>
</tbody>
</table>

**Py_ssize_t** `PyTypeObject.tp_weaklistoffset`

If the instances of this type are weakly referenceable, this field is greater than zero and contains the offset in the instance structure of the weak reference list head (ignoring the GC header, if present); this offset is used by `PyObject_ClearWeakRefs()` and the `PyWeakref_*()` functions. The instance structure needs
to include a field of type `PyObject*` which is initialized to `NULL`.

Do not confuse this field with `tp_weaklist`; that is the list head for weak references to the type object itself.

This field is inherited by subtypes, but see the rules listed below. A subtype may override this offset; this means that the subtype uses a different weak reference list head than the base type. Since the list head is always found via `tp_weaklistoffset`, this should not be a problem.

When a type defined by a class statement has no `__slots__` declaration, and none of its base types are weakly referenceable, the type is made weakly referenceable by adding a weak reference list head slot to the instance layout and setting the `tp_weaklistoffset` of that slot's offset.

When a type's `__slots__` declaration contains a slot named `__weakref__`, that slot becomes the weak reference list head for instances of the type, and the slot's offset is stored in the type's `tp_weaklistoffset`.

When a type's `__slots__` declaration does not contain a slot named `__weakref__`, the type inherits its `tp_weaklistoffset` from its base type.

`getiterfunc` **`PyTypeObject.tp_iter`**

An optional pointer to a function that returns an iterator for the object. Its presence normally signals that the instances of this type are iterable (although sequences may be iterable without this function).

This function has the same signature as `PyObject_GetIter()`.
This field is inherited by subtypes.

**iternextfunc PyTypeObject.tp_iternext**

An optional pointer to a function that returns the next item in an iterator. When the iterator is exhausted, it must return `NULL`; a `StopIteration` exception may or may not be set. When another error occurs, it must return `NULL` too. Its presence signals that the instances of this type are iterators.

Iterator types should also define the `tp_iter` function, and that function should return the iterator instance itself (not a new iterator instance).

This function has the same signature as `PyIter_Next()`.

This field is inherited by subtypes.

**struct PyMethodDef* PyTypeObject.tp_methods**

An optional pointer to a static `NULL`-terminated array of `PyMethodDef` structures, declaring regular methods of this type.

For each entry in the array, an entry is added to the type's dictionary (see `tp_dict` below) containing a method descriptor.

This field is not inherited by subtypes (methods are inherited through a different mechanism).

**struct PyMemberDef* PyTypeObject.tp_members**

An optional pointer to a static `NULL`-terminated array of `PyMemberDef` structures, declaring regular data members (fields or slots) of instances of this type.

For each entry in the array, an entry is added to the type's dictionary (see `tp_dict` below) containing a member descriptor.
This field is not inherited by subtypes (members are inherited through a different mechanism).

struct PyGetSetDef* `PyTypeObject.tp_getset`

An optional pointer to a static `NULL`-terminated array of `PyGetSetDef` structures, declaring computed attributes of instances of this type.

For each entry in the array, an entry is added to the type's dictionary (see `tp_dict` below) containing a getset descriptor.

This field is not inherited by subtypes (computed attributes are inherited through a different mechanism).

Docs for `PyGetSetDef`:

```c
typedef PyObject *(*getter)(PyObject *, void *);
typedef int (*setter)(PyObject *, PyObject *, void *);

typedef struct PyGetSetDef {
    char *name; /* attribute name */
    getter get; /* C function to get the attribute */
    setter set; /* C function to set the attribute */
    char *doc; /* optional doc string */
    void *closure; /* optional additional data for function */
} PyGetSetDef;
```

`PyTypeObject* PyTypeObject.tp_base`

An optional pointer to a base type from which type properties are inherited. At this level, only single inheritance is supported; multiple inheritance require dynamically creating a type object by calling the metatype.
This field is not inherited by subtypes (obviously), but it defaults to &PyBaseObject_Type (which to Python programmers is known as the type `object`).

**PyObject** `PyTypeObject.tp_dict`  
The type’s dictionary is stored here by `PyType_Ready()`.

This field should normally be initialized to `NULL` before `PyType_Ready` is called; it may also be initialized to a dictionary containing initial attributes for the type. Once `PyType_Ready()` has initialized the type, extra attributes for the type may be added to this dictionary only if they don’t correspond to overloaded operations (like `__add__()`).

This field is not inherited by subtypes (though the attributes defined in here are inherited through a different mechanism).

**Warning:** It is not safe to use `PyDict_SetItem()` on or otherwise modify `tp_dict` with the dictionary C-API.

descrgetfunc `PyTypeObject.tp_descr_get`  
An optional pointer to a “descriptor get” function.

The function signature is

```
PyObject * tp descr_get(PyObject *self, PyObject *)
```

This field is inherited by subtypes.

descrsetfunc `PyTypeObject.tp_descr_set`  
An optional pointer to a “descriptor set” function.
The function signature is

```c
int tp_descr_set(PyObject *self, PyObject *obj, PyObject *dict)
```

This field is inherited by subtypes.

Py_ssize_t `PyTypeObject.tp_dictoffset`

If the instances of this type have a dictionary containing instance variables, this field is non-zero and contains the offset in the instances of the type of the instance variable dictionary; this offset is used by `PyObject_GenericGetAttr()`.

Do not confuse this field with `tp_dict`; that is the dictionary for attributes of the type object itself.

If the value of this field is greater than zero, it specifies the offset from the start of the instance structure. If the value is less than zero, it specifies the offset from the end of the instance structure. A negative offset is more expensive to use, and should only be used when the instance structure contains a variable-length part. This is used for example to add an instance variable dictionary to subtypes of `str` or `tuple`. Note that the `tp_basicsize` field should account for the dictionary added to the end in that case, even though the dictionary is not included in the basic object layout. On a system with a pointer size of 4 bytes, `tp_dictoffset` should be set to -4 to indicate that the dictionary is at the very end of the structure.

The real dictionary offset in an instance can be computed from a negative `tp_dictoffset` as follows:

```c
dictoffset = tp_basicsize + abs(ob_size)*tp_items
```
if dictoffset is not aligned on sizeof(void*):
  round up to sizeof(void*)

where tp_basicsize, tp_itemsize and tp_dictoffset are taken from the type object, and ob_size is taken from the instance. The absolute value is taken because ints use the sign of ob_size to store the sign of the number. (There’s never a need to do this calculation yourself; it is done for you by _PyObject_GetDictPtr().)

This field is inherited by subtypes, but see the rules listed below. A subtype may override this offset; this means that the subtype instances store the dictionary at a difference offset than the base type. Since the dictionary is always found via tp_dictoffset, this should not be a problem.

When a type defined by a class statement has no __slots__ declaration, and none of its base types has an instance variable dictionary, a dictionary slot is added to the instance layout and the tp_dictoffset is set to that slot’s offset.

When a type defined by a class statement has a __slots__ declaration, the type inherits its tp_dictoffset from its base type.

(Adding a slot named __dict__ to the __slots__ declaration does not have the expected effect, it just causes confusion. Maybe this should be added as a feature just like __weakref__ though.)

initproc PyTypeObject.tp_init
An optional pointer to an instance initialization function.
This function corresponds to the `__init__()` method of classes. Like `__init__()` , it is possible to create an instance without calling `__init__()` , and it is possible to reinitialize an instance by calling its `__init__()` method again.

The function signature is

```c
int tp_init(PyObject *self, PyObject *args, PyObject *kwds);
```

The self argument is the instance to be initialized; the args and kwds arguments represent positional and keyword arguments of the call to `__init__()` .

The `tp_init` function, if not `NULL` , is called when an instance is created normally by calling its type, after the type's `tp_new` function has returned an instance of the type. If the `tp_new` function returns an instance of some other type that is not a subtype of the original type, no `tp_init` function is called; if `tp_new` returns an instance of a subtype of the original type, the subtype's `tp_init` is called.

This field is inherited by subtypes.

**allocfunc** `PyTypeObject.tp_alloc`

An optional pointer to an instance allocation function.

The function signature is

```c
PyObject *tp_alloc(PyTypeObject *self, Py_ssize_t);
```

The purpose of this function is to separate memory allocation from memory initialization. It should return a pointer to a block of
memory of adequate length for the instance, suitably aligned, and
initialized to zeros, but with ob_refcnt set to 1 and ob_type set
to the type argument. If the type’s `tp_itemsize` is non-zero, the
object’s `ob_size` field should be initialized to `nitems` and the
length of the allocated memory block should be `tp_basicsize +
nitems*tp_itemsize`, rounded up to a multiple of `sizeof(void*)`; otherwise, `nitems` is not used and the length of
the block should be `tp_basicsize`.

Do not use this function to do any other instance initialization, not
even to allocate additional memory; that should be done by
`tp_new`.

This field is inherited by static subtypes, but not by dynamic
subtypes (subtypes created by a class statement); in the latter, this
field is always set to `PyType_GenericAlloc()`, to force a
standard heap allocation strategy. That is also the recommended
value for statically defined types.

### newfunc `PyObject *tp_new`

An optional pointer to an instance creation function.

If this function is `NULL` for a particular type, that type cannot be
called to create new instances; presumably there is some other
way to create instances, like a factory function.

The function signature is

```c
PyObject *tp_new(PyTypeObject *subtype, PyObject
```

The subtype argument is the type of the object being created; the
`args` and `kwds` arguments represent positional and keyword
arguments of the call to the type. Note that subtype doesn’t have to equal the type whose `tp_new` function is called; it may be a subtype of that type (but not an unrelated type).

The `tp_new` function should call `subtype->tp_alloc(subtype, nitems)` to allocate space for the object, and then do only as much further initialization as is absolutely necessary. Initialization that can safely be ignored or repeated should be placed in the `tp_init` handler. A good rule of thumb is that for immutable types, all initialization should take place in `tp_new`, while for mutable types, most initialization should be deferred to `tp_init`.

This field is inherited by subtypes, except it is not inherited by static types whose `tp_base` is `NULL` or `&PyBaseObject_Type`.

**Destructor** `PyTypeObject.tp_free`  
An optional pointer to an instance deallocation function. Its signature is `freefunc`:

```c
void tp_free(void *)
```

An initializer that is compatible with this signature is `PyObject_Free()`.

This field is inherited by static subtypes, but not by dynamic subtypes (subtypes created by a class statement); in the latter, this field is set to a deallocator suitable to match `PyType_GenericAlloc()` and the value of the `Py_TPFLAGS_HAVE_GC` flag bit.

**Inquiry** `PyTypeObject.tp_is_gc`
An optional pointer to a function called by the garbage collector.

The garbage collector needs to know whether a particular object is collectible or not. Normally, it is sufficient to look at the object’s type’s tp_flags field, and check the Py_TPFLAGS_HAVE_GC flag bit. But some types have a mixture of statically and dynamically allocated instances, and the statically allocated instances are not collectible. Such types should define this function; it should return 1 for a collectible instance, and 0 for a non-collectible instance. The signature is

```c
int tp_is_gc(PyObject *self)
```

(The only example of this are types themselves. The metatype, PyType_Type, defines this function to distinguish between statically and dynamically allocated types.)

This field is inherited by subtypes.

**PyObject* PyTypeObject.tp_bases**

Tuple of base types.

This is set for types created by a class statement. It should be NULL for statically defined types.

This field is not inherited.

**PyObject* PyTypeObject.tp_mro**

Tuple containing the expanded set of base types, starting with the type itself and ending with object, in Method Resolution Order.

This field is not inherited; it is calculated fresh by PyType_Ready().
**destructor PyTypeObject.tp_finalize**

An optional pointer to an instance finalization function. Its signature is destructor:

```c
void tp_finalize(PyObject *)
```

If `tp_finalize` is set, the interpreter calls it once when finalizing an instance. It is called either from the garbage collector (if the instance is part of an isolated reference cycle) or just before the object is deallocated. Either way, it is guaranteed to be called before attempting to break reference cycles, ensuring that it finds the object in a sane state.

`tp_finalize` should not mutate the current exception status; therefore, a recommended way to write a non-trivial finalizer is:

```c
static void
local_finalize(PyObject *self)
{
    PyObject *error_type, *error_value, *error_traceback

    /* Save the current exception, if any. */
    PyErr_Fetch(&error_type, &error_value, &error_traceback

    /* ... */

    /* Restore the saved exception. */
    PyErr_Restore(error_type, error_value, error_traceback
}
```

For this field to be taken into account (even through inheritance), you must also set the `Py_TPFLAGS_HAVE_FINALIZE` flags bit.

This field is inherited by subtypes.
New in version 3.4.

See also: “Safe object finalization” (PEP 442)

PyObject* `PyTypeObject.tp_cache`
Unused. Not inherited. Internal use only.

PyObject* `PyTypeObject.tp_subclasses`
List of weak references to subclasses. Not inherited. Internal use only.

PyObject* `PyTypeObject.tp_weaklist`
Weak reference list head, for weak references to this type object. Not inherited. Internal use only.

The remaining fields are only defined if the feature test macro COUNT_ALLOCS is defined, and are for internal use only. They are documented here for completeness. None of these fields are inherited by subtypes.

Py_ssize_t `PyTypeObject.tp_allocs`
Number of allocations.

Py_ssize_t `PyTypeObject.tp_frees`
Number of frees.

Py_ssize_t `PyTypeObject.tp_maxalloc`
Maximum simultaneously allocated objects.

PyObject* `PyTypeObject.tp_next`
Pointer to the next type object with a non-zero `tp_allocs` field.

Also, note that, in a garbage collected Python, `tp_dealloc` may be
called from any Python thread, not just the thread which created the object (if the object becomes part of a refcount cycle, that cycle might be collected by a garbage collection on any thread). This is not a problem for Python API calls, since the thread on which tp_dealloc is called will own the Global Interpreter Lock (GIL). However, if the object being destroyed in turn destroys objects from some other C or C++ library, care should be taken to ensure that destroying those objects on the thread which called tp_dealloc will not violate any assumptions of the library.
Number Object Structures

PyNumberMethods

This structure holds pointers to the functions which an object uses to implement the number protocol. Each function is used by the function of similar name documented in the Number Protocol section.

Here is the structure definition:

```c
typedef struct {
    binaryfunc nb_add;
    binaryfunc nb_subtract;
    binaryfunc nb_multiply;
    binaryfunc nb_remainder;
    binaryfunc nb_divmod;
    ternaryfunc nb_power;
    unaryfunc nb_negative;
    unaryfunc nb_positive;
    unaryfunc nb_absolute;
    inquiry nb_bool;
    unaryfunc nb_invert;
    binaryfunc nb_lshift;
    binaryfunc nb_rshift;
    binaryfunc nb_and;
    binaryfunc nb_xor;
    binaryfunc nb_or;
    unaryfunc nb_int;
    void *nb_reserved;
    unaryfunc nb_float;
    binaryfunc nb_inplace_add;
    binaryfunc nb_inplace_subtract;
    binaryfunc nb_inplace_multiply;
} PyNumberMethods;
```
binaryfunc nb_inplace_remainder;
ternaryfunc nb_inplace_power;
binaryfunc nb_inplace_lshift;
binaryfunc nb_inplace_rshift;
binaryfunc nb_inplace_and;
binaryfunc nb_inplace_xor;
binaryfunc nb_inplace_or;

binaryfunc nb_floor_divide;
binaryfunc nb_true_divide;
binaryfunc nb_inplace_floor_divide;
binaryfunc nb_inplace_true_divide;

unaryfunc nb_index;

binaryfunc nb_matrix_multiply;
binaryfunc nb_inplace_matrix_multiply;
} PyNumberMethods;

**Note:** Binary and ternary functions must check the type of all their operands, and implement the necessary conversions (at least one of the operands is an instance of the defined type). If the operation is not defined for the given operands, binary and ternary functions must return `Py_NotImplemented`, if another error occurred they must return NULL and set an exception.

**Note:** The `nb_reserved` field should always be NULL. It was previously called `nb_long`, and was renamed in Python 3.0.1.
Mapping Object Structures

**PyMappingMethods**

This structure holds pointers to the functions which an object uses to implement the mapping protocol. It has three members:

1. **lenfunc PyMappingMethods.mp_length**
   
   This function is used by `PyMapping_Length()` and `PyObject_Size()`, and has the same signature. This slot may be set to `NULL` if the object has no defined length.

2. **binaryfunc PyMappingMethods.mp_subscript**
   
   This function is used by `PyObject_GetItem()` and has the same signature. This slot must be filled for the `PyMapping_Check()` function to return 1, it can be `NULL` otherwise.

3. **objobjargproc PyMappingMethods.mp_ass_subscript**
   
   This function is used by `PyObject_SetItem()` and has the same signature. If this slot is `NULL`, the object does not support item assignment.
Sequence Object Structures

**PySequenceMethods**

This structure holds pointers to the functions which an object uses to implement the sequence protocol.

**lenfunc PySequenceMethods.sq_length**

This function is used by `PySequence_Size()` and `PyObject_Size()`, and has the same signature.

**binaryfunc PySequenceMethods.sq_concat**

This function is used by `PySequence_Concat()` and has the same signature. It is also used by the + operator, after trying the numeric addition via the `nb_add` slot.

**ssizeargfunc PySequenceMethods.sq_repeat**

This function is used by `PySequence_Repeat()` and has the same signature. It is also used by the * operator, after trying numeric multiplication via the `nb_multiply` slot.

**ssizeargfunc PySequenceMethods.sq_item**

This function is used by `PySequence_GetItem()` and has the same signature. This slot must be filled for the `PySequence_Check()` function to return 1, it can be `NULL` otherwise.

Negative indexes are handled as follows: if the `sq_length` slot is filled, it is called and the sequence length is used to compute a positive index which is passed to `sq_item`. If `sq_length` is `NULL`, the index is passed as is to the function.
ssizeobjargproc  **PySequenceMethods.sq_ass_item**

This function is used by `PySequence_SetItem()` and has the same signature. This slot may be left to `NULL` if the object does not support item assignment.

objobjproc  **PySequenceMethods.sq_contains**

This function may be used by `PySequence_Contains()` and has the same signature. This slot may be left to `NULL`, in this case `PySequence_Contains()` simply traverses the sequence until it finds a match.

binaryfunc  **PySequenceMethods.sq_inplace_concat**

This function is used by `PySequence_InPlaceConcat()` and has the same signature. It should modify its first operand, and return it.

 ssizeargfunc  **PySequenceMethods.sq_inplace_repeat**

This function is used by `PySequence_InPlaceRepeat()` and has the same signature. It should modify its first operand, and return it.
Buffer Object Structures

**PyBufferProcs**

This structure holds pointers to the functions required by the Buffer protocol. The protocol defines how an exporter object can expose its internal data to consumer objects.

**getbufferproc** `PyBufferProcs.bf_getbuffer`

The signature of this function is:

```c
int (PyObject *exporter, Py_buffer *view, int flags)
```

Handle a request to `exporter` to fill in `view` as specified by `flags`. Except for point (3), an implementation of this function MUST take these steps:

1. Check if the request can be met. If not, raise `PyExc_BufferError`, set `view->obj` to `NULL` and return -1.
2. Fill in the requested fields.
3. Increment an internal counter for the number of exports.
4. Set `view->obj` to `exporter` and increment `view->obj`.
5. Return 0.

If `exporter` is part of a chain or tree of buffer providers, two main schemes can be used:

- **Re-export**: Each member of the tree acts as the exporting object and sets `view->obj` to a new reference to itself.
- **Redirect**: The buffer request is redirected to the root object of the tree. Here, `view->obj` will be a new reference to the root object.
The individual fields of view are described in section Buffer structure, the rules how an exporter must react to specific requests are in section Buffer request types.

All memory pointed to in the Py_buffer structure belongs to the exporter and must remain valid until there are no consumers left. format, shape, strides, suboffsets and internal are read-only for the consumer.

PyBuffer_FillInfo() provides an easy way of exposing a simple bytes buffer while dealing correctly with all request types.

PyObject_GetBuffer() is the interface for the consumer that wraps this function.

releasebufferproc PyBufferProcs.bf_releasebuffer

The signature of this function is:

```c
void (PyObject *exporter, Py_buffer *view);
```

Handle a request to release the resources of the buffer. If no resources need to be released, PyBufferProcs.bf_releasebuffer may be NULL. Otherwise, a standard implementation of this function will take these optional steps:

1. Decrement an internal counter for the number of exports.
2. If the counter is 0, free all memory associated with view.

The exporter MUST use the internal field to keep track of buffer-specific resources. This field is guaranteed to remain constant, while a consumer MAY pass a copy of the original buffer as the view argument.
This function MUST NOT decrement view->obj, since that is done automatically in `PyBuffer_Release()` (this scheme is useful for breaking reference cycles).

`PyBuffer_Release()` is the interface for the consumer that wraps this function.
Async Object Structures

New in version 3.5.

**PyAsyncMethods**

This structure holds pointers to the functions required to implement *awaitable* and *asynchronous iterator* objects.

Here is the structure definition:

```c
typedef struct {
    unaryfunc am_await;
    unaryfunc am_aiter;
    unaryfunc am_anext;
} PyAsyncMethods;
```

unaryfunc **PyAsyncMethods.am_await**

The signature of this function is:

```c
PyObject *am_await(PyObject *self)
```

The returned object must be an iterator, i.e. `PyIter_Check()` must return 1 for it.

This slot may be set to `NULL` if an object is not an *awaitable*.

unaryfunc **PyAsyncMethods.am_aiter**

The signature of this function is:

```c
PyObject *am_aiter(PyObject *self)
```

Must return an *awaitable* object. See `__anext__()` for details.
This slot may be set to NULL if an object does not implement asynchronous iteration protocol.

 unaryfunc **PyAsyncMethods.am_anext**

 The signature of this function is:

```
PyObject *am_anext(PyObject *self)
```

 Must return an *awaitable* object. See `__anext__()` for details.
 This slot may be set to NULL.
Supporting Cyclic Garbage Collection

Python's support for detecting and collecting garbage which involves circular references requires support from object types which are "containers" for other objects which may also be containers. Types which do not store references to other objects, or which only store references to atomic types (such as numbers or strings), do not need to provide any explicit support for garbage collection.

To create a container type, the \texttt{tp\_flags} field of the type object must include the \texttt{Py\_TPFLAGS\_HAVE\_GC} and provide an implementation of the \texttt{tp\_traverse} handler. If instances of the type are mutable, a \texttt{tp\_clear} implementation must also be provided.

\textbf{Py\_TPFLAGS\_HAVE\_GC}

Objects with a type with this flag set must conform with the rules documented here. For convenience these objects will be referred to as container objects.

Constructors for container types must conform to two rules:

1. The memory for the object must be allocated using \texttt{PyObject\_GC\_New()} or \texttt{PyObject\_GC\_NewVar().}
2. Once all the fields which may contain references to other containers are initialized, it must call \texttt{PyObject\_GC\_Track().}

\texttt{TYPE* PyObject\_GC\_New(TYPE, PyTypeObject *type)}

Analogous to \texttt{PyObject\_New()} but for container objects with the \texttt{Py\_TPFLAGS\_HAVE\_GC} flag set.
TYPE* **PyObject\_GC\_NewVar** (TYPE, PyTypeObject \*type, Py\_ssize\_t size)

  Analogous to **PyObject\_NewVar()** but for container objects with the Py\_TPFLAGS\_HAVE\_GC flag set.

TYPE* **PyObject\_GC\_Resize** (TYPE, PyVarObject \*op, Py\_ssize\_t newsize)

  Resize an object allocated by **PyObject\_NewVar()**. Returns the resized object or **NULL** on failure.

**void** **PyObject\_GC\_Track** (PyObject \*op)

  Adds the object \*op to the set of container objects tracked by the collector. The collector can run at unexpected times so objects must be valid while being tracked. This should be called once all the fields followed by the tp\_traverse handler become valid, usually near the end of the constructor.

**void** **_PyObject\_GC\_TRACK** (PyObject \*op)

  A macro version of **PyObject\_GC\_Track()**. It should not be used for extension modules.

Similarly, the deallocator for the object must conform to a similar pair of rules:

1. Before fields which refer to other containers are invalidated, **PyObject\_GC\_UnTrack()** must be called.
2. The object's memory must be deallocated using **PyObject\_GC\_Del()**.

**void** **PyObject\_GC\_Del** (void \*op)

  Releases memory allocated to an object using **PyObject\_GC\_New()** or **PyObject\_GC\_NewVar()**.
void `PyObject_GC_UnTrack`(void *op)

Remove the object `op` from the set of container objects tracked by the collector. Note that `PyObject_GC_Track()` can be called again on this object to add it back to the set of tracked objects. The deallocator (`tp_dealloc` handler) should call this for the object before any of the fields used by the `tp_traverse` handler become invalid.

void `__PyObject_GC_UNTRACK`(PyObject *op)

A macro version of `PyObject_GC_UnTrack()`. It should not be used for extension modules.

The `tp_traverse` handler accepts a function parameter of this type:

```c
int (*visitproc)(PyObject *object, void *arg)
```

Type of the visitor function passed to the `tp_traverse` handler. The function should be called with an object to traverse as `object` and the third parameter to the `tp_traverse` handler as `arg`. The Python core uses several visitor functions to implement cyclic garbage detection; it’s not expected that users will need to write their own visitor functions.

The `tp_traverse` handler must have the following type:

```c
int (*traverseproc)(PyObject *self, visitproc visit, void *arg)
```

Traversal function for a container object. Implementations must call the `visit` function for each object directly contained by `self`, with the parameters to `visit` being the contained object and the `arg` value passed to the handler. The `visit` function must not be called with a `NULL` object argument. If `visit` returns a non-zero value that value should be returned immediately.
To simplify writing `tp_traverse` handlers, a `Py_VISIT()` macro is provided. In order to use this macro, the `tp_traverse` implementation must name its arguments exactly `visit` and `arg`:

```c
void Py_VISIT(PyObject *o)

Call the `visit` callback, with arguments `o` and `arg`. If `visit` returns a non-zero value, then return it. Using this macro, `tp_traverse` handlers look like:

```c
static int
my_traverse(Noddy *self, visitproc visit, void *arg)
{
    Py_VISIT(self->foo);
    Py_VISIT(self->bar);
    return 0;
}
```

The `tp_clear` handler must be of the `inquiry` type, or `NULL` if the object is immutable.

```c
int (*inquiry)(PyObject *self)

Drop references that may have created reference cycles. Immutable objects do not have to define this method since they can never directly create reference cycles. Note that the object must still be valid after calling this method (don’t just call `Py_DECREF()` on a reference). The collector will call this method if it detects that this object is involved in a reference cycle.
Last updated on Dec 06, 2015. Found a bug?
Created using Sphinx 1.3.1.
API and ABI Versioning

PY_VERSION_HEX is the Python version number encoded in a single integer.

For example if the PY_VERSION_HEX is set to 0x030401a2, the underlying version information can be found by treating it as a 32 bit number in the following manner:

<table>
<thead>
<tr>
<th>Bytes</th>
<th>Bits (big endian order)</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-8</td>
<td>PY_MAJOR_VERSION (the 3 in 3.4.1a2)</td>
</tr>
<tr>
<td>2</td>
<td>9-16</td>
<td>PY_MINOR_VERSION (the 4 in 3.4.1a2)</td>
</tr>
<tr>
<td>3</td>
<td>17-24</td>
<td>PY_MICRO_VERSION (the 1 in 3.4.1a2)</td>
</tr>
<tr>
<td>4</td>
<td>25-28</td>
<td>PY_RELEASE_LEVEL (0xA for alpha, 0xB for beta, 0xC for release candidate and 0xF for final), in this case it is alpha.</td>
</tr>
<tr>
<td></td>
<td>29-32</td>
<td>PY_RELEASE_SERIAL (the 2 in 3.4.1a2, zero for final releases)</td>
</tr>
</tbody>
</table>

Thus 3.4.1a2 is hexversion 0x030401a2.

All the given macros are defined in Include/patchlevel.h.
Porting Python 2 Code to Python 3

author: Brett Cannon

Abstract

With Python 3 being the future of Python while Python 2 is still in active use, it is good to have your project available for both major releases of Python. This guide is meant to help you figure out how best to support both Python 2 & 3 simultaneously.

If you are looking to port an extension module instead of pure Python code, please see Porting Extension Modules to Python 3.

If you would like to read one core Python developer’s take on why Python 3 came into existence, you can read Nick Coghlan’s Python 3 Q & A.

For help with porting, you can email the python-porting mailing list with questions.
The Short Explanation

To make your project be single-source Python 2/3 compatible, the basic steps are:

1. Only worry about supporting Python 2.7
2. Make sure you have good test coverage (coverage.py can help; pip install coverage)
3. Learn the differences between Python 2 & 3
4. Use Modernize or Futurize to update your code (pip install modernize or pip install future, respectively)
5. Use Pylint to help make sure you don't regress on your Python 3 support (pip install pylint)
6. Use caniusepython3 to find out which of your dependencies are blocking your use of Python 3 (pip install caniusepython3)
7. Once your dependencies are no longer blocking you, use continuous integration to make sure you stay compatible with Python 2 & 3 (tox can help test against multiple versions of Python; pip install tox)

If you are dropping support for Python 2 entirely, then after you learn the differences between Python 2 & 3 you can run 2to3 over your code and skip the rest of the steps outlined above.
Details

A key point about supporting Python 2 & 3 simultaneously is that you can start **today**! Even if your dependencies are not supporting Python 3 yet that does not mean you can't modernize your code **now** to support Python 3. Most changes required to support Python 3 lead to cleaner code using newer practices even in Python 2.

Another key point is that modernizing your Python 2 code to also support Python 3 is largely automated for you. While you might have to make some API decisions thanks to Python 3 clarifying text data versus binary data, the lower-level work is now mostly done for you and thus can at least benefit from the automated changes immediately.

Keep those key points in mind while you read on about the details of porting your code to support Python 2 & 3 simultaneously.

**Drop support for Python 2.6 and older**

While you can make Python 2.5 work with Python 3, it is **much** easier if you only have to work with Python 2.7. If dropping Python 2.5 is not an option then the **six** project can help you support Python 2.5 & 3 simultaneously (**pip install six**). Do realize, though, that nearly all the projects listed in this HOWTO will not be available to you.

If you are able to skip Python 2.5 and older, then the required changes to your code should continue to look and feel like idiomatic Python code. At worst you will have to use a function instead of a method in some instances or have to import a function instead of using a built-in one, but otherwise the overall transformation should not feel foreign to you.
But you should aim for only supporting Python 2.7. Python 2.6 is no longer supported and thus is not receiving bugfixes. This means you will have to work around any issues you come across with Python 2.6. There are also some tools mentioned in this HOWTO which do not support Python 2.6 (e.g., Pylint), and this will become more commonplace as time goes on. It will simply be easier for you if you only support the versions of Python that you have to support.

Make sure you specify the proper version support in your setup.py file

In your setup.py file you should have the proper trove classifier specifying what versions of Python you support. As your project does not support Python 3 yet you should at least have Programming Language :: Python :: 2 :: Only specified. Ideally you should also specify each major/minor version of Python that you do support, e.g. Programming Language :: Python :: 2.7.

Have good test coverage

Once you have your code supporting the oldest version of Python 2 you want it to, you will want to make sure your test suite has good coverage. A good rule of thumb is that if you want to be confident enough in your test suite that any failures that appear after having tools rewrite your code are actual bugs in the tools and not in your code. If you want a number to aim for, try to get over 80% coverage (and don't feel bad if you can't easily get past 90%). If you don't already have a tool to measure test coverage then coverage.py is recommended.
Learn the differences between Python 2 & 3

Once you have your code well-tested you are ready to begin porting your code to Python 3! But to fully understand how your code is going to change and what you want to look out for while you code, you will want to learn what changes Python 3 makes in terms of Python 2. Typically the two best ways of doing that is reading the “What’s New” doc for each release of Python 3 and the Porting to Python 3 book (which is free online). There is also a handy cheat sheet from the Python-Future project.

Update your code

Once you feel like you know what is different in Python 3 compared to Python 2, it's time to update your code! You have a choice between two tools in porting your code automatically: Modernize and Futurize. Which tool you choose will depend on how much like Python 3 you want your code to be. Futurize does its best to make Python 3 idioms and practices exist in Python 2, e.g. backporting the bytes type from Python 3 so that you have semantic parity between the major versions of Python. Modernize, on the other hand, is more conservative and targets a Python 2/3 subset of Python, relying on six to help provide compatibility.

Regardless of which tool you choose, they will update your code to run under Python 3 while staying compatible with the version of Python 2 you started with. Depending on how conservative you want to be, you may want to run the tool over your test suite first and visually inspect the diff to make sure the transformation is accurate. After you have transformed your test suite and verified that all the tests still pass as expected, then you can transform your application code knowing that
any tests which fail is a translation failure.

Unfortunately the tools can’t automate everything to make your code work under Python 3 and so there are a handful of things you will need to update manually to get full Python 3 support (which of these steps are necessary vary between the tools). Read the documentation for the tool you choose to use to see what it fixes by default and what it can do optionally to know what will (not) be fixed for you and what you may have to fix on your own (e.g. using `io.open()` over the built-in `open()` function is off by default in Modernize). Luckily, though, there are only a couple of things to watch out for which can be considered large issues that may be hard to debug if not watched for.

Division

In Python 3, 5 / 2 == 2.5 and not 2; all division between int values result in a float. This change has actually been planned since Python 2.2 which was released in 2002. Since then users have been encouraged to add `from __future__ import division` to any and all files which use the `/` and `//` operators or to be running the interpreter with the `-Q` flag. If you have not been doing this then you will need to go through your code and do two things:

1. Add `from __future__ import division` to your files
2. Update any division operator as necessary to either use `//` to use floor division or continue using `/` and expect a float

The reason that `/` isn’t simply translated to `//` automatically is that if an object defines a `__truediv__` method but not `__floordiv__` then your code would begin to fail (e.g. a user-defined class that uses `/` to signify some operation but not `//` for the same thing or at all).
Text versus binary data

In Python 2 you could use the `str` type for both text and binary data. Unfortunately this confluence of two different concepts could lead to brittle code which sometimes worked for either kind of data, sometimes not. It also could lead to confusing APIs if people didn't explicitly state that something that accepted `str` accepted either text or binary data instead of one specific type. This complicated the situation especially for anyone supporting multiple languages as APIs wouldn't bother explicitly supporting `unicode` when they claimed text data support.

To make the distinction between text and binary data clearer and more pronounced, Python 3 did what most languages created in the age of the internet have done and made text and binary data distinct types that cannot blindly be mixed together (Python predates widespread access to the internet). For any code that only deals with text or only binary data, this separation doesn't pose an issue. But for code that has to deal with both, it does mean you might have to now care about when you are using text compared to binary data, which is why this cannot be entirely automated.

To start, you will need to decide which APIs take text and which take binary (it is **highly** recommended you don't design APIs that can take both due to the difficulty of keeping the code working; as stated earlier it is difficult to do well). In Python 2 this means making sure the APIs that take text can work with `unicode` in Python 2 and those that work with binary data work with the `bytes` type from Python 3 and thus a subset of `str` in Python 2 (which the `bytes` type in Python 2 is an alias for). Usually the biggest issue is realizing which methods exist for which types in Python 2 & 3 simultaneously (for text that's `unicode` in
Python 2 and str in Python 3, for binary that's str/bytes in Python 2 and bytes in Python 3). The following table lists the unique methods of each data type across Python 2 & 3 (e.g., the decode( ) method is usable on the equivalent binary data type in either Python 2 or 3, but it can't be used by the text data type consistently between Python 2 and 3 because str in Python 3 doesn't have the method). Do note that as of Python 3.5 the __mod__ method was added to the bytes type.

<table>
<thead>
<tr>
<th>Text data</th>
<th>Binary data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>decode</td>
</tr>
<tr>
<td>encode</td>
<td></td>
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<tr>
<td>format</td>
<td></td>
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<tr>
<td>isdecimal</td>
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<td>isnumeric</td>
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</tbody>
</table>

Making the distinction easier to handle can be accomplished by encoding and decoding between binary data and text at the edge of your code. This means that when you receive text in binary data, you should immediately decode it. And if your code needs to send text as binary data then encode it as late as possible. This allows your code to work with only text internally and thus eliminates having to keep track of what type of data you are working with.

The next issue is making sure you know whether the string literals in your code represent text or binary data. At minimum you should add a b prefix to any literal that presents binary data. For text you should either use the from __future__ import unicode_literals statement or add a u prefix to the text literal.

As part of this dichotomy you also need to be careful about opening
files. Unless you have been working on Windows, there is a chance you have not always bothered to add the b mode when opening a binary file (e.g., rb for binary reading). Under Python 3, binary files and text files are clearly distinct and mutually incompatible; see the io module for details. Therefore, you must make a decision of whether a file will be used for binary access (allowing to read and/or write binary data) or text access (allowing to read and/or write text data). You should also use io.open() for opening files instead of the built-in open() function as the io module is consistent from Python 2 to 3 while the built-in open() function is not (in Python 3 it’s actually io.open()).

The constructors of both str and bytes have different semantics for the same arguments between Python 2 & 3. Passing an integer to bytes in Python 2 will give you the string representation of the integer: bytes(3) == '3'. But in Python 3, an integer argument to bytes will give you a bytes object as long as the integer specified, filled with null bytes: bytes(3) == b'\x00\x00\x00'. A similar worry is necessary when passing a bytes object to str. In Python 2 you just get the bytes object back: str(b'3') == b'3'. But in Python 3 you get the string representation of the bytes object: str(b'3') == "b'3".

Finally, the indexing of binary data requires careful handling (slicing does not require any special handling). In Python 2, b'123'[1] == b'2' while in Python 3 b'123'[1] == 50. Because binary data is simply a collection of binary numbers, Python 3 returns the integer value for the byte you index on. But in Python 2 because bytes == str, indexing returns a one-item slice of bytes. The six project has a function named six.indexbytes() which will return an integer like in Python 3: six.indexbytes(b'123', 1).
To summarize:

1. Decide which of your APIs take text and which take binary data
2. Make sure that your code that works with text also works with unicode and code for binary data works with bytes in Python 2 (see the table above for what methods you cannot use for each type)
3. Mark all binary literals with a b prefix, use a u prefix or __future__ import statement for text literals
4. Decode binary data to text as soon as possible, encode text as binary data as late as possible
5. Open files using io.open() and make sure to specify the b mode when appropriate
6. Be careful when indexing binary data

Prevent compatibility regressions

Once you have fully translated your code to be compatible with Python 3, you will want to make sure your code doesn't regress and stop working under Python 3. This is especially true if you have a dependency which is blocking you from actually running under Python 3 at the moment.

To help with staying compatible, any new modules you create should have at least the following block of code at the top of it:

```python
from __future__ import absolute_import
from __future__ import division
from __future__ import print_function
from __future__ import unicode_literals
```

You can also run Python 2 with the -3 flag to be warned about various compatibility issues your code triggers during execution. If you turn
warnings into errors with -Werror then you can make sure that you don’t accidentally miss a warning.

You can also use the Pylint project and its --py3k flag to lint your code to receive warnings when your code begins to deviate from Python 3 compatibility. This also prevents you from having to run Modernize or Futurize over your code regularly to catch compatibility regressions. This does require you only support Python 2.7 and Python 3.4 or newer as that is Pylint’s minimum Python version support.

Check which dependencies block your transition

After you have made your code compatible with Python 3 you should begin to care about whether your dependencies have also been ported. The caniusepython3 project was created to help you determine which projects – directly or indirectly – are blocking you from supporting Python 3. There is both a command-line tool as well as a web interface at https://caniusepython3.com.

The project also provides code which you can integrate into your test suite so that you will have a failing test when you no longer have dependencies blocking you from using Python 3. This allows you to avoid having to manually check your dependencies and to be notified quickly when you can start running on Python 3.

Update your setup.py file to denote Python 3 compatibility

Once your code works under Python 3, you should update the classifiers in your setup.py to contain Programming Language
Python 3 and to not specify sole Python 2 support. This will tell anyone using your code that you support Python 2 and 3. Ideally you will also want to add classifiers for each major/minor version of Python you now support.

Use continuous integration to stay compatible

Once you are able to fully run under Python 3 you will want to make sure your code always works under both Python 2 & 3. Probably the best tool for running your tests under multiple Python interpreters is tox. You can then integrate tox with your continuous integration system so that you never accidentally break Python 2 or 3 support.

You may also want to use use the -bb flag with the Python 3 interpreter to trigger an exception when you are comparing bytes to strings or bytes to an int (the latter is available starting in Python 3.5). By default type-differing comparisons simply return False, but if you made a mistake in your separation of text/binary data handling or indexing on bytes you wouldn’t easily find the mistake. This flag will raise an exception when these kinds of comparisons occur, making the mistake much easier to track down.

And that’s mostly it! At this point your code base is compatible with both Python 2 and 3 simultaneously. Your testing will also be set up so that you don’t accidentally break Python 2 or 3 compatibility regardless of which version you typically run your tests under while developing.
Dropping Python 2 support completely

If you are able to fully drop support for Python 2, then the steps required to transition to Python 3 simplify greatly.

1. Update your code to only support Python 2.7
2. Make sure you have good test coverage (coverage.py can help)
3. Learn the differences between Python 2 & 3
4. Use 2to3 to rewrite your code to run only under Python 3

After this your code will be fully Python 3 compliant but in a way that is not supported by Python 2. You should also update the classifiers in your setup.py to contain Programming Language :: Python :: 3 :: Only.
Porting Extension Modules to Python 3

**author:** Benjamin Peterson

**Abstract**

Although changing the C-API was not one of Python 3's objectives, the many Python-level changes made leaving Python 2's API intact impossible. In fact, some changes such as `int()` and `long()` unification are more obvious on the C level. This document endeavors to document incompatibilities and how they can be worked around.
Conditional compilation

The easiest way to compile only some code for Python 3 is to check if PY_MAJOR_VERSION is greater than or equal to 3.

```c
#if PY_MAJOR_VERSION >= 3
#define IS_PY3K
#endif
```

API functions that are not present can be aliased to their equivalents within conditional blocks.
Changes to Object APIs

Python 3 merged together some types with similar functions while cleanly separating others.

str/unicode Unification

Python 3's `str()` type is equivalent to Python 2's `unicode()`; the C functions are called `PyUnicode_*` for both. The old 8-bit string type has become `bytes()`, with C functions called `PyBytes_*`. Python 2.6 and later provide a compatibility header, `bytesobject.h`, mapping `PyBytes` names to `PyString` ones. For best compatibility with Python 3, `PyUnicode` should be used for textual data and `PyBytes` for binary data. It's also important to remember that `PyBytes` and `PyUnicode` in Python 3 are not interchangeable like `PyString` and `PyUnicode` are in Python 2. The following example shows best practices with regards to `PyUnicode`, `PyString`, and `PyBytes`.

```c
#include "stdlib.h"
#include "Python.h"
#include "bytesobject.h"

/* text example */
static PyObject *
say_hello(PyObject *self, PyObject *args) {
    PyObject *name, *result;

    if (!PyArg_ParseTuple(args, "U:say_hello", &name)
        return NULL;

    result = PyUnicode_FromFormat("Hello, %S!", name)
```
long/int Unification

Python 3 has only one integer type, \texttt{int()}. But it actually corresponds to Python 2's \texttt{long()} type—the \texttt{int()} type used in Python 2 was removed. In the C-API, PyInt_* functions are replaced by their PyLong_* equivalents.
Module initialization and state

Python 3 has a revamped extension module initialization system. (See PEP 3121.) Instead of storing module state in globals, they should be stored in an interpreter specific structure. Creating modules that act correctly in both Python 2 and Python 3 is tricky. The following simple example demonstrates how.

```c
#include "Python.h"

struct module_state { 
    PyObject *error;
};

#if PY_MAJOR_VERSION >= 3 
#define GETSTATE(m) ((struct module_state*)PyModule_GetState(m))
#else
#define GETSTATE(m) (&_state)
#endif

static struct module_state _state;

static PyObject *
error_out(PyObject *m) {
    struct module_state *st = GETSTATE(m);
    PyErr_SetString(st->error, "something bad happened"
    return NULL;
}

static PyMethodDef myextension_methods[] = {
    {"error_out", (PyCFunction)error_out, METH_NOARGS
    {NULL, NULL}
};

#if PY_MAJOR_VERSION >= 3
```
static int myextension_traverse(PyObject *m, visitproc visitp)
    Py_VISIT(GETSTATE(m)->error);
    return 0;
}

static int myextension_clear(PyObject *m) {
    Py_CLEAR(GETSTATE(m)->error);
    return 0;
}

static struct PyModuleDef moduledef = {
    PyModuleDef_HEAD_INIT,
    "myextension",
    NULL,
    sizeof(struct module_state),
    myextension_methods,
    NULL,
    myextension_traverse,
    myextension_clear,
    NULL
};

#define INITERROR return NULL

PyObject *
PyInit_myextension(void)

#else
#define INITERROR return

void
initmyextension(void)
#endif
{
    #if PY_MAJOR_VERSION >= 3
        PyObject *module = PyModule_Create(&moduledef);
    
    #else
        PyObject *module = Py_InitModule("myextension", NULL);
    
    #endif
    
    if (module == NULL) {
        INITERROR
    }

    #if defined(PY_MODULE_NAME)
        PyModule_AddObject(module, PY_MODULE_NAME, NULL);
    
    #endif

    
    #if defined(PY_MODULE_AUTHOR)
        char *module_author = PyUnicode_AsUTF8(PyUnicode_FromEncodedString(PY_MODULE_AUTHOR, -1, NULL));
        PyModule_AddObject(module, "__author__", PyUnicode_FromEncodedString(module_author, -1, NULL));
        Py_DECREF(module_author);
    
    #endif

    
    #if defined(PY_MODULE_LICENSE)
        char *module_license = PyUnicode_AsUTF8(PyUnicode_FromEncodedString(PY_MODULE_LICENSE, -1, NULL));
        PyModule_AddObject(module, "__license__", PyUnicode_FromEncodedString(module_license, -1, NULL));
        Py_DECREF(module_license);
    
    #endif

    
    #if defined(PY_MODULE_URL)
        char *module_url = PyUnicode_AsUTF8(PyUnicode_FromEncodedString(PY_MODULE_URL, -1, NULL));
        PyModule_AddObject(module, "__url__", PyUnicode_FromEncodedString(module_url, -1, NULL));
        Py_DECREF(module_url);
    
    #endif

    
    #if defined(PY_MODULE_EMAIL)
        char *module_email = PyUnicode_AsUTF8(PyUnicode_FromEncodedString(PY_MODULE_EMAIL, -1, NULL));
        PyModule_AddObject(module, "__email__", PyUnicode_FromEncodedString(module_email, -1, NULL));
        Py_DECREF(module_email);
    
    #endif

    
    Py_INCREF(module);
    PyModule_AddObject(sys.modules, "myextension", (PyObject *)module);
    return module;

#endif

/* End of module definition */
#else
    PyObject *module = Py_InitModule("myextension",
#endif

    if (module == NULL)
        INITERROR;
    struct module_state *st = GETSTATE(module);

    st->error = PyErr_NewException("myextension.Error",
    if (st->error == NULL) {
        Py_DECREF(module);
        INITERROR;
    }

#if PY_MAJOR_VERSION >= 3
    return module;
#else
    
#endif
CObject replaced with Capsule

The Capsule object was introduced in Python 3.1 and 2.7 to replace CObject. CObjects were useful, but the CObject API was problematic: it didn’t permit distinguishing between valid CObjects, which allowed mismatched CObjects to crash the interpreter, and some of its APIs relied on undefined behavior in C. (For further reading on the rationale behind Capsules, please see issue 5630.)

If you’re currently using CObjects, and you want to migrate to 3.1 or newer, you’ll need to switch to Capsules. CObject was deprecated in 3.1 and 2.7 and completely removed in Python 3.2. If you only support 2.7, or 3.1 and above, you can simply switch to Capsule. If you need to support Python 3.0, or versions of Python earlier than 2.7, you’ll have to support both CObjects and Capsules. (Note that Python 3.0 is no longer supported, and it is not recommended for production use.)

The following example header file capsulethunk.h may solve the problem for you. Simply write your code against the Capsule API and include this header file after Python.h. Your code will automatically use Capsules in versions of Python with Capsules, and switch to CObjects when Capsules are unavailable.

capsulethunk.h simulates Capsules using CObjects. However, CObject provides no place to store the capsule’s “name”. As a result the simulated Capsule objects created by capsulethunk.h behave slightly differently from real Capsules. Specifically:

- The name parameter passed in to PyCapsule_New() is ignored.
- The name parameter passed in to PyCapsule_IsValid()
and `PyCapsule_GetPointer()` is ignored, and no error checking of the name is performed.

- `PyCapsule_GetName()` always returns NULL.
- `PyCapsule_SetName()` always raises an exception and returns failure. (Since there's no way to store a name in a CObject, noisy failure of `PyCapsule_SetName()` was deemed preferable to silent failure here. If this is inconvenient, feel free to modify your local copy as you see fit.)

You can find capsulethunk.h in the Python source distribution as `Doc/includes/capsulethunk.h`. We also include it here for your convenience:

```c
#ifndef __CAPSULETHUNK_H
#define __CAPSULETHUNK_H

#if ( (PY_VERSION_HEX < 0x02070000) \n    || ((PY_VERSION_HEX >= 0x03000000) \n        && (PY_VERSION_HEX < 0x03010000)) )

#define __PyCapsule_GetField(capsule, field, default_value)
    (PyCapsule_CheckExact(capsule) ? (((PyCObject *)capsule)->field) : (default_value) )

#define __PyCapsule_SetField(capsule, field, value)
    (PyCapsule_CheckExact(capsule) ? (((PyCObject *)capsule)->field = value), 1 : 0 )

#define PyCapsule_Type PyCObject_Type
```

```c
#endif
```
```c
#define PyCapsule_CheckExact(capsule) (PyCObject_Check(capsule))
#define PyCapsule_IsValid(capsule, name) (PyCObject_Check(capsule))
#define PyCapsule_New(pointer, name, destructor) 
    (PyCObject_FromVoidPtr(pointer, destructor))
#define PyCapsule_GetPointer(capsule, name) 
    (PyCObject_AsVoidPtr(capsule))
/* Don't call PyCObject_SetPointer here, it fails if 
   there's a destructor */
#define PyCapsule_SetPointer(capsule, pointer) 
    __PyCapsule_SetField(capsule, cobject, pointer)
#define PyCapsule_GetDestructor(capsule) 
    __PyCapsule_GetField(capsule, destructor)
#define PyCapsule_SetDestructor(capsule, dtor) 
    __PyCapsule_SetField(capsule, destructor, dtor)
/*
 * Sorry, there's simply no place 
 * to store a Capsule "name" in a CObject. 
 */
#define PyCapsule_GetName(capsule) NULL

static int
PyCapsule_SetName(PyObject *capsule, const char * unused)
{
    unused = unused;
    PyErr_SetString(PyExc_NotImplementedError, 
                    "can't use PyCapsule_SetName with CObjects")
    return 1;
```
#define PyCapsule_GetContext(capsule)    
    __PyCapsule_GetField(capsule, descr)

#define PyCapsule_SetContext(capsule, context)    
    __PyCapsule_SetField(capsule, descr, context)

static void *
PyCapsule_Import(const char *name, int no_block)
{
    PyObject *object = NULL;
    void *return_value = NULL;
    char *trace;
    size_t name_length = (strlen(name) + 1) * sizeof(char);
    char *name_dup = (char *)PyMem_MALLOC(name_length);

    if (!name_dup) {
        return NULL;
    }

    memcpy(name_dup, name, name_length);

    trace = name_dup;
    while (trace) {
        char *dot = strchr(trace, '.');
        if (dot) {
            *dot++ = '\0';
        }

        if (object == NULL) {
            if (no_block) {
                object = PyImport_ImportModuleNoBlock(name);
            } else {
                object = PyImport_Import(name);
            }
        } else {
            return_value = PyCapsule_GetContext(object);
        }
    }

    return return_value;
}

object = PyImport_ImportModule(trace)
if (!object) {
    PyErr_Format(PyExc_ImportError, "PyCapsule_Import could not import module \"%s\"", trace
    }
} else {
    PyObject *object2 = PyObject_GetAttrString
    Py_DECREF(object);
    object = object2;
    if (!object) {
        goto EXIT;
    }
    trace = dot;
}

if (PyCObject_Check(object)) {
    PyCObject *cobject = (PyCObject *)object;
    return_value = cobject->cobject;
} else {
    PyErr_Format(PyExc_AttributeError, "PyCapsule_Import \"%s\" is not valid", name);
}

EXIT:
Py_XDECREF(object);
if (name_dup) {
    PyMem_FREE(name_dup);
}
return return_value;

#endif /* #if PY_VERSION_HEX < 0x02070000 */
#endif /* __CAPSULETHUNK_H */
Other options

If you are writing a new extension module, you might consider Cython. It translates a Python-like language to C. The extension modules it creates are compatible with Python 3 and Python 2.
Abstract

This document describes how to use the *curses* extension module to control text-mode displays.
What is curses?

The curses library supplies a terminal-independent screen-painting and keyboard-handling facility for text-based terminals; such terminals include VT100s, the Linux console, and the simulated terminal provided by various programs. Display terminals support various control codes to perform common operations such as moving the cursor, scrolling the screen, and erasing areas. Different terminals use widely differing codes, and often have their own minor quirks.

In a world of graphical displays, one might ask “why bother”? It’s true that character-cell display terminals are an obsolete technology, but there are niches in which being able to do fancy things with them are still valuable. One niche is on small-footprint or embedded Unixes that don’t run an X server. Another is tools such as OS installers and kernel configurators that may have to run before any graphical support is available.

The curses library provides fairly basic functionality, providing the programmer with an abstraction of a display containing multiple non-overlapping windows of text. The contents of a window can be changed in various ways—adding text, erasing it, changing its appearance—and the curses library will figure out what control codes need to be sent to the terminal to produce the right output. curses doesn’t provide many user-interface concepts such as buttons, checkboxes, or dialogs; if you need such features, consider a user interface library such as Urwid.

The curses library was originally written for BSD Unix; the later System V versions of Unix from AT&T added many enhancements and new functions. BSD curses is no longer maintained, having been replaced by ncurses, which is an open-source implementation of the AT&T
interface. If you’re using an open-source Unix such as Linux or FreeBSD, your system almost certainly uses n curses. Since most current commercial Unix versions are based on System V code, all the functions described here will probably be available. The older versions of curses carried by some proprietary Unixes may not support everything, though.

The Windows version of Python doesn’t include the curses module. A ported version called UniCurses is available. You could also try the Console module written by Fredrik Lundh, which doesn’t use the same API as curses but provides cursor-addressable text output and full support for mouse and keyboard input.

The Python curses module

Thy Python module is a fairly simple wrapper over the C functions provided by curses; if you’re already familiar with curses programming in C, it’s really easy to transfer that knowledge to Python. The biggest difference is that the Python interface makes things simpler by merging different C functions such as addstr(), mvaddstr(), and mvwaddstr() into a single addstr() method. You’ll see this covered in more detail later.

This HOWTO is an introduction to writing text-mode programs with curses and Python. It doesn’t attempt to be a complete guide to the curses API; for that, see the Python library guide’s section on n curses, and the C manual pages for ncurses. It will, however, give you the basic ideas.
Starting and ending a curses application

Before doing anything, curses must be initialized. This is done by calling the `initscr()` function, which will determine the terminal type, send any required setup codes to the terminal, and create various internal data structures. If successful, `initscr()` returns a window object representing the entire screen; this is usually called `stdscr` after the name of the corresponding C variable.

```python
import curses
stdscr = curses.initscr()
```

Usually curses applications turn off automatic echoing of keys to the screen, in order to be able to read keys and only display them under certain circumstances. This requires calling the `noecho()` function.

```python
curses.noecho()
```

Applications will also commonly need to react to keys instantly, without requiring the Enter key to be pressed; this is called cbreak mode, as opposed to the usual buffered input mode.

```python
curses.cbreak()
```

Terminals usually return special keys, such as the cursor keys or navigation keys such as Page Up and Home, as a multibyte escape sequence. While you could write your application to expect such sequences and process them accordingly, curses can do it for you, returning a special value such as `curses.KEY_LEFT`. To get curses to do the job, you'll have to enable keypad mode.

```python
stdscr.keypad(True)
```
Terminating a curses application is much easier than starting one. You'll need to call:

```python
curses.nocbreak()
stdscr.keypad(False)
curses.echo()
```

to reverse the curses-friendly terminal settings. Then call the `endwin()` function to restore the terminal to its original operating mode.

```python
curses.endwin()
```

A common problem when debugging a curses application is to get your terminal messed up when the application dies without restoring the terminal to its previous state. In Python this commonly happens when your code is buggy and raises an uncaught exception. Keys are no longer echoed to the screen when you type them, for example, which makes using the shell difficult.

In Python you can avoid these complications and make debugging much easier by importing the `curses.wrapper()` function and using it like this:

```python
from curses import wrapper

def main(stdscr):
    # Clear screen
    stdscr.clear()

    # This raises ZeroDivisionError when i == 10.
    for i in range(0, 11):
        v = i-10
```
The `wrapper()` function takes a callable object and does the initializations described above, also initializing colors if color support is present. `wrapper()` then runs your provided callable. Once the callable returns, `wrapper()` will restore the original state of the terminal. The callable is called inside a `try...except` that catches exceptions, restores the state of the terminal, and then re-raises the exception. Therefore your terminal won't be left in a funny state on exception and you'll be able to read the exception's message and traceback.
Windows and Pads

Windows are the basic abstraction in curses. A window object represents a rectangular area of the screen, and supports methods to display text, erase it, allow the user to input strings, and so forth.

The `stdscr` object returned by the `initscr()` function is a window object that covers the entire screen. Many programs may need only this single window, but you might wish to divide the screen into smaller windows, in order to redraw or clear them separately. The `newwin()` function creates a new window of a given size, returning the new window object.

```python
begin_x = 20; begin_y = 7
height = 5; width = 40
win = curses.newwin(height, width, begin_y, begin_x)
```

Note that the coordinate system used in curses is unusual. Coordinates are always passed in the order `y,x`, and the top-left corner of a window is coordinate `(0,0)`. This breaks the normal convention for handling coordinates where the `x` coordinate comes first. This is an unfortunate difference from most other computer applications, but it's been part of curses since it was first written, and it's too late to change things now.

Your application can determine the size of the screen by using the `curses.LINES` and `curses.COLS` variables to obtain the `y` and `x` sizes. Legal coordinates will then extend from `(0,0)` to `(curses.LINES - 1, curses.COLS - 1).

When you call a method to display or erase text, the effect doesn’t
immediately show up on the display. Instead you must call the `refresh()` method of window objects to update the screen.

This is because curses was originally written with slow 300-baud terminal connections in mind; with these terminals, minimizing the time required to redraw the screen was very important. Instead curses accumulates changes to the screen and displays them in the most efficient manner when you call `refresh()`. For example, if your program displays some text in a window and then clears the window, there’s no need to send the original text because they’re never visible.

In practice, explicitly telling curses to redraw a window doesn’t really complicate programming with curses much. Most programs go into a flurry of activity, and then pause waiting for a keypress or some other action on the part of the user. All you have to do is to be sure that the screen has been redrawn before pausing to wait for user input, by first calling `stdscr.refresh()` or the `refresh()` method of some other relevant window.

A pad is a special case of a window; it can be larger than the actual display screen, and only a portion of the pad displayed at a time. Creating a pad requires the pad’s height and width, while refreshing a pad requires giving the coordinates of the on-screen area where a subsection of the pad will be displayed.

```python
class curses:
    newpad(100, 100)
    # These loops fill the pad with letters; addch() is
    # explained in the next section
    for y in range(0, 99):
        for x in range(0, 99):
            pad.addch(y, x, ord('a') + (x*x+y*y) % 26)
    # Displays a section of the pad in the middle of the
    # (0,0): coordinate of upper-left corner of pad are
```

```
The `refresh()` call displays a section of the pad in the rectangle extending from coordinate (5,5) to coordinate (20,75) on the screen; the upper left corner of the displayed section is coordinate (0,0) on the pad. Beyond that difference, pads are exactly like ordinary windows and support the same methods.

If you have multiple windows and pads on screen there is a more efficient way to update the screen and prevent annoying screen flicker as each part of the screen gets updated. `refresh()` actually does two things:

1. Calls the `noutrefresh()` method of each window to update an underlying data structure representing the desired state of the screen.
2. Calls the function `doupdate()` function to change the physical screen to match the desired state recorded in the data structure.

Instead you can call `noutrefresh()` on a number of windows to update the data structure, and then call `doupdate()` to update the screen.
Displaying Text

From a C programmer’s point of view, curses may sometimes look like a twisty maze of functions, all subtly different. For example, `addstr()` displays a string at the current cursor location in the `stdscr` window, while `mvaddstr()` moves to a given y,x coordinate first before displaying the string. `waddstr()` is just like `addstr()`, but allows specifying a window to use instead of using `stdscr` by default. `mvwaddstr()` allows specifying both a window and a coordinate.

Fortunately the Python interface hides all these details. `stdscr` is a window object like any other, and methods such as `addstr()` accept multiple argument forms. Usually there are four different forms.

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>str</code> or <code>ch</code></td>
<td>Display the string <code>str</code> or character <code>ch</code> at the current position</td>
</tr>
<tr>
<td><code>str</code> or <code>ch</code>, <code>attr</code></td>
<td>Display the string <code>str</code> or character <code>ch</code>, using attribute <code>attr</code> at the current position</td>
</tr>
<tr>
<td><code>y</code>, <code>x</code>, <code>str</code> or <code>ch</code></td>
<td>Move to position <code>y</code>,<code>x</code> within the window, and display <code>str</code> or <code>ch</code></td>
</tr>
<tr>
<td><code>y</code>, <code>x</code>, <code>str</code> or <code>ch</code>, <code>attr</code></td>
<td>Move to position <code>y</code>,<code>x</code> within the window, and display <code>str</code> or <code>ch</code>, using attribute <code>attr</code></td>
</tr>
</tbody>
</table>

Attributes allow displaying text in highlighted forms such as boldface, underline, reverse code, or in color. They’ll be explained in more detail in the next subsection.

The `addstr()` method takes a Python string or bytestring as the
value to be displayed. The contents of bytestrings are sent to the terminal as-is. Strings are encoded to bytes using the value of the window's encoding attribute; this defaults to the default system encoding as returned by `locale.getpreferredencoding()`.

The `addch()` methods take a character, which can be either a string of length 1, a bytestring of length 1, or an integer.

Constants are provided for extension characters; these constants are integers greater than 255. For example, ACS_PLMINUS is a +/- symbol, and ACS_ULCORNER is the upper left corner of a box (handy for drawing borders). You can also use the appropriate Unicode character.

Windows remember where the cursor was left after the last operation, so if you leave out the y,x coordinates, the string or character will be displayed wherever the last operation left off. You can also move the cursor with the `move(y,x)` method. Because some terminals always display a flashing cursor, you may want to ensure that the cursor is positioned in some location where it won’t be distracting; it can be confusing to have the cursor blinking at some apparently random location.

If your application doesn’t need a blinking cursor at all, you can call `curs_set(False)` to make it invisible. For compatibility with older curses versions, there’s a `leaveok(bool)` function that’s a synonym for `curs_set()`. When `bool` is true, the curses library will attempt to suppress the flashing cursor, and you won’t need to worry about leaving it in odd locations.

**Attributes and Color**
Characters can be displayed in different ways. Status lines in a text-based application are commonly shown in reverse video, or a text viewer may need to highlight certain words. curses supports this by allowing you to specify an attribute for each cell on the screen.

An attribute is an integer, each bit representing a different attribute. You can try to display text with multiple attribute bits set, but curses doesn’t guarantee that all the possible combinations are available, or that they're all visually distinct. That depends on the ability of the terminal being used, so it’s safest to stick to the most commonly available attributes, listed here.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_BLINK</td>
<td>Blinking text</td>
</tr>
<tr>
<td>A_BOLD</td>
<td>Extra bright or bold text</td>
</tr>
<tr>
<td>A_DIM</td>
<td>Half bright text</td>
</tr>
<tr>
<td>A_REVERSE</td>
<td>Reverse-video text</td>
</tr>
<tr>
<td>A_STANDOUT</td>
<td>The best highlighting mode available</td>
</tr>
<tr>
<td>A_UNDERLINE</td>
<td>Underlined text</td>
</tr>
</tbody>
</table>

So, to display a reverse-video status line on the top line of the screen, you could code:

```python
stdscr.addstr(0, 0, "Current mode: Typing mode", curses.A_REVERSE)
stdscr.refresh()
```

The curses library also supports color on those terminals that provide it. The most common such terminal is probably the Linux console, followed by color xterms.
To use color, you must call the `start_color()` function soon after calling `initscr()`, to initialize the default color set (the `curses.wrapper()` function does this automatically). Once that’s done, the `has_colors()` function returns `TRUE` if the terminal in use can actually display color. (Note: curses uses the American spelling ‘color’, instead of the Canadian/British spelling ‘colour’. If you’re used to the British spelling, you’ll have to resign yourself to misspelling it for the sake of these functions.)

The `curses` library maintains a finite number of color pairs, containing a foreground (or text) color and a background color. You can get the attribute value corresponding to a color pair with the `color_pair()` function; this can be bitwise-OR’ed with other attributes such as `A_REVERSE`, but again, such combinations are not guaranteed to work on all terminals.

An example, which displays a line of text using color pair 1:

```python
stdscr.addstr("Pretty text", curses.color_pair(1))
stdscr.refresh()
```

As I said before, a color pair consists of a foreground and background color. The `init_pair(n, f, b)` function changes the definition of color pair `n`, to foreground color `f` and background color `b`. Color pair 0 is hard-wired to white on black, and cannot be changed.

Colors are numbered, and `start_color()` initializes 8 basic colors when it activates color mode. They are: 0:black, 1:red, 2:green, 3:yellow, 4:blue, 5:magenta, 6:cyan, and 7:white. The `curses` module defines named constants for each of these colors: `curses.COLOR_BLACK`, `curses.COLOR_RED`, and so forth.

Let’s put all this together. To change color 1 to red text on a white
background, you would call:

```python
curses.init_pair(1, curses.COLOR_RED, curses.COLOR_WHITE)
```

When you change a color pair, any text already displayed using that color pair will change to the new colors. You can also display new text in this color with:

```python
stdscr.addstr(0, 0, "RED ALERT!", curses.color_pair(1))
```

Very fancy terminals can change the definitions of the actual colors to a given RGB value. This lets you change color 1, which is usually red, to purple or blue or any other color you like. Unfortunately, the Linux console doesn’t support this, so I’m unable to try it out, and can’t provide any examples. You can check if your terminal can do this by calling `can_change_color()`, which returns `True` if the capability is there. If you’re lucky enough to have such a talented terminal, consult your system’s man pages for more information.
User Input

The C curses library offers only very simple input mechanisms. Python’s `curses` module adds a basic text-input widget. (Other libraries such as Urwid have more extensive collections of widgets.)

There are two methods for getting input from a window:

- `getch()` refreshes the screen and then waits for the user to hit a key, displaying the key if `echo()` has been called earlier. You can optionally specify a coordinate to which the cursor should be moved before pausing.
- `getkey()` does the same thing but converts the integer to a string. Individual characters are returned as 1-character strings, and special keys such as function keys return longer strings containing a key name such as `KEY_UP` or `^G`.

It’s possible to not wait for the user using the `nodelay()` window method. After `nodelay(True)`, `getch()` and `getkey()` for the window become non-blocking. To signal that no input is ready, `getch()` returns `curses.ERR` (a value of -1) and `getkey()` raises an exception. There’s also a `halfdelay()` function, which can be used to (in effect) set a timer on each `getch()`; if no input becomes available within a specified delay (measured in tenths of a second), `curses` raises an exception.

The `getch()` method returns an integer; if it’s between 0 and 255, it represents the ASCII code of the key pressed. Values greater than 255 are special keys such as Page Up, Home, or the cursor keys. You can compare the value returned to constants such as `curses.KEY_PPAGE`, `curses.KEY_HOME`, or `curses.KEY_LEFT`. The main loop of your program may look something like this:
```python
while True:
    c = stdscr.getch()
    if c == ord('p'):
        PrintDocument()
    elif c == ord('q'):
        break  # Exit the while loop
    elif c == curses.KEY_HOME:
        x = y = 0
```

The `curses.ascii` module supplies ASCII class membership functions that take either integer or 1-character string arguments; these may be useful in writing more readable tests for such loops. It also supplies conversion functions that take either integer or 1-character-string arguments and return the same type. For example, `curses.ascii.ctrl()` returns the control character corresponding to its argument.

There's also a method to retrieve an entire string, `getstr()`. It isn't used very often, because its functionality is quite limited; the only editing keys available are the backspace key and the Enter key, which terminates the string. It can optionally be limited to a fixed number of characters.

```python
curses.echo()  # Enable echoing of characters

# Get a 15-character string, with the cursor on the
s = stdscr.getstr(0, 0, 15)
```

The `curses.textpad` module supplies a text box that supports an Emacs-like set of keybindings. Various methods of the Textbox class support editing with input validation and gathering the edit results either with or without trailing spaces. Here’s an example:
import curses
from curses.textpad import Textbox, rectangle

def main(stdscr):
    stdscr.addstr(0, 0, "Enter IM message: (hit Ctrl-G)")

    editwin = curses.newwin(5, 30, 2, 1)
    rectangle(stdscr, 1, 0, 1+5+1, 1+30+1)
    stdscr.refresh()

    box = Textbox(editwin)

    # Let the user edit until Ctrl-G is struck.
    box.edit()

    # Get resulting contents
    message = box.gather()

See the library documentation on curses.textpad for more details.
For More Information

This HOWTO doesn’t cover some advanced topics, such as reading the contents of the screen or capturing mouse events from an xterm instance, but the Python library page for the `curses` module is now reasonably complete. You should browse it next.

If you’re in doubt about the detailed behavior of the curses functions, consult the manual pages for your curses implementation, whether it’s ncurses or a proprietary Unix vendor’s. The manual pages will document any quirks, and provide complete lists of all the functions, attributes, and ACS_* characters available to you.

Because the curses API is so large, some functions aren’t supported in the Python interface. Often this isn’t because they’re difficult to implement, but because no one has needed them yet. Also, Python doesn’t yet support the menu library associated with ncurses. Patches adding support for these would be welcome; see the Python Developer’s Guide to learn more about submitting patches to Python.

- **Writing Programs with NCURSES**: a lengthy tutorial for C programmers.
- **The ncurses man page**
- **The ncurses FAQ**
- **“Use curses... don’t swear”:** video of a PyCon 2013 talk on controlling terminals using curses or Urwid.
- **“Console Applications with Urwid”:** video of a PyCon CA 2012 talk demonstrating some applications written using Urwid.
Last updated on Dec 06, 2015. Found a bug?
Created using Sphinx 1.3.1.
Descriptor HowTo Guide

<table>
<thead>
<tr>
<th>Author:</th>
<th>Raymond Hettinger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact:</td>
<td>&lt;python at rcn dot com&gt;</td>
</tr>
</tbody>
</table>

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  - Abstract
  - Definition and Introduction
  - Descriptor Protocol
  - Invoking Descriptors
  - Descriptor Example
  - Properties
  - Functions and Methods
  - Static Methods and Class Methods
Abstract

Defines descriptors, summarizes the protocol, and shows how descriptors are called. Examines a custom descriptor and several built-in python descriptors including functions, properties, static methods, and class methods. Shows how each works by giving a pure Python equivalent and a sample application.

Learning about descriptors not only provides access to a larger toolset, it creates a deeper understanding of how Python works and an appreciation for the elegance of its design.
Definition and Introduction

In general, a descriptor is an object attribute with “binding behavior”, one whose attribute access has been overridden by methods in the descriptor protocol. Those methods are __get__(), __set__(), and __delete__(). If any of those methods are defined for an object, it is said to be a descriptor.

The default behavior for attribute access is to get, set, or delete the attribute from an object’s dictionary. For instance, a.x has a lookup chain starting with a.__dict__['x'], then type(a).__dict__['x'], and continuing through the base classes of type(a) excluding metaclasses. If the looked-up value is an object defining one of the descriptor methods, then Python may override the default behavior and invoke the descriptor method instead. Where this occurs in the precedence chain depends on which descriptor methods were defined.

Descriptors are a powerful, general purpose protocol. They are the mechanism behind properties, methods, static methods, class methods, and super(). They are used throughout Python itself to implement the new style classes introduced in version 2.2. Descriptors simplify the underlying C-code and offer a flexible set of new tools for everyday Python programs.
Descriptor Protocol

descr.__get__(self, obj, type=None) --> value

descr.__set__(self, obj, value) --> None

descr.__delete__(self, obj) --> None

That is all there is to it. Define any of these methods and an object is considered a descriptor and can override default behavior upon being looked up as an attribute.

If an object defines both __get__() and __set__(), it is considered a data descriptor. Descriptors that only define __get__() are called non-data descriptors (they are typically used for methods but other uses are possible).

Data and non-data descriptors differ in how overrides are calculated with respect to entries in an instance's dictionary. If an instance's dictionary has an entry with the same name as a data descriptor, the data descriptor takes precedence. If an instance's dictionary has an entry with the same name as a non-data descriptor, the dictionary entry takes precedence.

To make a read-only data descriptor, define both __get__() and __set__() with the __set__() raising an AttributeError when called. Defining the __set__() method with an exception raising placeholder is enough to make it a data descriptor.
Invoking Descriptors

A descriptor can be called directly by its method name. For example, `d.__get__(obj)`.

Alternatively, it is more common for a descriptor to be invoked automatically upon attribute access. For example, `obj.d` looks up `d` in the dictionary of `obj`. If `d` defines the method `__get__()`, then `d.__get__(obj)` is invoked according to the precedence rules listed below.

The details of invocation depend on whether `obj` is an object or a class.

For objects, the machinery is in `object.__getattribute__()`, which transforms `b.x` into `type(b).__dict__['x'].__get__(b, type(b))`. The implementation works through a precedence chain that gives data descriptors priority over instance variables, instance variables priority over non-data descriptors, and assigns lowest priority to `__getattr__()` if provided. The full C implementation can be found in `PyObject_GenericGetAttr()` in `Objects/object.c`.

For classes, the machinery is in `type.__getattribute__()`, which transforms `B.x` into `B.__dict__['x'].__get__(None, B)`. In pure Python, it looks like:

```python
def __getattribute__(self, key):
    "Emulate type_getattro() in Objects/typeobject.c"
    v = object.__getattribute__(self, key)
    if hasattr(v, '__get__'):
        return v.__get__(None, self)
    return v
```
The important points to remember are:

- descriptors are invoked by the __getattribute__() method
- overriding __getattribute__() prevents automatic descriptor calls
- object.__getattribute__() and type.__getattribute__() make different calls to __get__().
- data descriptors always override instance dictionaries.
- non-data descriptors may be overridden by instance dictionaries.

The object returned by super() also has a custom __getattribute__() method for invoking descriptors. The call super(B, obj).m() searches obj.__class__.__mro__ for the base class A immediately following B and then returns A.__dict__['m'].__get__(obj, B). If not a descriptor, m is returned unchanged. If not in the dictionary, m reverts to a search using object.__getattribute__().

The implementation details are in super_getattro() in Objects/typeobject.c. and a pure Python equivalent can be found in Guido's Tutorial.

The details above show that the mechanism for descriptors is embedded in the __getattribute__() methods for object, type, and super(). Classes inherit this machinery when they derive from object or if they have a meta-class providing similar functionality. Likewise, classes can turn-off descriptor invocation by overriding __getattribute__().
Descriptor Example

The following code creates a class whose objects are data descriptors which print a message for each get or set. Overriding `__getattribute__()` is alternate approach that could do this for every attribute. However, this descriptor is useful for monitoring just a few chosen attributes:

```python
class RevealAccess(object):
    """A data descriptor that sets and returns values normally and prints a message logging their access. """
    def __init__(self, initval=None, name='var'):
        self.val = initval
        self.name = name
    def __get__(self, obj, objtype):
        print('Retrieving', self.name)
        return self.val
    def __set__(self, obj, val):
        print('Updating', self.name)
        self.val = val
```

```python
>>> class MyClass(object):
    x = RevealAccess(10, 'var "x"')
    y = 5

>>> m = MyClass()
>>> m.x
Retrieving var "x"
10
>>> m.x = 20
Updating var "x"
```

The protocol is simple and offers exciting possibilities. Several use cases are so common that they have been packaged into individual function calls. Properties, bound and unbound methods, static methods, and class methods are all based on the descriptor protocol.
Properties

Calling `property()` is a succinct way of building a data descriptor that triggers function calls upon access to an attribute. Its signature is:

```
property(fget=None, fset=None, fdel=None, doc=None)
```

The documentation shows a typical use to define a managed attribute `x`:

```
class C(object):
    def getx(self): return self.__x
    def setx(self, value): self.__x = value
    def delx(self): del self.__x
    x = property(getx, setx, delx, "I'm the 'x' property.")
```

To see how `property()` is implemented in terms of the descriptor protocol, here is a pure Python equivalent:

```
class Property(object):
    "Emulate PyProperty_Type() in Objects/descrobject.c"
    def __init__(self, fget=None, fset=None, fdel=None, doc=None):
        self.fget = fget
        self.fset = fset
        self.fdel = fdel
        if doc is None and fget is not None:
            doc = fget.__doc__
        self.__doc__ = doc

    def __get__(self, obj, objtype=None):
        if obj is None:
            return self
```
The `property()` builtin helps whenever a user interface has granted attribute access and then subsequent changes require the intervention of a method.

For instance, a spreadsheet class may grant access to a cell value through `Cell('b10').value`. Subsequent improvements to the program require the cell to be recalculated on every access; however, the programmer does not want to affect existing client code accessing the attribute directly. The solution is to wrap access to the value attribute in a property data descriptor:

```python
class Cell(object):
    def __get__(self, obj, value):
        if self.fget is None:
            raise AttributeError("unreadable attribute")
        return self.fget(obj)

    def __set__(self, obj, value):
        if self.fset is None:
            raise AttributeError("can't set attribute")
        self.fset(obj, value)

    def __delete__(self, obj):
        if self.fdel is None:
            raise AttributeError("can't delete attribute")
        self.fdel(obj)

    def getter(self, fget):
        return type(self)(fget, self.fset, self.fdel)

    def setter(self, fset):
        return type(self)(self.fget, fset, self.fdel)

    def deleter(self, fdel):
        return type(self)(self.fget, self.fset, fdel)
```

The `property()` builtin helps whenever a user interface has granted attribute access and then subsequent changes require the intervention of a method.
..
def getvalue(self, obj):
    "Recalculate cell before returning value"
    self.recalc()
    return obj._value
value = property(getvalue)
Functions and Methods

Python’s object oriented features are built upon a function based environment. Using non-data descriptors, the two are merged seamlessly.

Class dictionaries store methods as functions. In a class definition, methods are written using `def` and `lambda`, the usual tools for creating functions. The only difference from regular functions is that the first argument is reserved for the object instance. By Python convention, the instance reference is called `self` but may be called `this` or any other variable name.

To support method calls, functions include the `__get__()` method for binding methods during attribute access. This means that all functions are non-data descriptors which return bound or unbound methods depending whether they are invoked from an object or a class. In pure python, it works like this:

```python
class Function(object):
    ...
    def __get__(self, obj, objtype=None):
        "Simulate func_descr_get() in Objects/funcobject.c"
        return types.MethodType(self, obj, objtype)
```

Running the interpreter shows how the function descriptor works in practice:

```python
>>> class D(object):
    def f(self, x):
        return x
```
The output suggests that bound and unbound methods are two different types. While they could have been implemented that way, the actual C implementation of `PyMethod_Type` in `Objects/classobject.c` is a single object with two different representations depending on whether the `im_self` field is set or is `NULL` (the C equivalent of `None`).

Likewise, the effects of calling a method object depend on the `im_self` field. If set (meaning bound), the original function (stored in the `im_func` field) is called as expected with the first argument set to the instance. If unbound, all of the arguments are passed unchanged to the original function. The actual C implementation of `instancemethod_call()` is only slightly more complex in that it includes some type checking.
Static Methods and Class Methods

Non-data descriptors provide a simple mechanism for variations on the usual patterns of binding functions into methods.

To recap, functions have a `__get__()` method so that they can be converted to a method when accessed as attributes. The non-data descriptor transforms an `obj.f(*args)` call into `f(obj, *args)`. Calling `klass.f(*args)` becomes `f(*args)`.

This chart summarizes the binding and its two most useful variants:

<table>
<thead>
<tr>
<th>Transformation</th>
<th>Called from an Object</th>
<th>Called from a Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>function</td>
<td><code>f(obj, *args)</code></td>
<td><code>f(*args)</code></td>
</tr>
<tr>
<td>staticmethod</td>
<td><code>f(*args)</code></td>
<td><code>f(*args)</code></td>
</tr>
<tr>
<td>classmethod</td>
<td><code>f(type(obj), *args)</code></td>
<td><code>f(klass, *args)</code></td>
</tr>
</tbody>
</table>

Static methods return the underlying function without changes. Calling either `c.f` or `C.f` is the equivalent of a direct lookup into `object.__getattribute__(c, "f")` or `object.__getattribute__(C, "f")`. As a result, the function becomes identically accessible from either an object or a class.

Good candidates for static methods are methods that do not reference the `self` variable.

For instance, a statistics package may include a container class for experimental data. The class provides normal methods for computing the average, mean, median, and other descriptive statistics that depend on the data. However, there may be useful functions which are
conceptually related but do not depend on the data. For instance, erf(x) is handy conversion routine that comes up in statistical work but does not directly depend on a particular dataset. It can be called either from an object or the class: s.erf(1.5) --> .9332 or Sample.erf(1.5) --> .9332.

Since staticmethods return the underlying function with no changes, the example calls are unexciting:

```python
class E(object):
    def f(x):
        print(x)
    f = staticmethod(f)

>>> print(E.f(3))
3
>>> print(E().f(3))
3
```

Using the non-data descriptor protocol, a pure Python version of `staticmethod()` would look like this:

```python
class StaticMethod(object):
    "Emulate PyStaticMethod_Type() in Objects/funcobject.c"

    def __init__(self, f):
        self.f = f

    def __get__(self, obj, objtype=None):
        return self.f
```

Unlike static methods, class methods prepend the class reference to the argument list before calling the function. This format is the same for whether the caller is an object or a class:
```python
class E(object):
    def f(klass, x):
        return klass.__name__, x
    f = classmethod(f)

>>> print(E.f(3))
('E', 3)
>>> print(E().f(3))
('E', 3)
```

This behavior is useful whenever the function only needs to have a class reference and does not care about any underlying data. One use for classmethods is to create alternate class constructors. In Python 2.3, the classmethod `dict.fromkeys()` creates a new dictionary from a list of keys. The pure Python equivalent is:

```python
class Dict(object):
    def fromkeys(klass, iterable, value=None):
        """Emulate dict_fromkeys() in Objects/dictobject.c"
        d = klass()
        for key in iterable:
            d[key] = value
        return d
    fromkeys = classmethod(fromkeys)
```

Now a new dictionary of unique keys can be constructed like this:

```python
>>> Dict.fromkeys('abracadabra')
{'a': None, 'r': None, 'b': None, 'c': None, 'd': None}
```

Using the non-data descriptor protocol, a pure Python version of `classmethod()` would look like this:
class ClassMethod(object):
    "Emulate PyClassMethod_Type() in Objects/funcobject.c"

    def __init__(self, f):
        self.f = f

    def __get__(self, obj, klass=None):
        if klass is None:
            klass = type(obj)
        def newfunc(*args):
            return self.f(klass, *args)
        return newfunc
In this document, we'll take a tour of Python’s features suitable for implementing programs in a functional style. After an introduction to the concepts of functional programming, we'll look at language features such as iterators and generators and relevant library modules such as itertools and functools.
Introduction

This section explains the basic concept of functional programming; if you’re just interested in learning about Python language features, skip to the next section on Iterators.

Programming languages support decomposing problems in several different ways:

- Most programming languages are **procedural**: programs are lists of instructions that tell the computer what to do with the program’s input. C, Pascal, and even Unix shells are procedural languages.
- In **declarative** languages, you write a specification that describes the problem to be solved, and the language implementation figures out how to perform the computation efficiently. SQL is the declarative language you’re most likely to be familiar with; a SQL query describes the data set you want to retrieve, and the SQL engine decides whether to scan tables or use indexes, which subclauses should be performed first, etc.
- **Object-oriented** programs manipulate collections of objects. Objects have internal state and support methods that query or modify this internal state in some way. Smalltalk and Java are object-oriented languages. C++ and Python are languages that support object-oriented programming, but don’t force the use of object-oriented features.
- **Functional** programming decomposes a problem into a set of functions. Ideally, functions only take inputs and produce outputs, and don’t have any internal state that affects the output produced for a given input. Well-known functional languages include the ML family (Standard ML, OCaml, and other variants) and Haskell.

The designers of some computer languages choose to emphasize one particular approach to programming. This often makes it difficult to
write programs that use a different approach. Other languages are multi-paradigm languages that support several different approaches. Lisp, C++, and Python are multi-paradigm; you can write programs or libraries that are largely procedural, object-oriented, or functional in all of these languages. In a large program, different sections might be written using different approaches; the GUI might be object-oriented while the processing logic is procedural or functional, for example.

In a functional program, input flows through a set of functions. Each function operates on its input and produces some output. Functional style discourages functions with side effects that modify internal state or make other changes that aren’t visible in the function’s return value. Functions that have no side effects at all are called purely functional. Avoiding side effects means not using data structures that get updated as a program runs; every function’s output must only depend on its input.

Some languages are very strict about purity and don’t even have assignment statements such as a=3 or c = a + b, but it’s difficult to avoid all side effects. Printing to the screen or writing to a disk file are side effects, for example. For example, in Python a call to the print() or time.sleep() function both return no useful value; they’re only called for their side effects of sending some text to the screen or pausing execution for a second.

Python programs written in functional style usually won’t go to the extreme of avoiding all I/O or all assignments; instead, they’ll provide a functional-appearing interface but will use non-functional features internally. For example, the implementation of a function will still use assignments to local variables, but won’t modify global variables or have other side effects.

Functional programming can be considered the opposite of object-
oriented programming. Objects are little capsules containing some internal state along with a collection of method calls that let you modify this state, and programs consist of making the right set of state changes. Functional programming wants to avoid state changes as much as possible and works with data flowing between functions. In Python you might combine the two approaches by writing functions that take and return instances representing objects in your application (e-mail messages, transactions, etc.).

Functional design may seem like an odd constraint to work under. Why should you avoid objects and side effects? There are theoretical and practical advantages to the functional style:

- Formal provability.
- Modularity.
- Composability.
- Ease of debugging and testing.

**Formal provability**

A theoretical benefit is that it's easier to construct a mathematical proof that a functional program is correct.

For a long time researchers have been interested in finding ways to mathematically prove programs correct. This is different from testing a program on numerous inputs and concluding that its output is usually correct, or reading a program’s source code and concluding that the code looks right; the goal is instead a rigorous proof that a program produces the right result for all possible inputs.

The technique used to prove programs correct is to write down invariants, properties of the input data and of the program’s variables that are always true. For each line of code, you then show that if
invariants X and Y are true before the line is executed, the slightly different invariants X' and Y' are true after the line is executed. This continues until you reach the end of the program, at which point the invariants should match the desired conditions on the program’s output.

Functional programming’s avoidance of assignments arose because assignments are difficult to handle with this technique; assignments can break invariants that were true before the assignment without producing any new invariants that can be propagated onward.

Unfortunately, proving programs correct is largely impractical and not relevant to Python software. Even trivial programs require proofs that are several pages long; the proof of correctness for a moderately complicated program would be enormous, and few or none of the programs you use daily (the Python interpreter, your XML parser, your web browser) could be proven correct. Even if you wrote down or generated a proof, there would then be the question of verifying the proof; maybe there's an error in it, and you wrongly believe you've proved the program correct.

Modularity

A more practical benefit of functional programming is that it forces you to break apart your problem into small pieces. Programs are more modular as a result. It’s easier to specify and write a small function that does one thing than a large function that performs a complicated transformation. Small functions are also easier to read and to check for errors.

Ease of debugging and testing
Testing and debugging a functional-style program is easier.

Debugging is simplified because functions are generally small and clearly specified. When a program doesn’t work, each function is an interface point where you can check that the data are correct. You can look at the intermediate inputs and outputs to quickly isolate the function that’s responsible for a bug.

Testing is easier because each function is a potential subject for a unit test. Functions don’t depend on system state that needs to be replicated before running a test; instead you only have to synthesize the right input and then check that the output matches expectations.

Composability

As you work on a functional-style program, you’ll write a number of functions with varying inputs and outputs. Some of these functions will be unavoidably specialized to a particular application, but others will be useful in a wide variety of programs. For example, a function that takes a directory path and returns all the XML files in the directory, or a function that takes a filename and returns its contents, can be applied to many different situations.

Over time you’ll form a personal library of utilities. Often you’ll assemble new programs by arranging existing functions in a new configuration and writing a few functions specialized for the current task.
Iterators

I'll start by looking at a Python language feature that's an important foundation for writing functional-style programs: iterators.

An iterator is an object representing a stream of data; this object returns the data one element at a time. A Python iterator must support a method called `__next__()` that takes no arguments and always returns the next element of the stream. If there are no more elements in the stream, `__next__()` must raise the `StopIteration` exception. Iterators don't have to be finite, though; it's perfectly reasonable to write an iterator that produces an infinite stream of data.

The built-in `iter()` function takes an arbitrary object and tries to return an iterator that will return the object's contents or elements, raising `TypeError` if the object doesn't support iteration. Several of Python's built-in data types support iteration, the most common being lists and dictionaries. An object is called `iterable` if you can get an iterator for it.

You can experiment with the iteration interface manually:

```python
>>> L = [1, 2, 3]
>>> it = iter(L)
>>> it
<...iterator object at ...>
>>> it.__next__()  # same as next(it)
1
>>> next(it)
2
>>> next(it)
3
>>> next(it)
```

>>> L = [1, 2, 3]
...```
Python expects iterable objects in several different contexts, the most important being the `for` statement. In the statement `for X in Y`, `Y` must be an iterator or some object for which `iter()` can create an iterator. These two statements are equivalent:

```python
for i in iter(obj):
    print(i)

for i in obj:
    print(i)
```

Iterators can be materialized as lists or tuples by using the `list()` or `tuple()` constructor functions:

```python
>>> L = [1,2,3]
>>> iterator = iter(L)
>>> t = tuple(iterator)
>>> t
(1, 2, 3)
```

Sequence unpacking also supports iterators: if you know an iterator will return N elements, you can unpack them into an N-tuple:

```python
>>> L = [1,2,3]
>>> iterator = iter(L)
>>> a,b,c = iterator
>>> a,b,c
(1, 2, 3)
```

Built-in functions such as `max()` and `min()` can take a single iterator
argument and will return the largest or smallest element. The "in" and "not in" operators also support iterators: X in iterator is true if X is found in the stream returned by the iterator. You'll run into obvious problems if the iterator is infinite; max(), min() will never return, and if the element X never appears in the stream, the "in" and "not in" operators won't return either.

Note that you can only go forward in an iterator; there's no way to get the previous element, reset the iterator, or make a copy of it. Iterator objects can optionally provide these additional capabilities, but the iterator protocol only specifies the __next__() method. Functions may therefore consume all of the iterator's output, and if you need to do something different with the same stream, you'll have to create a new iterator.

Data Types That Support Iterators

We've already seen how lists and tuples support iterators. In fact, any Python sequence type, such as strings, will automatically support creation of an iterator.

Calling iter() on a dictionary returns an iterator that will loop over the dictionary's keys:

```python
g>>> m = {'Jan': 1, 'Feb': 2, 'Mar': 3, 'Apr': 4, 'May': 5, ... 'Jul': 7, 'Aug': 8, 'Sep': 9, 'Oct': 10, 'Nov': 11, ...}'

>>> for key in m:
...     print(key, m[key])
Mar 3
Feb 2
Aug 8
Sep 9
Apr 4
```
Note that the order is essentially random, because it’s based on the hash ordering of the objects in the dictionary.

Applying `iter()` to a dictionary always loops over the keys, but dictionaries have methods that return other iterators. If you want to iterate over values or key/value pairs, you can explicitly call the `values()` or `items()` methods to get an appropriate iterator.

The `dict()` constructor can accept an iterator that returns a finite stream of (key, value) tuples:

```python
L = [('Italy', 'Rome'), ('France', 'Paris'), ('US', 'Washington DC')]
>>> dict(iter(L))
{'Italy': 'Rome', 'US': 'Washington DC', 'France': 'Paris'}
```

Files also support iteration by calling the `readline()` method until there are no more lines in the file. This means you can read each line of a file like this:

```python
for line in file:
    # do something for each line
    ...
```

Sets can take their contents from an iterable and let you iterate over the set's elements:
S = {2, 3, 5, 7, 11, 13}
for i in S:
    print(i)
Generator expressions and list comprehensions

Two common operations on an iterator’s output are 1) performing some operation for every element, 2) selecting a subset of elements that meet some condition. For example, given a list of strings, you might want to strip off trailing whitespace from each line or extract all the strings containing a given substring.

List comprehensions and generator expressions (short form: “listcomps” and “genexps”) are a concise notation for such operations, borrowed from the functional programming language Haskell (http://www.haskell.org/). You can strip all the whitespace from a stream of strings with the following code:

```python
line_list = [' line 1
\', 'line 2  \n', ...]

# Generator expression -- returns iterator
stripped_iter = (line.strip() for line in line_list)

# List comprehension -- returns list
stripped_list = [line.strip() for line in line_list]
```

You can select only certain elements by adding an "if" condition:

```python
stripped_list = [line.strip() for line in line_list if line != '"
```

With a list comprehension, you get back a Python list; stripped_list is a list containing the resulting lines, not an iterator. Generator expressions return an iterator that computes the values as necessary, not needing to materialize all the values at once. This
means that list comprehensions aren’t useful if you’re working with iterators that return an infinite stream or a very large amount of data. Generator expressions are preferable in these situations.

Generator expressions are surrounded by parentheses ("()") and list comprehensions are surrounded by square brackets ("[]"). Generator expressions have the form:

```python
( expression for expr in sequence1
  if condition1
  for expr2 in sequence2
  if condition2
  for expr3 in sequence3 ...
  if condition3
  for exprN in sequenceN
  if conditionN )
```

Again, for a list comprehension only the outside brackets are different (square brackets instead of parentheses).

The elements of the generated output will be the successive values of expression. The if clauses are all optional; if present, expression is only evaluated and added to the result when condition is true.

Generator expressions always have to be written inside parentheses, but the parentheses signalling a function call also count. If you want to create an iterator that will be immediately passed to a function you can write:

```python
obj_total = sum(obj.count for obj in list_all_objects)
```

The for...in clauses contain the sequences to be iterated over. The
sequences do not have to be the same length, because they are iterated over from left to right, not in parallel. For each element in sequence1, sequence2 is looped over from the beginning. sequence3 is then looped over for each resulting pair of elements from sequence1 and sequence2.

To put it another way, a list comprehension or generator expression is equivalent to the following Python code:

```python
for expr1 in sequence1:
    if not (condition1):
        continue  # Skip this element
    for expr2 in sequence2:
        if not (condition2):
            continue  # Skip this element
    ... 
    for exprN in sequenceN:
        if not (conditionN):
            continue  # Skip this element

    # Output the value of
    # the expression.
```

This means that when there are multiple for...in clauses but no if clauses, the length of the resulting output will be equal to the product of the lengths of all the sequences. If you have two lists of length 3, the output list is 9 elements long:

```python
>>> seq1 = 'abc'
>>> seq2 = (1, 2, 3)
>>> [(x, y) for x in seq1 for y in seq2]
[('a', 1), ('a', 2), ('a', 3), ('b', 1), ('b', 2), ('b', 3), ('c', 1), ('c', 2), ('c', 3)]
```
To avoid introducing an ambiguity into Python’s grammar, if expression is creating a tuple, it must be surrounded with parentheses. The first list comprehension below is a syntax error, while the second one is correct:

```
# Syntax error
[x, y for x in seq1 for y in seq2]

# Correct
[(x, y) for x in seq1 for y in seq2]
```
Generators

Generators are a special class of functions that simplify the task of writing iterators. Regular functions compute a value and return it, but generators return an iterator that returns a stream of values.

You’re doubtless familiar with how regular function calls work in Python or C. When you call a function, it gets a private namespace where its local variables are created. When the function reaches a return statement, the local variables are destroyed and the value is returned to the caller. A later call to the same function creates a new private namespace and a fresh set of local variables. But, what if the local variables weren’t thrown away on exiting a function? What if you could later resume the function where it left off? This is what generators provide; they can be thought of as resumable functions.

Here’s the simplest example of a generator function:

```python
>>> def generate_ints(N):
...    for i in range(N):
...        yield i
```

Any function containing a yield keyword is a generator function; this is detected by Python’s bytecode compiler which compiles the function specially as a result.

When you call a generator function, it doesn’t return a single value; instead it returns a generator object that supports the iterator protocol. On executing the yield expression, the generator outputs the value of i, similar to a return statement. The big difference between yield and a return statement is that on reaching a yield the generator’s state of execution is suspended and local variables are
preserved. On the next call to the generator’s __next__() method, the function will resume executing.

Here’s a sample usage of the `generate_ints()` generator:

```python
>>> gen = generate_ints(3)
>>> gen
<generator object generate_ints at ...>
>>> next(gen)
0
>>> next(gen)
1
>>> next(gen)
2
>>> next(gen)
Traceback (most recent call last):
  File "stdin", line 1, in ?
  File "stdin", line 2, in generate_ints
StopIteration
```

You could equally write for `i in generate_ints(5)`, or `a, b, c = generate_ints(3)`.

Inside a generator function, return value causes `StopIteration(value)` to be raised from the __next__() method. Once this happens, or the bottom of the function is reached, the procession of values ends and the generator cannot yield any further values.

You could achieve the effect of generators manually by writing your own class and storing all the local variables of the generator as instance variables. For example, returning a list of integers could be done by setting `self.count` to 0, and having the __next__() method increment `self.count` and return it. However, for a
moderately complicated generator, writing a corresponding class can be much messier.

The test suite included with Python’s library, `Lib/test/test_generators.py`, contains a number of more interesting examples. Here’s one generator that implements an in-order traversal of a tree using generators recursively.

```python
# A recursive generator that generates Tree leaves in
# an inorder traversal recursively.

def inorder(t):
    if t:
        for x in inorder(t.left):
            yield x

        yield t.label

        for x in inorder(t.right):
            yield x
```

Two other examples in `test_generators.py` produce solutions for the N-Queens problem (placing N queens on an N x N chess board so that no queen threatens another) and the Knight’s Tour (finding a route that takes a knight to every square of an N x N chess board without visiting any square twice).

**Passing values into a generator**

In Python 2.4 and earlier, generators only produced output. Once a generator’s code was invoked to create an iterator, there was no way to pass any new information into the function when its execution is resumed. You could hack together this ability by making the generator look at a global variable or by passing in some mutable object that callers then modify, but these approaches are messy.
In Python 2.5 there's a simple way to pass values into a generator. `yield` became an expression, returning a value that can be assigned to a variable or otherwise operated on:

```python
val = (yield i)
```

I recommend that you **always** put parentheses around a `yield` expression when you're doing something with the returned value, as in the above example. The parentheses aren't always necessary, but it's easier to always add them instead of having to remember when they're needed.

(PEP 342 explains the exact rules, which are that a `yield-expression` must always be parenthesized except when it occurs at the top-level expression on the right-hand side of an assignment. This means you can write `val = yield i` but have to use parentheses when there's an operation, as in `val = (yield i) + 12`.)

Values are sent into a generator by calling its `send(value)` method. This method resumes the generator's code and the `yield` expression returns the specified value. If the regular `__next__()` method is called, the `yield` returns None.

Here's a simple counter that increments by 1 and allows changing the value of the internal counter.

```python
def counter(maximum):
    i = 0
    while i < maximum:
        val = (yield i)
        # If value provided, change counter
        if val is not None:
            i = val
```
And here's an example of changing the counter:

```python
>>> it = counter(10)
>>> next(it)
0
>>> next(it)
1
>>> it.send(8)
8
>>> next(it)
9
>>> next(it)
Traceback (most recent call last):
  File "t.py", line 15, in ?
    it.next()
StopIteration
```

Because `yield` will often be returning `None`, you should always check for this case. Don’t just use its value in expressions unless you’re sure that the `send()` method will be the only method used to resume your generator function.

In addition to `send()`, there are two other methods on generators:

- `throw(type, value=None, traceback=None)` is used to raise an exception inside the generator; the exception is raised by the `yield` expression where the generator’s execution is paused.

- `close()` raises a `GeneratorExit` exception inside the generator to terminate the iteration. On receiving this exception, the generator’s code must either raise `GeneratorExit` or
StopIteration; catching the exception and doing anything else is illegal and will trigger a RuntimeError. close() will also be called by Python's garbage collector when the generator is garbage-collected.

If you need to run cleanup code when a GeneratorExit occurs, I suggest using a try: ... finally: suite instead of catching GeneratorExit.

The cumulative effect of these changes is to turn generators from one-way producers of information into both producers and consumers.

Generators also become coroutines, a more generalized form of subroutines. Subroutines are entered at one point and exited at another point (the top of the function, and a return statement), but coroutines can be entered, exited, and resumed at many different points (the yield statements).
Built-in functions

Let's look in more detail at built-in functions often used with iterators.

Two of Python's built-in functions, `map()` and `filter()` duplicate the features of generator expressions:

\[
\text{map}(f, \text{iterA}, \text{iterB}, \ldots) \text{ returns an iterator over the sequence }
\]
\[
f(\text{iterA}[0], \text{iterB}[0]), f(\text{iterA}[1], \text{iterB}[1]), f(\text{iterA}[2], \text{iterB}[2]), \ldots.
\]

\[
>>> \text{def upper}(s):
... \quad \text{return } s.\text{upper}()
\]

\[
>>> \text{list(map(upper, ['sentence', 'fragment'])))}
['SENTENCE', 'FRAGMENT']
>>> [upper(s) \text{ for } s \text{ in ['sentence', 'fragment']}]\n['SENTENCE', 'FRAGMENT']
\]

You can of course achieve the same effect with a list comprehension.

\[
\text{filter(predicate, iter) returns an iterator over all the sequence elements that meet a certain condition, and is similarly duplicated by list comprehensions. A predicate is a function that returns the truth value of some condition; for use with filter(), the predicate must take a single value.}
\]

\[
>>> \text{def is_even}(x):
... \quad \text{return } (x \% 2) == 0
\]

\[
>>> \text{list(filter(is_even, range(10)))}
[0, 2, 4, 6, 8]
\]
This can also be written as a list comprehension:

```python
>>> list(x for x in range(10) if is_even(x))
[0, 2, 4, 6, 8]
```

`enumerate(iter)` counts off the elements in the iterable, returning 2-tuples containing the count and each element.

```python
>>> for item in enumerate(['subject', 'verb', 'object', ...
... print(item)
(0, 'subject')
(1, 'verb')
(2, 'object')
```

`enumerate()` is often used when looping through a list and recording the indexes at which certain conditions are met:

```python
f = open('data.txt', 'r')
for i, line in enumerate(f):
    if line.strip() == '':
        print('Blank line at line #%i' % i)
```

`sorted(iterable, key=None, reverse=False)` collects all the elements of the iterable into a list, sorts the list, and returns the sorted result. The `key` and `reverse` arguments are passed through to the constructed list's `sort()` method.

```python
>>> import random
>>> # Generate 8 random numbers between [0, 10000)
>>> rand_list = random.sample(range(10000), 8)
>>> rand_list
[769, 7953, 9828, 6431, 8442, 9878, 6213, 2207]
>>> sorted(rand_list)
[769, 2207, 6213, 6431, 7953, 8442, 9828, 9878]
```
Sorted (rand_list, reverse=True)
[9878, 9828, 8442, 7953, 6431, 6213, 2207, 769]

(For a more detailed discussion of sorting, see the Sorting HOW TO.)

The \texttt{any(iter)} and \texttt{all(iter)} built-ins look at the truth values of an iterable’s contents. \texttt{any()} returns \texttt{True} if any element in the iterable is a true value, and \texttt{all()} returns \texttt{True} if all of the elements are true values:

\begin{verbatim}
>>> any([0,1,0])
True
>>> any([0,0,0])
False
>>> any([1,1,1])
True
>>> all([0,1,0])
False
>>> all([0,0,0])
False
>>> all([1,1,1])
True
\end{verbatim}

\texttt{zip(iterA, iterB, \ldots)} takes one element from each iterable and returns them in a tuple:

\begin{verbatim}
zip(['a', 'b', 'c'], (1, 2, 3)) =>
('a', 1), ('b', 2), ('c', 3)
\end{verbatim}

It doesn’t construct an in-memory list and exhaust all the input iterators before returning; instead tuples are constructed and returned only if they’re requested. (The technical term for this behaviour is lazy evaluation.)

This iterator is intended to be used with iterables that are all of the
same length. If the iterables are of different lengths, the resulting stream will be the same length as the shortest iterable.

```python
zip(['a', 'b'], (1, 2, 3)) => ('a', 1), ('b', 2)
```

You should avoid doing this, though, because an element may be taken from the longer iterators and discarded. This means you can’t go on to use the iterators further because you risk skipping a discarded element.
The **itertools** module

The **itertools** module contains a number of commonly-used iterators as well as functions for combining several iterators. This section will introduce the module’s contents by showing small examples.

The module’s functions fall into a few broad classes:

- Functions that create a new iterator based on an existing iterator.
- Functions for treating an iterator’s elements as function arguments.
- Functions for selecting portions of an iterator’s output.
- A function for grouping an iterator’s output.

Creating new iterators

**itertools.count(n)** returns an infinite stream of integers, increasing by 1 each time. You can optionally supply the starting number, which defaults to 0:

```python
itertools.count() => 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, ...

itertools.count(10) => 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, ...
```

**itertools.cycle(iter)** saves a copy of the contents of a provided iterable and returns a new iterator that returns its elements from first to last. The new iterator will repeat these elements infinitely.

```python
itertools.cycle([1,2,3,4,5]) => 1, 2, 3, 4, 5, 1, 2, 3, 4, 5, ...
```
*itertools.repeat(elem, [n])** returns the provided element \(n\) times, or returns the element endlessly if \(n\) is not provided.

```python
# Example usage
itertools.repeat('abc') => abc, abc, abc, abc, abc, abc, abc, abc, abc
itertools.repeat('abc', 5) => abc, abc, abc, abc, abc
```

*itertools.chain(iterA, iterB, ...)** takes an arbitrary number of iterables as input, and returns all the elements of the first iterator, then all the elements of the second, and so on, until all of the iterables have been exhausted.

```python
# Example usage
itertools.chain(['a', 'b', 'c'], (1, 2, 3)) => a, b, c, 1, 2, 3
```

*itertools.islice(iter, [start], stop, [step])** returns a stream that’s a slice of the iterator. With a single *stop* argument, it will return the first *stop* elements. If you supply a starting index, you’ll get *stop-start* elements, and if you supply a value for *step*, elements will be skipped accordingly. Unlike Python’s string and list slicing, you can’t use negative values for *start*, *stop*, or *step*.

```python
# Example usage
itertools.islice(range(10), 8) => 0, 1, 2, 3, 4, 5, 6, 7
itertools.islice(range(10), 2, 8) => 2, 3, 4, 5, 6, 7
itertools.islice(range(10), 2, 8, 2) => 2, 4, 6
```

*itertools.tee(iter, [n])** replicates an iterator; it returns \(n\) independent iterators that will all return the contents of the source iterator. If you don’t supply a value for \(n\), the default is 2. Replicating
iterators requires saving some of the contents of the source iterator, so this can consume significant memory if the iterator is large and one of the new iterators is consumed more than the others.

```python
import itertools

itertools.tee( itertools.count() ) => iterA, iterB

where iterA ->
  0, 1, 2, 3, 4, 5, 6, 7, 8, 9, ...

and   iterB ->
  0, 1, 2, 3, 4, 5, 6, 7, 8, 9, ...
```

**Calling functions on elements**

The `operator` module contains a set of functions corresponding to Python’s operators. Some examples are `operator.add(a, b)` (adds two values), `operator.ne(a, b)` (same as `a != b`), and `operator.attrgetter('id')` (returns a callable that fetches the `.id` attribute).

`itertools.starmap(func, iter)` assumes that the iterable will return a stream of tuples, and calls `func` using these tuples as the arguments:

```python
import os

itertools.starmap(os.path.join,
                   [('/bin', 'python'), ('/usr', 'bin', '/usr/bin/perl'), ('/usr',
                     =>
                    '/bin/python', '/usr/bin/java', '/usr/bin/perl', '/usr/bin/perl'))
```

**Selecting elements**
Another group of functions chooses a subset of an iterator’s elements based on a predicate.

`itertools.filterfalse(predicate, iter)` is the opposite of `filter()`, returning all elements for which the predicate returns false:

```
>>> itertools.filterfalse(is_even, itertools.count()) =>
1, 3, 5, 7, 9, 11, 13, 15, ...
```

`itertools.takewhile(predicate, iter)` returns elements for as long as the predicate returns true. Once the predicate returns false, the iterator will signal the end of its results.

```
def less_than_10(x):
    return x < 10

>>> itertools.takewhile(less_than_10, itertools.count())
0, 1, 2, 3, 4, 5, 6, 7, 8, 9

>>> itertools.takewhile(is_even, itertools.count()) =>
0
```

`itertools.dropwhile(predicate, iter)` discards elements while the predicate returns true, and then returns the rest of the iterable’s results.

```
>>> itertools.dropwhile(less_than_10, itertools.count())
10, 11, 12, 13, 14, 15, 16, 17, 18, 19, ...

>>> itertools.dropwhile(is_even, itertools.count()) =>
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, ...
```
**itertools.compress(data, selectors)** takes two iterators and returns only those elements of *data* for which the corresponding element of *selectors* is true, stopping whenever either one is exhausted:

```python
itertools.compress([1,2,3,4,5], [True, True, False, 1, 2, 5])
```

**Combinatoric functions**

The **itertools.combinations(iterable, r)** function returns an iterator giving all possible *r*-tuple combinations of the elements contained in *iterable*.

```python
itertools.combinations([1, 2, 3, 4, 5], 2) =>
(1, 2), (1, 3), (1, 4), (1, 5),
(2, 3), (2, 4), (2, 5),
(3, 4), (3, 5),
(4, 5)
```

```python
itertools.combinations([1, 2, 3, 4, 5], 3) =>
(1, 2, 3), (1, 2, 4), (1, 2, 5), (1, 3, 4), (1, 3,
(2, 3, 4), (2, 3, 5), (2, 4, 5),
(3, 4, 5)
```

The elements within each tuple remain in the same order as *iterable* returned them. For example, the number 1 is always before 2, 3, 4, or 5 in the examples above. A similar function, **itertools.permutations(iterable, r=None)**, removes this constraint on the order, returning all possible arrangements of length *r*:

```python
itertools.permutations([1, 2, 3, 4, 5], 2) =>
```
\[
(1, 2), (1, 3), (1, 4), (1, 5),
(2, 1), (2, 3), (2, 4), (2, 5),
(3, 1), (3, 2), (3, 4), (3, 5),
(4, 1), (4, 2), (4, 3), (4, 5),
(5, 1), (5, 2), (5, 3), (5, 4)
\]

\[
\text{itertools.permutations([1, 2, 3, 4, 5]) => (1, 2, 3, 4, 5), (1, 2, 3, 5, 4), (1, 2, 4, 3, 5), ... (5, 4, 3, 2, 1)}
\]

If you don’t supply a value for \( r \) the length of the iterable is used, meaning that all the elements are permuted.

Note that these functions produce all of the possible combinations by position and don’t require that the contents of \( \text{iterable} \) are unique:

\[
\text{itertools.permutations('aba', 3) => ('a', 'b', 'a'), ('a', 'a', 'b'), ('b', 'a', 'a'), ('b', 'a', 'a'), ('a', 'a', 'b'), ('a', 'b', 'a')}
\]

The identical tuple ('a', 'a', 'b') occurs twice, but the two ‘a’ strings came from different positions.

The \( \text{itertools.combinations_with_replacement(iterable, r)} \) function relaxes a different constraint: elements can be repeated within a single tuple. Conceptually an element is selected for the first position of each tuple and then is replaced before the second element is selected.

\[
\text{itertools.combinations_with_replacement([1, 2, 3, 4, (1, 1), (1, 2), (1, 3), (1, 4), (1, 5), (2, 2), (2, 3), (2, 4), (2, 5)},}
\]
Grouping elements

The last function I'll discuss, `itertools.groupby(iter, key_func=None)`, is the most complicated. `key_func(elem)` is a function that can compute a key value for each element returned by the iterable. If you don't supply a key function, the key is simply each element itself.

`groupby()` collects all the consecutive elements from the underlying iterable that have the same key value, and returns a stream of 2-tuples containing a key value and an iterator for the elements with that key.

```python
city_list = [('Decatur', 'AL'), ('Huntsville', 'AL'),
             ('Anchorage', 'AK'), ('Nome', 'AK'),
             ('Flagstaff', 'AZ'), ('Phoenix', 'AZ'),
             ...
]

def get_state(city_state):
    return city_state[1]

itertools.groupby(city_list, get_state) =>
    ('AL', iterator-1),
    ('AK', iterator-2),
    ('AZ', iterator-3), ...

where
    iterator-1 =>
        ('Decatur', 'AL'), ('Huntsville', 'AL'), ('Selma',
        iterator-2 =>
groupby() assumes that the underlying iterable’s contents will already be sorted based on the key. Note that the returned iterators also use the underlying iterable, so you have to consume the results of iterator-1 before requesting iterator-2 and its corresponding key.
The **functools** module

The **functools** module in Python 2.5 contains some higher-order functions. A **higher-order function** takes one or more functions as input and returns a new function. The most useful tool in this module is the **functools.partial()** function.

For programs written in a functional style, you'll sometimes want to construct variants of existing functions that have some of the parameters filled in. Consider a Python function $f(a, b, c)$; you may wish to create a new function $g(b, c)$ that's equivalent to $f(1, b, c)$; you're filling in a value for one of $f()$'s parameters. This is called “partial function application”.

The constructor for **partial()** takes the arguments (function, arg1, arg2, ..., kwarg1=value1, kwarg2=value2). The resulting object is callable, so you can just call it to invoke function with the filled-in arguments.

Here's a small but realistic example:

```python
import functools

def log(message, subsystem):
    """Write the contents of 'message' to the specified subsystem."
    print('%s: %s' % (subsystem, message))
...

server_log = functools.partial(log, subsystem='server')
server_log('Unable to open socket')

functools.reduce(func, iter, [initial_value])
```
cumulatively performs an operation on all the iterable's elements and, therefore, can't be applied to infinite iterables. `func` must be a function that takes two elements and returns a single value. `functools.reduce()` takes the first two elements A and B returned by the iterator and calculates `func(A, B)`. It then requests the third element, C, calculates `func(func(A, B), C)`, combines this result with the fourth element returned, and continues until the iterable is exhausted. If the iterable returns no values at all, a `TypeError` exception is raised. If the initial value is supplied, it's used as a starting point and `func(initial_value, A)` is the first calculation.

```python
>>> import operator, functools
>>> functools.reduce(operator.concat, ['A', 'BB', 'C', 'ABBC'])
Traceback (most recent call last):
  ...TypeError: reduce() of empty sequence with no initial value
>>> functools.reduce(operator.concat, [])
>>> functools.reduce(operator.mul, [1,2,3], 1)
6
>>> functools.reduce(operator.mul, [], 1)
1
```

If you use `operator.add()` with `functools.reduce()`, you'll add up all the elements of the iterable. This case is so common that there's a special built-in called `sum()` to compute it:

```python
>>> import functools
>>> functools.reduce(operator.add, [1,2,3,4], 0)
10
>>> sum([1,2,3,4])
10
>>> sum([])
```

For many uses of `functools.reduce()`, though, it can be clearer to just write the obvious `for` loop:

```python
import functools

# Instead of:
product = functools.reduce(operator.mul, [1, 2, 3], 1)

# You can write:
product = 1
for i in [1, 2, 3]:
    product *= i
```

A related function is `itertools.accumulate(iterable, func=operator.add)`.<code>itertools.accumulate</code>. It performs the same calculation, but instead of returning only the final result, `accumulate()` returns an iterator that also yields each partial result:

```python
itertools.accumulate([1, 2, 3, 4, 5]) =>
    1, 3, 6, 10, 15

itertools.accumulate([1, 2, 3, 4, 5], operator.mul) =>
    1, 2, 6, 24, 120
```

**The operator module**

The `operator` module was mentioned earlier. It contains a set of functions corresponding to Python's operators. These functions are often useful in functional-style code because they save you from writing trivial functions that perform a single operation.

Some of the functions in this module are:
- Math operations: `add()`, `sub()`, `mul()`, `floordiv()`, `abs()`, ...
- Logical operations: `not_()`, `truth()`.
- Bitwise operations: `and_()`, `or_()`, `invert()`.
- Comparisons: `eq()`, `ne()`, `lt()`, `le()`, `gt()`, and `ge()`.
- Object identity: `is_()`, `is_not()`.

Consult the operator module’s documentation for a complete list.
Small functions and the lambda expression

When writing functional-style programs, you'll often need little functions that act as predicates or that combine elements in some way.

If there's a Python built-in or a module function that's suitable, you don't need to define a new function at all:

```python
stripped_lines = [line.strip() for line in lines]
existing_files = filter(os.path.exists, file_list)
```

If the function you need doesn't exist, you need to write it. One way to write small functions is to use the `lambda` statement. `lambda` takes a number of parameters and an expression combining these parameters, and creates an anonymous function that returns the value of the expression:

```python
adder = lambda x, y: x+y
print_assign = lambda name, value: name + '=' + str(value)
```

An alternative is to just use the `def` statement and define a function in the usual way:

```python
def adder(x, y):
    return x + y

def print_assign(name, value):
    return name + '=' + str(value)
```

Which alternative is preferable? That's a style question; my usual
course is to avoid using lambda.

One reason for my preference is that lambda is quite limited in the functions it can define. The result has to be computable as a single expression, which means you can't have multiway if... elif... else comparisons or try... except statements. If you try to do too much in a lambda statement, you'll end up with an overly complicated expression that's hard to read. Quick, what's the following code doing?

```python
import functools
total = functools.reduce(lambda a, b: (0, a[1] + b[1]), items)
```

You can figure it out, but it takes time to disentangle the expression to figure out what's going on. Using a short nested def statements makes things a little bit better:

```python
import functools
def combine(a, b):
    return 0, a[1] + b[1]
total = functools.reduce(combine, items)[1]
```

But it would be best of all if I had simply used a for loop:

```python
total = 0
for a, b in items:
    total += b
```

Or the `sum()` built-in and a generator expression:

```python
total = sum(b for a, b in items)
```

Many uses of `functools.reduce()` are clearer when written as
for loops.

Fredrik Lundh once suggested the following set of rules for refactoring uses of lambda:

1. Write a lambda function.
2. Write a comment explaining what the heck that lambda does.
3. Study the comment for a while, and think of a name that captures the essence of the comment.
4. Convert the lambda to a def statement, using that name.
5. Remove the comment.

I really like these rules, but you’re free to disagree about whether this lambda-free style is better.
Revision History and Acknowledgements

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Version 0.1: posted June 30 2006.

Version 0.11: posted July 1 2006. Typo fixes.

Version 0.2: posted July 10 2006. Merged genexp and listcomp sections into one. Typo fixes.

Version 0.21: Added more references suggested on the tutor mailing list.

Version 0.30: Adds a section on the functional module written by Collin Winter; adds short section on the operator module; a few other edits.
References

General

**Structure and Interpretation of Computer Programs**, by Harold Abelson and Gerald Jay Sussman with Julie Sussman. Full text at [http://mitpress.mit.edu/sicp/](http://mitpress.mit.edu/sicp/). In this classic textbook of computer science, chapters 2 and 3 discuss the use of sequences and streams to organize the data flow inside a program. The book uses Scheme for its examples, but many of the design approaches described in these chapters are applicable to functional-style Python code.

[http://www.defmacro.org/ramblings/fp.html](http://www.defmacro.org/ramblings/fp.html): A general introduction to functional programming that uses Java examples and has a lengthy historical introduction.


Python-specific


Mertz also wrote a 3-part series of articles on functional programming for IBM's DeveloperWorks site; see [part 1](http://www.defmacro.org/ramblings/fp.html), [part 2](http://en.wikipedia.org/wiki/Functional_programming), and [part 3](http://en.wikipedia.org/wiki/Coroutine),
Python documentation

Documentation for the `itertools` module.

Documentation for the `operator` module.

**PEP 289**: “Generator Expressions”

**PEP 342**: “Coroutines via Enhanced Generators” describes the new generator features in Python 2.5.
Basic Logging Tutorial

Logging is a means of tracking events that happen when some software runs. The software's developer adds logging calls to their code to indicate that certain events have occurred. An event is described by a descriptive message which can optionally contain variable data (i.e. data that is potentially different for each occurrence of the event). Events also have an importance which the developer ascribes to the event; the importance can also be called the level or severity.

When to use logging

Logging provides a set of convenience functions for simple logging usage. These are debug(), info(), warning(), error() and critical(). To determine when to use logging, see the table below, which states, for each of a set of common tasks, the best tool to use for it.

<table>
<thead>
<tr>
<th>Task you want to perform</th>
<th>The best tool for the task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display console output for ordinary usage of a command line script or program</td>
<td>print()</td>
</tr>
<tr>
<td>Report events that occur during normal operation of a program (e.g. for status monitoring or fault investigation)</td>
<td>logging.info() (or logging.debug() for very detailed output for diagnostic purposes)</td>
</tr>
<tr>
<td></td>
<td>warnings.warn() in library code if the issue is avoidable and the client application should be</td>
</tr>
</tbody>
</table>
Issue a warning regarding a particular runtime event

modified to eliminate the warning

`logging.warning()` if there is nothing the client application can do about the situation, but the event should still be noted

Report an error regarding a particular runtime event

Raise an exception

Report suppression of an error without raising an exception (e.g. error handler in a long-running server process)

`logging.error()`, `logging.exception()` or `logging.critical()` as appropriate for the specific error and application domain

The logging functions are named after the level or severity of the events they are used to track. The standard levels and their applicability are described below (in increasing order of severity):

<table>
<thead>
<tr>
<th>Level</th>
<th>When it's used</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEBUG</td>
<td>Detailed information, typically of interest only when diagnosing problems.</td>
</tr>
<tr>
<td>INFO</td>
<td>Confirmation that things are working as expected.</td>
</tr>
<tr>
<td>WARNING</td>
<td>An indication that something unexpected happened, or indicative of some problem in the near future (e.g. ‘disk space low’). The software is still working as expected.</td>
</tr>
<tr>
<td>ERROR</td>
<td>Due to a more serious problem, the software has not been able to perform some function.</td>
</tr>
<tr>
<td>CRITICAL</td>
<td>A serious error, indicating that the program itself may be unable to continue running.</td>
</tr>
</tbody>
</table>
The default level is WARNING, which means that only events of this level and above will be tracked, unless the logging package is configured to do otherwise.

Events that are tracked can be handled in different ways. The simplest way of handling tracked events is to print them to the console. Another common way is to write them to a disk file.

A simple example

A very simple example is:

```python
import logging
logging.warning('Watch out!') # will print a message
logging.info('I told you so') # will not print anything
```

If you type these lines into a script and run it, you’ll see:

```
WARNING:root:Watch out!
```

printed out on the console. The INFO message doesn’t appear because the default level is WARNING. The printed message includes the indication of the level and the description of the event provided in the logging call, i.e. ‘Watch out!’. Don’t worry about the ‘root’ part for now: it will be explained later. The actual output can be formatted quite flexibly if you need that; formatting options will also be explained later.

Logging to a file

A very common situation is that of recording logging events in a file, so let’s look at that next. Be sure to try the following in a newly-started Python interpreter, and don’t just continue from the session described
above:

```python
import logging
logging.basicConfig(filename='example.log', level=logging.DEBUG)
logging.debug('This message should go to the log file')
logging.info('So should this')
logging.warning('And this, too')
```

And now if we open the file and look at what we have, we should find the log messages:

```
DEBUG:root:This message should go to the log file
INFO:root:So should this
WARNING:root:And this, too
```

This example also shows how you can set the logging level which acts as the threshold for tracking. In this case, because we set the threshold to DEBUG, all of the messages were printed.

If you want to set the logging level from a command-line option such as:

```
--log=INFO
```

and you have the value of the parameter passed for --log in some variable `loglevel`, you can use:

```
getattr(logging, loglevel.upper())
```

to get the value which you’ll pass to `basicConfig()` via the `level` argument. You may want to error check any user input value, perhaps as in the following example:
# assuming loglevel is bound to the string value obtained from
# command line argument. Convert to upper case to allow the user
to specify --log=DEBUG or --log=debug
numeric_level = getattr(logging, loglevel.upper(), None)
if not isinstance(numeric_level, int):
    raise ValueError('Invalid log level: %s' % loglevel)
logging.basicConfig(level=numeric_level, ...)

The call to `basicConfig()` should come before any calls to `debug()`, `info()` etc. As it's intended as a one-off simple configuration facility, only the first call will actually do anything; subsequent calls are effectively no-ops.

If you run the above script several times, the messages from successive runs are appended to the file `example.log`. If you want each run to start afresh, not remembering the messages from earlier runs, you can specify the `filemode` argument, by changing the call in the above example to:

```
logging.basicConfig(filename='example.log', filemode=
```

The output will be the same as before, but the log file is no longer appended to, so the messages from earlier runs are lost.

**Logging from multiple modules**

If your program consists of multiple modules, here's an example of how you could organize logging in it:

```
# myapp.py
import logging
import mylib
```
```python
def main():
    logging.basicConfig(filename='myapp.log', level=logging.info('Started'))
    mylib.do_something()
    logging.info('Finished')

if __name__ == '__main__':
    main()
```

```python
# mylib.py
import logging

def do_something():
    logging.info('Doing something')
```

If you run `myapp.py`, you should see this in `myapp.log`:

```
INFO:root:Started
INFO:root:Doing something
INFO:root:Finished
```

which is hopefully what you were expecting to see. You can generalize this to multiple modules, using the pattern in `mylib.py`. Note that for this simple usage pattern, you won’t know, by looking in the log file, where in your application your messages came from, apart from looking at the event description. If you want to track the location of your messages, you’ll need to refer to the documentation beyond the tutorial level – see [Advanced Logging Tutorial](#).

**Logging variable data**

To log variable data, use a format string for the event description.
message and append the variable data as arguments. For example:

```python
import logging
logging.warning('%s before you %s', 'Look', 'leap!')
```

will display:

```
WARNING:root:Look before you leap!
```

As you can see, merging of variable data into the event description message uses the old, %-style of string formatting. This is for backwards compatibility: the logging package pre-dates newer formatting options such as `str.format()` and `string.Template`. These newer formatting options are supported, but exploring them is outside the scope of this tutorial: see Using particular formatting styles throughout your application for more information.

**Changing the format of displayed messages**

To change the format which is used to display messages, you need to specify the format you want to use:

```python
import logging
logging.basicConfig(format='%(levelname)s:%(message)s')
logging.debug('This message should appear on the console')
logging.info('So should this')
logging.warning('And this, too')
```

which would print:

```
DEBUG:This message should appear on the console
INFO:So should this
```
WARNING: And this, too

Notice that the ‘root’ which appeared in earlier examples has disappeared. For a full set of things that can appear in format strings, you can refer to the documentation for LogRecord attributes, but for simple usage, you just need thelevelname (severity), message (event description, including variable data) and perhaps to display when the event occurred. This is described in the next section.

Displaying the date/time in messages

To display the date and time of an event, you would place ‘% (asctime)s’ in your format string:

```python
import logging
logging.basicConfig(format='%(asctime)s %(message)s')
logging.warning('is when this event was logged.')
```

which should print something like this:

```
2010-12-12 11:41:42,612 is when this event was logged.
```

The default format for date/time display (shown above) is ISO8601. If you need more control over the formatting of the date/time, provide a datefmt argument to basicConfig, as in this example:

```python
import logging
logging.basicConfig(format='%(asctime)s %(message)s', datefmt='%Y-%m-%d %H:%M:%S')
logging.warning('is when this event was logged.')
```

which would display something like this:
The format of the `datefmt` argument is the same as supported by `time.strftime()`.

Next Steps

That concludes the basic tutorial. It should be enough to get you up and running with logging. There’s a lot more that the logging package offers, but to get the best out of it, you’ll need to invest a little more of your time in reading the following sections. If you’re ready for that, grab some of your favourite beverage and carry on.

If your logging needs are simple, then use the above examples to incorporate logging into your own scripts, and if you run into problems or don’t understand something, please post a question on the comp.lang.python Usenet group (available at [http://groups.google.com/group/comp.lang.python](http://groups.google.com/group/comp.lang.python)) and you should receive help before too long.

Still here? You can carry on reading the next few sections, which provide a slightly more advanced/in-depth tutorial than the basic one above. After that, you can take a look at the Logging Cookbook.
Advanced Logging Tutorial

The logging library takes a modular approach and offers several categories of components: loggers, handlers, filters, and formatters.

- Loggers expose the interface that application code directly uses.
- Handlers send the log records (created by loggers) to the appropriate destination.
- Filters provide a finer grained facility for determining which log records to output.
- Formatters specify the layout of log records in the final output.

Log event information is passed between loggers, handlers, filters and formatters in a LogRecord instance.

Logging is performed by calling methods on instances of the Logger class (hereafter called loggers). Each instance has a name, and they are conceptually arranged in a namespace hierarchy using dots (periods) as separators. For example, a logger named ‘scan’ is the parent of loggers ‘scan.text’, ‘scan.html’ and ‘scan.pdf’. Logger names can be anything you want, and indicate the area of an application in which a logged message originates.

A good convention to use when naming loggers is to use a module-level logger, in each module which uses logging, named as follows:

```
logger = logging.getLogger(__name__)
```

This means that logger names track the package/module hierarchy, and it’s intuitively obvious where events are logged just from the logger name.

The root of the hierarchy of loggers is called the root logger. That’s the
logger used by the functions `debug()`, `info()`, `warning()`, `error()` and `critical()`, which just call the same-named method of the root logger. The functions and the methods have the same signatures. The root logger’s name is printed as ‘root’ in the logged output.

It is, of course, possible to log messages to different destinations. Support is included in the package for writing log messages to files, HTTP GET/POST locations, email via SMTP, generic sockets, queues, or OS-specific logging mechanisms such as syslog or the Windows NT event log. Destinations are served by `handler` classes. You can create your own log destination class if you have special requirements not met by any of the built-in handler classes.

By default, no destination is set for any logging messages. You can specify a destination (such as console or file) by using `basicConfig()` as in the tutorial examples. If you call the functions `debug()`, `info()`, `warning()`, `error()` and `critical()`, they will check to see if no destination is set; and if one is not set, they will set a destination of the console (`sys.stderr`) and a default format for the displayed message before delegating to the root logger to do the actual message output.

The default format set by `basicConfig()` for messages is:

```
severity:logger name:message
```

You can change this by passing a format string to `basicConfig()` with the `format` keyword argument. For all options regarding how a format string is constructed, see `Formatter Objects`.

Logging Flow
The flow of log event information in loggers and handlers is illustrated in the following diagram.

**Loggers**

*Logger* objects have a threefold job. First, they expose several methods to application code so that applications can log messages at runtime. Second, logger objects determine which log messages to act upon based upon severity (the default filtering facility) or filter objects. Third, logger objects pass along relevant log messages to all interested log handlers.

The most widely used methods on logger objects fall into two categories: configuration and message sending.
These are the most common configuration methods:

- `Logger.setLevel()` specifies the lowest-severity log message a logger will handle, where debug is the lowest built-in severity level and critical is the highest built-in severity. For example, if the severity level is INFO, the logger will handle only INFO, WARNING, ERROR, and CRITICAL messages and will ignore DEBUG messages.
- `Logger.addHandler()` and `Logger.removeHandler()` add and remove handler objects from the logger object. Handlers are covered in more detail in [Handlers](#).
- `Logger.addFilter()` and `Logger.removeFilter()` add and remove filter objects from the logger object. Filters are covered in more detail in [Filter Objects](#).

You don’t need to always call these methods on every logger you create. See the last two paragraphs in this section.

With the logger object configured, the following methods create log messages:

- `Logger.debug()`, `Logger.info()`, `Logger.warning()`, `Logger.error()`, and `Logger.critical()` all create log records with a message and a level that corresponds to their respective method names. The message is actually a format string, which may contain the standard string substitution syntax of `%s`, `%d`, `%f`, and so on. The rest of their arguments is a list of objects that correspond with the substitution fields in the message. With regard to **kwargs, the logging methods care only about a keyword of exc_info and use it to determine whether to log exception information.
- `Logger.exception()` creates a log message similar to `Logger.error()`. The difference is that `Logger.exception()` dumps a stack trace along with it. Call
this method only from an exception handler.

- **Logger.log()** takes a log level as an explicit argument. This is a little more verbose for logging messages than using the log level convenience methods listed above, but this is how to log at custom log levels.

**getLogger()** returns a reference to a logger instance with the specified name if it is provided, or root if not. The names are period-separated hierarchical structures. Multiple calls to **getLogger()** with the same name will return a reference to the same logger object. Loggers that are further down in the hierarchical list are children of loggers higher up in the list. For example, given a logger with a name of foo, loggers with names of foo.bar, foo.bar.baz, and foo.bam are all descendants of foo.

Loggers have a concept of *effective level*. If a level is not explicitly set on a logger, the level of its parent is used instead as its effective level. If the parent has no explicit level set, its parent is examined, and so on - all ancestors are searched until an explicitly set level is found. The root logger always has an explicit level set (*WARNING* by default).

When deciding whether to process an event, the effective level of the logger is used to determine whether the event is passed to the logger’s handlers.

Child loggers propagate messages up to the handlers associated with their ancestor loggers. Because of this, it is unnecessary to define and configure handlers for all the loggers an application uses. It is sufficient to configure handlers for a top-level logger and create child loggers as needed. (You can, however, turn off propagation by setting the *propagate* attribute of a logger to *False*.)

**Handlers**
Handler objects are responsible for dispatching the appropriate log messages (based on the log messages' severity) to the handler's specified destination. Logger objects can add zero or more handler objects to themselves with an addHandler() method. As an example scenario, an application may want to send all log messages to a log file, all log messages of error or higher to stdout, and all messages of critical to an email address. This scenario requires three individual handlers where each handler is responsible for sending messages of a specific severity to a specific location.

The standard library includes quite a few handler types (see Useful Handlers); the tutorials use mainly StreamHandler and FileHandler in its examples.

There are very few methods in a handler for application developers to concern themselves with. The only handler methods that seem relevant for application developers who are using the built-in handler objects (that is, not creating custom handlers) are the following configuration methods:

- The setLevel() method, just as in logger objects, specifies the lowest severity that will be dispatched to the appropriate destination. Why are there two setLevel() methods? The level set in the logger determines which severity of messages it will pass to its handlers. The level set in each handler determines which messages that handler will send on.
- setFormatter() selects a Formatter object for this handler to use.
- addFilter() and removeFilter() respectively configure and deconfigure filter objects on handlers.

Application code should not directly instantiate and use instances of Handler. Instead, the Handler class is a base class that defines the
interface that all handlers should have and establishes some default behavior that child classes can use (or override).

**Formatters**

Formatter objects configure the final order, structure, and contents of the log message. Unlike the base logging.Handler class, application code may instantiate formatter classes, although you could likely subclass the formatter if your application needs special behavior. The constructor takes three optional arguments – a message format string, a date format string and a style indicator.

```python
logging.Formatter.__init__(fmt=None, datefmt=None, style='%')
```

If there is no message format string, the default is to use the raw message. If there is no date format string, the default date format is:

```
%Y-%m-%d %H:%M:%S
```

with the milliseconds tacked on at the end. The style is one of %, '{' or '$'. If one of these is not specified, then '%' will be used.

If the style is '%', the message format string uses %(<dictionary key>)s styled string substitution; the possible keys are documented in LogRecord attributes. If the style is '{', the message format string is assumed to be compatible with str.format() (using keyword arguments), while if the style is '$' then the message format string should conform to what is expected by string.Template.substitute().

*Changed in version 3.2:* Added the style parameter.
The following message format string will log the time in a human-readable format, the severity of the message, and the contents of the message, in that order:

'%(asctime)s - %(levelname)s - %(message)s'

Formatters use a user-configurable function to convert the creation time of a record to a tuple. By default, `time.localtime()` is used; to change this for a particular formatter instance, set the converter attribute of the instance to a function with the same signature as `time.localtime()` or `time.gmtime()`. To change it for all formatters, for example if you want all logging times to be shown in GMT, set the converter attribute in the Formatter class (to `time.gmtime` for GMT display).

**Configuring Logging**

Programmers can configure logging in three ways:

1. Creating loggers, handlers, and formatters explicitly using Python code that calls the configuration methods listed above.
2. Creating a logging config file and reading it using the `fileConfig()` function.
3. Creating a dictionary of configuration information and passing it to the `dictConfig()` function.

For the reference documentation on the last two options, see [Configuration functions](#). The following example configures a very simple logger, a console handler, and a simple formatter using Python code:

```python
import logging
```
# create logger
logger = logging.getLogger('simple_example')
logger.setLevel(logging.DEBUG)

# create console handler and set level to debug
ch = logging.StreamHandler()
ch.setLevel(logging.DEBUG)

# create formatter
formatter = logging.Formatter('%(asctime)s - %(name)s - %(levelname)s - %(message)s')

# add formatter to ch
ch.setFormatter(formatter)

# add ch to logger
logger.addHandler(ch)

# 'application' code
logger.debug('debug message')
logger.info('info message')
logger.warn('warn message')
logger.error('error message')
logger.critical('critical message')

Running this module from the command line produces the following output:

$ python simple_logging_module.py
2005-03-19 15:10:26,618 - simple_example - DEBUG - debug message
2005-03-19 15:10:26,620 - simple_example - INFO - info message
2005-03-19 15:10:26,695 - simple_example - WARNING - warn message
2005-03-19 15:10:26,697 - simple_example - ERROR - error message
2005-03-19 15:10:26,773 - simple_example - CRITICAL - critical message

The following Python module creates a logger, handler, and formatter
nearly identical to those in the example listed above, with the only
difference being the names of the objects:

```python
import logging
import logging.config
logging.config.fileConfig('logging.conf')

# create logger
logger = logging.getLogger('simpleExample')

# 'application' code
logger.debug('debug message')
logger.info('info message')
logger.warn('warn message')
logger.error('error message')
logger.critical('critical message')
```

Here is the logging.conf file:

```ini
[loggers]
keys=root,simpleExample

[handlers]
keys=consoleHandler

[formatters]
keys=simpleFormatter

[logger_root]
level=DEBUG
handlers=consoleHandler

[logger_simpleExample]
level=DEBUG
handlers=consoleHandler
```
qualname=simpleExample
propagate=0

[handler_consoleHandler]
class=StreamHandler
level=DEBUG
formatter=simpleFormatter
args=(sys.stdout,)

[formatter_simpleFormatter]
format=%(asctime)s - %(name)s - %(levelname)s - %(message)s
datefmt=

The output is nearly identical to that of the non-config-file-based example:

$ python simple_logging_config.py
2005-03-19 15:38:55,977 - simpleExample - DEBUG - debug message
2005-03-19 15:38:55,979 - simpleExample - INFO - info message
2005-03-19 15:38:56,054 - simpleExample - WARNING - warn message
2005-03-19 15:38:56,055 - simpleExample - ERROR - error message
2005-03-19 15:38:56,130 - simpleExample - CRITICAL - critical message

You can see that the config file approach has a few advantages over the Python code approach, mainly separation of configuration and code and the ability of noncoders to easily modify the logging properties.

**Warning:** The *fileConfig()* function takes a default parameter, *disable_existing_loggers*, which defaults to True for reasons of backward compatibility. This may or may not be what you want, since it will cause any loggers existing before the *fileConfig()* call to be disabled unless they (or an ancestor) are explicitly named
The dictionary passed to dictConfig() can also specify a Boolean value with key disable_existing_loggers, which if not specified explicitly in the dictionary also defaults to being interpreted as True. This leads to the logger-disabling behaviour described above, which may not be what you want - in which case, provide the key explicitly with a value of False.

Note that the class names referenced in config files need to be either relative to the logging module, or absolute values which can be resolved using normal import mechanisms. Thus, you could use either WatchedFileHandler (relative to the logging module) or mypackage.mymodule.MyHandler (for a class defined in package mypackage and module mymodule, where mypackage is available on the Python import path).

In Python 3.2, a new means of configuring logging has been introduced, using dictionaries to hold configuration information. This provides a superset of the functionality of the config-file-based approach outlined above, and is the recommended configuration method for new applications and deployments. Because a Python dictionary is used to hold configuration information, and since you can populate that dictionary using different means, you have more options for configuration. For example, you can use a configuration file in JSON format, or, if you have access to YAML processing functionality, a file in YAML format, to populate the configuration dictionary. Or, of course, you can construct the dictionary in Python code, receive it in pickled form over a socket, or use whatever approach makes sense for your application.
Here's an example of the same configuration as above, in YAML format for the new dictionary-based approach:

```
version: 1
formatters:
  simple:
    format: '(%asctime)s - (%name)s - (%levelname)s

handlers:
  console:
    class: logging.StreamHandler
    level: DEBUG
    formatter: simple
    stream: ext://sys.stdout

loggers:
  simpleExample:
    level: DEBUG
    handlers: [console]
    propagate: no

root:
  level: DEBUG
  handlers: [console]
```

For more information about logging using a dictionary, see Configuration functions.

**What happens if no configuration is provided**

If no logging configuration is provided, it is possible to have a situation where a logging event needs to be output, but no handlers can be found to output the event. The behaviour of the logging package in these circumstances is dependent on the Python version.

For versions of Python prior to 3.2, the behaviour is as follows:
• If `logging.raiseExceptions` is `False` (production mode), the event is silently dropped.
• If `logging.raiseExceptions` is `True` (development mode), a message ‘No handlers could be found for logger X.Y.Z’ is printed once.

In Python 3.2 and later, the behaviour is as follows:

• The event is output using a ‘handler of last resort’, stored in `logging.lastResort`. This internal handler is not associated with any logger, and acts like a `StreamHandler` which writes the event description message to the current value of `sys.stderr` (therefore respecting any redirections which may be in effect). No formatting is done on the message - just the bare event description message is printed. The handler’s level is set to `WARNING`, so all events at this and greater severities will be output.

To obtain the pre-3.2 behaviour, `logging.lastResort` can be set to `None`.

Configuring Logging for a Library

When developing a library which uses logging, you should take care to document how the library uses logging - for example, the names of loggers used. Some consideration also needs to be given to its logging configuration. If the using application does not use logging, and library code makes logging calls, then (as described in the previous section) events of severity `WARNING` and greater will be printed to `sys.stderr`. This is regarded as the best default behaviour.

If for some reason you *don’t* want these messages printed in the absence of any logging configuration, you can attach a do-nothing
handler to the top-level logger for your library. This avoids the message being printed, since a handler will be always be found for the library’s events: it just doesn't produce any output. If the library user configures logging for application use, presumably that configuration will add some handlers, and if levels are suitably configured then logging calls made in library code will send output to those handlers, as normal.

A do-nothing handler is included in the logging package: NullHandler (since Python 3.1). An instance of this handler could be added to the top-level logger of the logging namespace used by the library (if you want to prevent your library’s logged events being output to sys.stderr in the absence of logging configuration). If all logging by a library foo is done using loggers with names matching ‘foo.x’, ‘foo.x.y’, etc. then the code:

```python
import logging
terminating
logging.getLogger('foo').addHandler(logging.NullHandler)
```

should have the desired effect. If an organisation produces a number of libraries, then the logger name specified can be ‘orgname.foo’ rather than just ‘foo’.

**Note:** It is strongly advised that you do not add any handlers other than NullHandler to your library’s loggers. This is because the configuration of handlers is the prerogative of the application developer who uses your library. The application developer knows their target audience and what handlers are most appropriate for their application: if you add handlers ‘under the hood’, you might well interfere with their ability to carry out unit tests and deliver logs which suit their requirements.
Logging Levels

The numeric values of logging levels are given in the following table. These are primarily of interest if you want to define your own levels, and need them to have specific values relative to the predefined levels. If you define a level with the same numeric value, it overwrites the predefined value; the predefined name is lost.

<table>
<thead>
<tr>
<th>Level</th>
<th>Numeric value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRITICAL</td>
<td>50</td>
</tr>
<tr>
<td>ERROR</td>
<td>40</td>
</tr>
<tr>
<td>WARNING</td>
<td>30</td>
</tr>
<tr>
<td>INFO</td>
<td>20</td>
</tr>
<tr>
<td>DEBUG</td>
<td>10</td>
</tr>
<tr>
<td>NOTSET</td>
<td>0</td>
</tr>
</tbody>
</table>

Levels can also be associated with loggers, being set either by the developer or through loading a saved logging configuration. When a logging method is called on a logger, the logger compares its own level with the level associated with the method call. If the logger’s level is higher than the method call’s, no logging message is actually generated. This is the basic mechanism controlling the verbosity of logging output.

Logging messages are encoded as instances of the `LogRecord` class. When a logger decides to actually log an event, a `LogRecord` instance is created from the logging message.

Logging messages are subjected to a dispatch mechanism through
the use of *handlers*, which are instances of subclasses of the Handler class. Handlers are responsible for ensuring that a logged message (in the form of a *LogRecord*) ends up in a particular location (or set of locations) which is useful for the target audience for that message (such as end users, support desk staff, system administrators, developers). Handlers are passed *LogRecord* instances intended for particular destinations. Each logger can have zero, one or more handlers associated with it (via the *addHandler()* method of *Logger*). In addition to any handlers directly associated with a logger, *all handlers associated with all ancestors of the logger* are called to dispatch the message (unless the *propagate* flag for a logger is set to a false value, at which point the passing to ancestor handlers stops).

Just as for loggers, handlers can have levels associated with them. A handler’s level acts as a filter in the same way as a logger’s level does. If a handler decides to actually dispatch an event, the *emit()* method is used to send the message to its destination. Most user-defined subclasses of *Handler* will need to override this *emit()*.

**Custom Levels**

Defining your own levels is possible, but should not be necessary, as the existing levels have been chosen on the basis of practical experience. However, if you are convinced that you need custom levels, great care should be exercised when doing this, and it is possibly a *very bad idea to define custom levels if you are developing a library*. That’s because if multiple library authors all define their own custom levels, there is a chance that the logging output from such multiple libraries used together will be difficult for the using developer to control and/or interpret, because a given numeric value might mean
different things for different libraries.
Useful Handlers

In addition to the base Handler class, many useful subclasses are provided:

1. **StreamHandler** instances send messages to streams (file-like objects).
2. **FileHandler** instances send messages to disk files.
3. **BaseRotatingHandler** is the base class for handlers that rotate log files at a certain point. It is not meant to be instantiated directly. Instead, use **RotatingFileHandler** or **TimedRotatingFileHandler**.
4. **RotatingFileHandler** instances send messages to disk files, with support for maximum log file sizes and log file rotation.
5. **TimedRotatingFileHandler** instances send messages to disk files, rotating the log file at certain timed intervals.
6. **SocketHandler** instances send messages to TCP/IP sockets. Since 3.4, Unix domain sockets are also supported.
7. **DatagramHandler** instances send messages to UDP sockets. Since 3.4, Unix domain sockets are also supported.
8. **SMTPHandler** instances send messages to a designated email address.
9. **SysLogHandler** instances send messages to a Unix syslog daemon, possibly on a remote machine.
10. **NTEventLogHandler** instances send messages to a Windows NT/2000/XP event log.
11. **MemoryHandler** instances send messages to a buffer in memory, which is flushed whenever specific criteria are met.
12. **HTTPHandler** instances send messages to an HTTP server using either GET or POST semantics.
13. **WatchedFileHandler** instances watch the file they are logging to. If the file changes, it is closed and reopened using the file...
name. This handler is only useful on Unix-like systems; Windows does not support the underlying mechanism used.

14. **QueueHandler** instances send messages to a queue, such as those implemented in the `queue` or `multiprocessing` modules.

15. **NullHandler** instances do nothing with error messages. They are used by library developers who want to use logging, but want to avoid the 'No handlers could be found for logger XXX' message which can be displayed if the library user has not configured logging. See Configuring Logging for a Library for more information.

*New in version 3.1:* The **NullHandler** class.

*New in version 3.2:* The **QueueHandler** class.

The **NullHandler**, **StreamHandler** and **FileHandler** classes are defined in the core logging package. The other handlers are defined in a sub-module, `logging.handlers`. (There is also another sub-module, `logging.config`, for configuration functionality.)

Logged messages are formatted for presentation through instances of the **Formatter** class. They are initialized with a format string suitable for use with the % operator and a dictionary.

For formatting multiple messages in a batch, instances of **BufferingFormatter** can be used. In addition to the format string (which is applied to each message in the batch), there is provision for header and trailer format strings.

When filtering based on logger level and/or handler level is not enough, instances of **Filter** can be added to both **Logger** and **Handler** instances (through their `addFilter()` method). Before deciding to process a message further, both loggers and handlers
consult all their filters for permission. If any filter returns a false value, the message is not processed further.

The basic Filter functionality allows filtering by specific logger name. If this feature is used, messages sent to the named logger and its children are allowed through the filter, and all others dropped.
Exceptions raised during logging

The logging package is designed to swallow exceptions which occur while logging in production. This is so that errors which occur while handling logging events - such as logging misconfiguration, network or other similar errors - do not cause the application using logging to terminate prematurely.

SystemExit and KeyboardInterrupt exceptions are never swallowed. Other exceptions which occur during the emit() method of a Handler subclass are passed to its handleError() method.

The default implementation of handleError() in Handler checks to see if a module-level variable, raiseExceptions, is set. If set, a traceback is printed to sys.stderr. If not set, the exception is swallowed.

Note: The default value of raiseExceptions is True. This is because during development, you typically want to be notified of any exceptions that occur. It’s advised that you set raiseExceptions to False for production usage.
Using arbitrary objects as messages

In the preceding sections and examples, it has been assumed that the message passed when logging the event is a string. However, this is not the only possibility. You can pass an arbitrary object as a message, and its `__str__()` method will be called when the logging system needs to convert it to a string representation. In fact, if you want to, you can avoid computing a string representation altogether - for example, the `SocketHandler` emits an event by pickling it and sending it over the wire.
Optimization

Formatting of message arguments is deferred until it cannot be avoided. However, computing the arguments passed to the logging method can also be expensive, and you may want to avoid doing it if the logger will just throw away your event. To decide what to do, you can call the `isEnabledFor()` method which takes a level argument and returns true if the event would be created by the Logger for that level of call. You can write code like this:

```python
if logger.isEnabledFor(logging.DEBUG):
    logger.debug('Message with %s, %s', expensive_func1, expensive_func2)
```

so that if the logger’s threshold is set above `DEBUG`, the calls to `expensive_func1()` and `expensive_func2()` are never made.

**Note:** In some cases, `isEnabledFor()` can itself be more expensive than you’d like (e.g. for deeply nested loggers where an explicit level is only set high up in the logger hierarchy). In such cases (or if you want to avoid calling a method in tight loops), you can cache the result of a call to `isEnabledFor()` in a local or instance variable, and use that instead of calling the method each time. Such a cached value would only need to be recomputed when the logging configuration changes dynamically while the application is running (which is not all that common).

There are other optimizations which can be made for specific applications which need more precise control over what logging information is collected. Here’s a list of things you can do to avoid
processing during logging which you don’t need:

<table>
<thead>
<tr>
<th>What you don’t want to collect</th>
<th>How to avoid collecting it</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information about where calls were made from.</td>
<td>Set <code>logging._srcfile</code> to <code>None</code>. This avoids calling <code>sys._getframe()</code>, which may help to speed up your code in environments like PyPy (which can’t speed up code that uses <code>sys._getframe()</code>), if and when PyPy supports Python 3.x.</td>
</tr>
<tr>
<td>Threading information.</td>
<td>Set <code>logging.logThreads</code> to 0.</td>
</tr>
<tr>
<td>Process information.</td>
<td>Set <code>logging.logProcesses</code> to 0.</td>
</tr>
</tbody>
</table>

Also note that the core logging module only includes the basic handlers. If you don’t import `logging.handlers` and `logging.config`, they won’t take up any memory.

See also:

- **Module** `logging`
  
  API reference for the logging module.

- **Module** `logging.config`
  
  Configuration API for the logging module.

- **Module** `logging.handlers`
  
  Useful handlers included with the logging module.

- A logging cookbook
Logging Cookbook

**Author:** Vinay Sajip <vinay_sajip at red-dove dot com>

This page contains a number of recipes related to logging, which have been found useful in the past.
Using logging in multiple modules

Multiple calls to `logging.getLogger('someLogger')` return a reference to the same logger object. This is true not only within the same module, but also across modules as long as it is in the same Python interpreter process. It is true for references to the same object; additionally, application code can define and configure a parent logger in one module and create (but not configure) a child logger in a separate module, and all logger calls to the child will pass up to the parent. Here is a main module:

```python
import logging
import auxiliary_module

# create logger with 'spam_application'
logger = logging.getLogger('spam_application')
logger.setLevel(logging.DEBUG)
# create file handler which logs even debug messages
fh = logging.FileHandler('spam.log')
fh.setLevel(logging.DEBUG)
# create console handler with a higher log level
ch = logging.StreamHandler()
ch.setLevel(logging.ERROR)
# create formatter and add it to the handlers
formatter = logging.Formatter('%(asctime)s - %(name)s - %(levelname)s - %(message)s')
fh.setFormatter(formatter)
ch.setFormatter(formatter)
# add the handlers to the logger
logger.addHandler(fh)
logger.addHandler(ch)

logger.info('creating an instance of auxiliary_module.Auxiliary')
a = auxiliary_module.Auxiliary()
logger.info('created an instance of auxiliary_module.Auxiliary')
```
logger.info('calling auxiliary_module.Auxiliary.do_something()')
logger.info('finished auxiliary_module.Auxiliary.do_something()')
logger.info('calling auxiliary_module.some_function()')
auxiliary_module.some_function()
logger.info('done with auxiliary_module.some_function()')

Here is the auxiliary module:

```python
import logging

# create logger
module_logger = logging.getLogger('spam_application.auxiliary')

class Auxiliary:
    def __init__(self):
        self.logger = logging.getLogger('spam_application.auxiliary.Auxiliary')
        self.logger.info('creating an instance of Auxiliary')
    def do_something(self):
        self.logger.info('doing something')
        a = 1 + 1
        self.logger.info('done doing something')

def some_function():
    module_logger.info('received a call to "some_function"')

The output looks like this:

```
2005-03-23 23:47:11,668 - spam_application - INFO -`
calling auxiliary_module.Auxiliary.do_something
2005-03-23 23:47:11,668 - spam_application.auxiliary
doing something
2005-03-23 23:47:11,669 - spam_application.auxiliary
done doing something
2005-03-23 23:47:11,670 - spam_application - INFO -
finished auxiliary_module.Auxiliary.do_something
2005-03-23 23:47:11,671 - spam_application - INFO -
calling auxiliary_module.some_function()
2005-03-23 23:47:11,672 - spam_application.auxiliary
received a call to 'some_function'
2005-03-23 23:47:11,673 - spam_application - INFO -
done with auxiliary_module.some_function()
Multiple handlers and formatters

Loggers are plain Python objects. The `addHandler()` method has no minimum or maximum quota for the number of handlers you may add. Sometimes it will be beneficial for an application to log all messages of all severities to a text file while simultaneously logging errors or above to the console. To set this up, simply configure the appropriate handlers. The logging calls in the application code will remain unchanged. Here is a slight modification to the previous simple module-based configuration example:

```python
import logging

logger = logging.getLogger('simple_example')
logger.setLevel(logging.DEBUG)
# create file handler which logs even debug messages
fh = logging.FileHandler('spam.log')
fh.setLevel(logging.DEBUG)
# create console handler with a higher log level
ch = logging.StreamHandler()
ch.setLevel(logging.ERROR)
# create formatter and add it to the handlers
formatter = logging.Formatter('%(asctime)s - %(name)s - %(levelname)s - %(message)s')
ch.setFormatter(formatter)
fh.setFormatter(formatter)
# add the handlers to logger
logger.addHandler(ch)
logger.addHandler(fh)

# 'application' code
logger.debug('debug message')
logger.info('info message')
logger.warn('warn message')
logger.error('error message')
```
Notice that the ‘application’ code does not care about multiple handlers. All that changed was the addition and configuration of a new handler named `fh`.

The ability to create new handlers with higher- or lower-severity filters can be very helpful when writing and testing an application. Instead of using many `print` statements for debugging, use `logger.debug`: Unlike the print statements, which you will have to delete or comment out later, the `logger.debug` statements can remain intact in the source code and remain dormant until you need them again. At that time, the only change that needs to happen is to modify the severity level of the logger and/or handler to debug.
Logging to multiple destinations

Let's say you want to log to console and file with different message formats and in differing circumstances. Say you want to log messages with levels of DEBUG and higher to file, and those messages at level INFO and higher to the console. Let's also assume that the file should contain timestamps, but the console messages should not. Here's how you can achieve this:

```python
import logging

# set up logging to file - see previous section for
logging.basicConfig(level=logging.DEBUG,
    format='%(asctime)s %(name)-12s %(levelname)-8s %(message)s
    datefmt='%m-%d %H:%M',
    filename='/temp/myapp.log',
    filemode='w')

# define a Handler which writes INFO messages or higher
cpu = logging.StreamHandler()
cpu.setLevel(logging.INFO)

# set a format which is simpler for console use
formatter = logging.Formatter('%(name)-12s: %(levelname)-8s %(message)s')

# tell the handler to use this format
cpu.setFormatter(formatter)

# add the handler to the root logger
logging.getLogger('').addHandler(cpu)

# Now, we can log to the root logger, or any other logger
logging.info('Jackdaws love my big sphinx of quartz.

# Now, define a couple of other loggers which might
# application:

logger1 = logging.getLogger('myapp.area1')
logger2 = logging.getLogger('myapp.area2')
```
When you run this, on the console you will see

```
root    : INFO   Jackdaws love my big sphinx of a bu
myapp.area1 : INFO   How quickly daft jumping zebras 
myapp.area2 : WARNING  Jail zesty vixen who grabbed
myapp.area2 : ERROR    The five boxing wizards jump 
```

and in the file you will see something like

```
10-22 22:19 root    : INFO   Jackdaws love my big sphinx of a bu
10-22 22:19 myapp.area1 : DEBUG Quick zephyrs blow
10-22 22:19 myapp.area1 : INFO   How quickly daft j
10-22 22:19 myapp.area2 : WARNING  Jail zesty vixen who grabbed
10-22 22:19 myapp.area2 : ERROR    The five boxing wizards jump
```

As you can see, the DEBUG message only shows up in the file. The other messages are sent to both destinations.

This example uses console and file handlers, but you can use any number and combination of handlers you choose.
Configuration server example

Here is an example of a module using the logging configuration server:

```python
import logging
import logging.config
import time
import os

# read initial config file
logging.config.fileConfig('logging.conf')

# create and start listener on port 9999
t = logging.config.listen(9999)
t.start()

logger = logging.getLogger('simpleExample')

try:
    # loop through logging calls to see the difference
    # new configurations make, until Ctrl+C is pressed
    while True:
        logger.debug('debug message')
        logger.info('info message')
        logger.warn('warn message')
        logger.error('error message')
        logger.critical('critical message')
        time.sleep(5)
except KeyboardInterrupt:
    # cleanup
    logging.config.stopListening()
t.join()
```

And here is a script that takes a filename and sends that file to the
server, properly preceded with the binary-encoded length, as the new logging configuration:

```python
#!/usr/bin/env python
import socket, sys, struct

with open(sys.argv[1], 'rb') as f:
    data_to_send = f.read()

HOST = 'localhost'
PORT = 9999
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
print('connecting...')
s.connect((HOST, PORT))
print('sending config...')
s.send(struct.pack('>L', len(data_to_send)))
s.send(data_to_send)
s.close()
print('complete')
```
Dealing with handlers that block

Sometimes you have to get your logging handlers to do their work without blocking the thread you're logging from. This is common in Web applications, though of course it also occurs in other scenarios.

A common culprit which demonstrates sluggish behaviour is the SMTPHandler: sending emails can take a long time, for a number of reasons outside the developer's control (for example, a poorly performing mail or network infrastructure). But almost any network-based handler can block: Even a SocketHandler operation may do a DNS query under the hood which is too slow (and this query can be deep in the socket library code, below the Python layer, and outside your control).

One solution is to use a two-part approach. For the first part, attach only a QueueHandler to those loggers which are accessed from performance-critical threads. They simply write to their queue, which can be sized to a large enough capacity or initialized with no upper bound to their size. The write to the queue will typically be accepted quickly, though you will probably need to catch the queue.Full exception as a precaution in your code. If you are a library developer who has performance-critical threads in their code, be sure to document this (together with a suggestion to attach only QueueHandlers to your loggers) for the benefit of other developers who will use your code.

The second part of the solution is QueueListener, which has been designed as the counterpart to QueueHandler. A QueueListener is very simple: it's passed a queue and some handlers, and it fires up an internal thread which listens to its queue for LogRecords sent from
QueueHandlers (or any other source of LogRecords, for that matter). The LogRecords are removed from the queue and passed to the handlers for processing.

The advantage of having a separate `QueueListener` class is that you can use the same instance to service multiple `QueueHandlers`. This is more resource-friendly than, say, having threaded versions of the existing handler classes, which would eat up one thread per handler for no particular benefit.

An example of using these two classes follows (imports omitted):

```python
que = queue.Queue(-1)  # no limit on size
queue_handler = QueueHandler(que)
handler = logging.StreamHandler()
listener = QueueListener(que, handler)
root = logging.getLogger()
root.addHandler(queue_handler)
formatter = logging.Formatter('%(threadName)s: %(message)s')
handler.setFormatter(formatter)
listener.start()
# The log output will display the thread which generated the event (the main thread) rather than the internal thread which monitors the internal queue. This is what you want to happen.
root.warning('Look out!')
listener.stop()
```

which, when run, will produce:

MainThread: Look out!

Changed in version 3.5: Prior to Python 3.5, the `QueueListener` always passed every message received from the queue to every
handler it was initialized with. (This was because it was assumed that level filtering was all done on the other side, where the queue is filled.) From 3.5 onwards, this behaviour can be changed by passing a keyword argument `respect_handler_level=True` to the listener's constructor. When this is done, the listener compares the level of each message with the handler's level, and only passes a message to a handler if it's appropriate to do so.
Sending and receiving logging events across a network

Let's say you want to send logging events across a network, and handle them at the receiving end. A simple way of doing this is attaching a `SocketHandler` instance to the root logger at the sending end:

```python
import logging, logging.handlers

rootLogger = logging.getLogger('')
rootLogger.setLevel(logging.DEBUG)
socketHandler = logging.handlers.SocketHandler('localhost',
                                             logging.handlers.DEFAULT_TCP_LOGGING_PORT)
# don't bother with a formatter, since a socket handler
# an unformatted pickle
rootLogger.addHandler(socketHandler)

# Now, we can log to the root logger, or any other logger:
logging.info('Jackdaws love my big sphinx of quartz.

# Now, define a couple of other loggers which might be application:
logger1 = logging.getLogger('myapp.area1')
logger2 = logging.getLogger('myapp.area2')

logger1.debug('Quick zephyrs blow, vexing daft Jim.
logger1.info('How quickly daft jumping zebras vex.')
logger2.warning('Jail zesty vixen who grabbed pay from quack.'
logger2.error('The five boxing wizards jump quickly.
```

At the receiving end, you can set up a receiver using the
socketserver module. Here is a basic working example:
import
import
import
import
import

pickle
logging
logging.handlers
socketserver
struct

class LogRecordStreamHandler(socketserver.StreamRequestHandle
"""Handler for a streaming logging request.

This basically logs the record using whatever logging pol
configured locally.
"""

def handle(self):
"""
Handle multiple requests - each expected to be a 4-by
followed by the LogRecord in pickle format. Logs the
according to whatever policy is configured locally.
"""
while True:
chunk = self.connection.recv(4)
if len(chunk) < 4:
break
slen = struct.unpack('>L', chunk)[0]
chunk = self.connection.recv(slen)
while len(chunk) < slen:
chunk = chunk + self.connection.recv
obj = self.unPickle(chunk)
record = logging.makeLogRecord(obj)
self.handleLogRecord(record)
def unPickle(self, data):
return pickle.loads(data)


def handleLogRecord(self, record):
    # if a name is specified, we use the named logger
    # implied by the record.
    if self.server.logname is not None:
        name = self.server.logname
    else:
        name = record.name
    logger = logging.getLogger(name)
    # N.B. EVERY record gets logged. This is because
    # is normally called AFTER logger-level filtering
    # to do filtering, do it at the client end to
    # cycles and network bandwidth!
    logger.handle(record)

class LogRecordSocketReceiver(socketserver.ThreadingTCPServer):
    """Simple TCP socket-based logging receiver suitable for testing."
    """
    allow_reuse_address = True

    def __init__(self, host='localhost',
                 port=logging.handlers.DEFAULT_TCP_LOGGING_PORT,
                 handler=LogRecordStreamHandler):
        socketserver.ThreadingTCPServer.__init__(self)
        self.abort = 0
        self.timeout = 1
        self.logname = None

    def serve_until_stopped(self):
        import select
        abort = 0
        while not abort:
            rd, wr, ex = select.select([self.socket.], [], [self.timeout])
            if rd:
```python
self.handle_request()
abort = self.abort

def main():
    logging.basicConfig(
        format='%(relativeCreated)5d %(name)-15s %(levelname)-8s %(message)s'
    tcpserver = LogRecordSocketReceiver()
    print('About to start TCP server...')
    tcpserver.serve_until_stopped()

if __name__ == '__main__':
    main()
```

First run the server, and then the client. On the client side, nothing is printed on the console; on the server side, you should see something like:

```
About to start TCP server...
  59 root      INFO   Jackdaws love my big
  59 myapp.area1 DEBUG  Quick zephyrs blow, v
  69 myapp.area1 INFO   How quickly daft jump
  69 myapp.area1 WARNING Jail zesty vixen who
  69 myapp.area2 ERROR  The five boxing wizard
```

Note that there are some security issues with pickle in some scenarios. If these affect you, you can use an alternative serialization scheme by overriding the makePickle() method and implementing your alternative there, as well as adapting the above script to use your alternative serialization.
Adding contextual information to your logging output

Sometimes you want logging output to contain contextual information in addition to the parameters passed to the logging call. For example, in a networked application, it may be desirable to log client-specific information in the log (e.g. remote client’s username, or IP address). Although you could use the `extra` parameter to achieve this, it’s not always convenient to pass the information in this way. While it might be tempting to create Logger instances on a per-connection basis, this is not a good idea because these instances are not garbage collected. While this is not a problem in practice, when the number of Logger instances is dependent on the level of granularity you want to use in logging an application, it could be hard to manage if the number of Logger instances becomes effectively unbounded.

Using LoggerAdapters to impart contextual information

An easy way in which you can pass contextual information to be output along with logging event information is to use the LoggerAdapter class. This class is designed to look like a Logger, so that you can call `debug()`, `info()`, `warning()`, `error()`, `exception()`, `critical()` and `log()`. These methods have the same signatures as their counterparts in Logger, so you can use the two types of instances interchangeably.

When you create an instance of LoggerAdapter, you pass it a Logger instance and a dict-like object which contains your contextual information. When you call one of the logging methods on an instance
of LoggerAdapter, it delegates the call to the underlying instance of Logger passed to its constructor, and arranges to pass the contextual information in the delegated call. Here's a snippet from the code of LoggerAdapter:

```python
def debug(self, msg, *args, **kwargs):
    ""
    Delegate a debug call to the underlying logger, contextual information from this adapter instance
    ""
    msg, kwargs = self.process(msg, kwargs)
    self.logger.debug(msg, *args, **kwargs)
```

The process() method of LoggerAdapter is where the contextual information is added to the logging output. It's passed the message and keyword arguments of the logging call, and it passes back (potentially) modified versions of these to use in the call to the underlying logger. The default implementation of this method leaves the message alone, but inserts an ‘extra’ key in the keyword argument whose value is the dict-like object passed to the constructor. Of course, if you had passed an ‘extra’ keyword argument in the call to the adapter, it will be silently overwritten.

The advantage of using ‘extra’ is that the values in the dict-like object are merged into the LogRecord instance’s __dict__, allowing you to use customized strings with your Formatter instances which know about the keys of the dict-like object. If you need a different method, e.g. if you want to prepend or append the contextual information to the message string, you just need to subclass LoggerAdapter and override process() to do what you need. Here is a simple example:

```python
class CustomAdapter(logging.LoggerAdapter):
```

This example adapter expects the passed in dict-like object to have a 'connid' key, whose value in brackets is prepended to the log message.

```python
def process(self, msg, kwargs):
    return '[%s] %s' % (self.extra['connid'], msg)
```

which you can use like this:

```python
logger = logging.getLogger(__name__)
adapter = CustomAdapter(logger, {'connid': some_conn_id})
```

Then any events that you log to the adapter will have the value of some_conn_id prepended to the log messages.

Using objects other than dicts to pass contextual information

You don’t need to pass an actual dict to a LoggerAdapter - you could pass an instance of a class which implements __getitem__ and __iter__ so that it looks like a dict to logging. This would be useful if you want to generate values dynamically (whereas the values in a dict would be constant).

Using Filters to impart contextual information

You can also add contextual information to log output using a user-defined Filter. Filter instances are allowed to modify the LogRecords passed to them, including adding additional attributes which can then be output using a suitable format string, or if needed a custom Formatter.

For example in a web application, the request being processed (or at
least, the interesting parts of it) can be stored in a threadlocal
(threading.local) variable, and then accessed from a Filter to
add, say, information from the request - say, the remote IP address
and remote user's username - to the LogRecord, using the attribute
names ‘ip' and ‘user' as in the LoggerAdapter example above. In
that case, the same format string can be used to get similar output to
that shown above. Here's an example script:

```python
import logging
from random import choice

class ContextFilter(logging.Filter):
    """
    This is a filter which injects contextual information
    Rather than use actual contextual information, we just use
    random data in this demo.
    """

    USERS = ['jim', 'fred', 'sheila']
    IPS = ['123.231.231.123', '127.0.0.1', '192.168.

    def filter(self, record):
        record.ip = choice(ContextFilter.IPS)
        record.user = choice(ContextFilter.USERS)
        return True

if __name__ == '__main__':
    levels = (logging.DEBUG, logging.INFO, logging.WARNING
    logging.basicConfig(level=logging.DEBUG,
                        format='%(asctime)-15s	%(name)-5s	%(levelname)-8s	IP:	%(ip)-15s	User:	%(user)-8s	%(message)s'
    a1 = logging.getLogger('a.b.c')
    a2 = logging.getLogger('d.e.f')

    f = ContextFilter()
```
a1.addFilter(f)
a2.addFilter(f)
a1.debug('A debug message')
a1.info('An info message with %s', 'some parameters')
for x in range(10):
    lvl = choice(levels)
    lvlname = logging.getLevelName(lvl)
a2.log(lvl, 'A message at %s level with %d %s')

which, when run, produces something like:

```
2010-09-06 22:38:15,292 a.b.c DEBUG    IP: 123.231.123.0
2010-09-06 22:38:15,300 a.b.c INFO     IP: 192.168.0.1
2010-09-06 22:38:15,300 d.e.f CRITICAL IP: 127.0.0.1
2010-09-06 22:38:15,300 d.e.f ERROR    IP: 127.0.0.1
2010-09-06 22:38:15,300 d.e.f CRITICAL IP: 127.0.0.1
2010-09-06 22:38:15,300 d.e.f CRITICAL IP: 127.0.0.1
2010-09-06 22:38:15,300 d.e.f DEBUG    IP: 127.0.0.1
2010-09-06 22:38:15,300 d.e.f ERROR    IP: 123.231.123.0
2010-09-06 22:38:15,300 d.e.f CRITICAL IP: 192.168.0.1
2010-09-06 22:38:15,300 d.e.f CRITICAL IP: 127.0.0.1
2010-09-06 22:38:15,300 d.e.f ERROR    IP: 127.0.0.1
2010-09-06 22:38:15,300 d.e.f DEBUG    IP: 123.231.231.0
2010-09-06 22:38:15,300 d.e.f ERROR    IP: 123.231.231.0
```
Logging to a single file from multiple processes

Although logging is thread-safe, and logging to a single file from multiple threads in a single process is supported, logging to a single file from multiple processes is not supported, because there is no standard way to serialize access to a single file across multiple processes in Python. If you need to log to a single file from multiple processes, one way of doing this is to have all the processes log to a SocketHandler, and have a separate process which implements a socket server which reads from the socket and logs to file. (If you prefer, you can dedicate one thread in one of the existing processes to perform this function.) This section documents this approach in more detail and includes a working socket receiver which can be used as a starting point for you to adapt in your own applications.

If you are using a recent version of Python which includes the multiprocessing module, you could write your own handler which uses the Lock class from this module to serialize access to the file from your processes. The existing FileHandler and subclasses do not make use of multiprocessing at present, though they may do so in the future. Note that at present, the multiprocessing module does not provide working lock functionality on all platforms (see https://bugs.python.org/issue3770).

Alternatively, you can use a Queue and a QueueHandler to send all logging events to one of the processes in your multi-process application. The following example script demonstrates how you can do this; in the example a separate listener process listens for events sent by other processes and logs them according to its own logging configuration. Although the example only demonstrates one way of
doing it (for example, you may want to use a listener thread rather than a separate listener process – the implementation would be analogous) it does allow for completely different logging configurations for the listener and the other processes in your application, and can be used as the basis for code meeting your own specific requirements:

```python
# You'll need these imports in your own code
import logging
import logging.handlers
import multiprocessing

# Next two import lines for this demo only
from random import choice, random
import time

# Because you'll want to define the logging configurations for the listener and worker process functions take a configurer parameter which they use for communication.
#
# In practice, you can configure the listener however you want, but in this simple example, the listener does not apply level or filter logic to received records. In practice, you would probably want to do this logic in the worker processes, to avoid sending events which would be filtered out between processes.
#
# The size of the rotated files is made small so you can see the results easily.

def listener_configurer():
    root = logging.getLogger()
    h = logging.handlers.RotatingFileHandler('mptest.log', 'a', 1000000, 5)
    f = logging.Formatter('%(asctime)s (%(processName)s) %(levelname)s: %(message)s')
    h.setFormatter(f)
    root.addHandler(h)

# This is the listener process top-level loop: wait for LogRecords on the queue and handle them, quit when
```
# LogRecord.

def listener_process(queue, configurer):
    configurer()
    while True:
        try:
            record = queue.get()
            if record is None:
                # We send this as a sentinel to tell the listener to quit.
                break
            logger = logging.getLogger(record.name)
            logger.handle(record)  # No level or filter logic applied - just do it!
        except Exception:
            import sys, traceback
            print('Whoops! Problem:', file=sys.stderr)
            traceback.print_exc(file=sys.stderr)

    # Arrays used for random selections in this demo

LEVELS = [logging.DEBUG, logging.INFO, logging.WARN, logging.ERROR, logging.CRITICAL]
LOGGERS = ['a.b.c', 'd.e.f']
MESSAGES = [
    'Random message #1',
    'Random message #2',
    'Random message #3',
]

    # The worker configuration is done at the start of this process.
    # Note that on Windows you can't rely on fork semantics,
    # will run the logging configuration code when it starts.

def worker_configurer(queue):
    h = logging.handlers.QueueHandler(queue)  # Just one handler needed
    root = logging.getLogger()  # send all messages
    root.addHandler(h)
    root.setLevel(logging.DEBUG)  # send all messages
# This is the worker process top-level loop, which just logs ten events with random intervening delays before terminating. # The print messages are just so you know it's doing something!

def worker_process(queue, configurer):
    configurer(queue)
    name = multiprocessing.current_process().name
    print('Worker started: %s' % name)
    for i in range(10):
        time.sleep(random())
        logger = logging.getLogger(choice(LOGGERS))
        level = choice(LEVELS)
        message = choice(MESSAGES)
        logger.log(level, message)
        print('Worker finished: %s' % name)

# Here's where the demo gets orchestrated. Create the queue, create and start the listener, create ten workers and start them, and then send a None to the queue to tell the listener to finish.

def main():
    queue = multiprocessing.Queue(-1)
    listener = multiprocessing.Process(target=listener_process, args=(queue,
        None
    )
    listener.start()
    workers = []
    for i in range(10):
        worker = multiprocessing.Process(target=worker_process, args=(queue,
            None
        )
        workers.append(worker)
        worker.start()
    for w in workers:
        w.join()
    queue.put_nowait(None)
    listener.join()

if __name__ == '__main__':
    main()
A variant of the above script keeps the logging in the main process, in a separate thread:

```python
import logging
import logging.config
import logging.handlers
from multiprocessing import Process, Queue
import random
import threading
import time

def logger_thread(q):
    while True:
        record = q.get()
        if record is None:
            break
        logger = logging.getLogger(record.name)
        logger.handle(record)

def worker_process(q):
    qh = logging.handlers.QueueHandler(q)
    root = logging.getLogger()
    root.setLevel(logging.DEBUG)
    root.addHandler(qh)
    levels = [logging.DEBUG, logging.INFO, logging.WARNING, logging.CRITICAL]
    loggers = ['foo', 'foo.bar', 'foo.bar.baz', 'spam', 'spam.ham', 'spam.ham.eggs']
    for i in range(100):
        lvl = random.choice(levels)
        logger = logging.getLogger(random.choice(loggers))
        logger.log(lvl, 'Message no. %d', i)

if __name__ == '__main__':
    q = Queue()
    d = {
```
'version': 1,
'formatters': {
    'detailed': {
        'class': 'logging.Formatter',
        'format': '%(asctime)s	%(name)-15s	%(levelname)-8s	%(processName)-10s	%(message)s'
    }
},
'handlers': {
    'console': {
        'class': 'logging.StreamHandler',
        'level': 'INFO',
    },
    'file': {
        'class': 'logging.FileHandler',
        'filename': 'mplog.log',
        'mode': 'w',
        'formatter': 'detailed',
    },
    'foofile': {
        'class': 'logging.FileHandler',
        'filename': 'mplog-foo.log',
        'mode': 'w',
        'formatter': 'detailed',
    },
    'errors': {
        'class': 'logging.FileHandler',
        'filename': 'mplog-errors.log',
        'mode': 'w',
        'level': 'ERROR',
        'formatter': 'detailed',
    },
},
'loggers': {
    'foo': {
        'handlers': ['foofile']
    }
}
'root': {
    'level': 'DEBUG',
    'handlers': ['console', 'file', 'errors']
},
}

workers = []
for i in range(5):
    wp = Process(target=worker_process, name='wd%d' % i)
    workers.append(wp)
    wp.start()
logging.config.dictConfig(d)
lp = threading.Thread(target=logger_thread, args=)
lp.start()
# At this point, the main process could do some
# Once it's done that, it can wait for the workers
for wp in workers:
    wp.join()
# And now tell the logging thread to finish up,
q.put(None)
lp.join()

This variant shows how you can e.g. apply configuration for particular
loggers - e.g. the foo logger has a special handler which stores all
events in the foo subsystem in a file mplog-foo.log. This will be
used by the logging machinery in the main process (even though the
logging events are generated in the worker processes) to direct the
messages to the appropriate destinations.
Using file rotation

Sometimes you want to let a log file grow to a certain size, then open a new file and log to that. You may want to keep a certain number of these files, and when that many files have been created, rotate the files so that the number of files and the size of the files both remain bounded. For this usage pattern, the logging package provides a RotatingFileHandler:

```python
import glob
import logging
import logging.handlers

LOG_FILENAME = 'logging_rotatingfile_example.out'

# Set up a specific logger with our desired output level
my_logger = logging.getLogger('MyLogger')
my_logger.setLevel(logging.DEBUG)

# Add the log message handler to the logger
handler = logging.handlers.RotatingFileHandler(
    LOG_FILENAME, maxBytes=20, backupCount=5)
my_logger.addHandler(handler)

# Log some messages
for i in range(20):
    my_logger.debug('i = %d' % i)

# See what files are created
logfiles = glob.glob('%s*' % LOG_FILENAME)

for filename in logfiles:
    print(filename)
```
The result should be 6 separate files, each with part of the log history for the application:

```
logging_rotatingfile_example.out
logging_rotatingfile_example.out.1
logging_rotatingfile_example.out.2
logging_rotatingfile_example.out.3
logging_rotatingfile_example.out.4
logging_rotatingfile_example.out.5
```

The most current file is always `logging_rotatingfile_example.out`, and each time it reaches the size limit it is renamed with the suffix `.1`. Each of the existing backup files is renamed to increment the suffix (`.1` becomes `.2`, etc.) and the `.6` file is erased.

Obviously this example sets the log length much too small as an extreme example. You would want to set `maxBytes` to an appropriate value.
Use of alternative formatting styles

When logging was added to the Python standard library, the only way of formatting messages with variable content was to use the %-formatting method. Since then, Python has gained two new formatting approaches: string.Template (added in Python 2.4) and str.format() (added in Python 2.6).

Logging (as of 3.2) provides improved support for these two additional formatting styles. The Formatter class been enhanced to take an additional, optional keyword parameter named style. This defaults to '%', but other possible values are '{' and '$', which correspond to the other two formatting styles. Backwards compatibility is maintained by default (as you would expect), but by explicitly specifying a style parameter, you get the ability to specify format strings which work with str.format() or string.Template. Here's an example console session to show the possibilities:

```python
>>> import logging
>>> root = logging.getLogger()
>>> root.setLevel(logging.DEBUG)
>>> handler = logging.StreamHandler()
>>> bf = logging.Formatter('{asctime} {name} {levelname:8s} {message}
... style = '{
>>> handler.setFormatter(bf)
>>> root.addHandler(handler)
>>> logger = logging.getLogger('foo.bar')
>>> logger.debug('This is a DEBUG message')
2010-10-28 15:11:55,341 foo.bar DEBUG  This is a DEBUG message
>>> logger.critical('This is a CRITICAL message')
2010-10-28 15:12:11,526 foo.bar CRITICAL This is a CRITICAL message
>>> df = logging.Formatter('${asctime} $name ${levelname} $message
... style = '$')
```
Note that the formatting of logging messages for final output to logs is completely independent of how an individual logging message is constructed. That can still use %-formatting, as shown here:

Logging calls (logger.debug(), logger.info() etc.) only take positional parameters for the actual logging message itself, with keyword parameters used only for determining options for how to handle the actual logging call (e.g. the exc_info keyword parameter to indicate that traceback information should be logged, or the extra keyword parameter to indicate additional contextual information to be added to the log). So you cannot directly make logging calls using `str.format()` or `string.Template` syntax, because internally the logging package uses %-formatting to merge the format string and the variable arguments. There would no changing this while preserving backward compatibility, since all logging calls which are out there in existing code will be using %-format strings.

There is, however, a way that you can use {}- and $- formatting to construct your individual log messages. Recall that for a message you can use an arbitrary object as a message format string, and that the logging package will call `str()` on that object to get the actual format
string. Consider the following two classes:

```python
class BraceMessage:
    def __init__(self, fmt, *args, **kwargs):
        self.fmt = fmt
        self.args = args
        self.kwargs = kwargs

    def __str__(self):
        return self.fmt.format(*self.args, **self.kwargs)

class DollarMessage:
    def __init__(self, fmt, **kwargs):
        self.fmt = fmt
        self.kwargs = kwargs

    def __str__(self):
        from string import Template
        return Template(self.fmt).substitute(**self.kwargs)
```

Either of these can be used in place of a format string, to allow {}- or $-formatting to be used to build the actual “message” part which appears in the formatted log output in place of “%(message)s” or “{message}” or “$message”. It’s a little unwieldy to use the class names whenever you want to log something, but it’s quite palatable if you use an alias such as __ (double underscore – not to be confused with _, the single underscore used as a synonym/alias for gettext.gettext() or its brethren).

The above classes are not included in Python, though they’re easy enough to copy and paste into your own code. They can be used as follows (assuming that they’re declared in a module called wherever):

```python
>>> from wherever import BraceMessage as __
```
```python
>>> print(__('Message with {0} {name}', 2, name='placeholders'))
Message with 2 placeholders
>>> class Point: pass
...
>>> p = Point()  
>>> p.x = 0.5  
>>> p.y = 0.5  
>>> print(__('Message with coordinates: ({point.x:.2f}, {point.y:.2f})', point=p))
Message with coordinates: (0.50, 0.50)
>>> from wherever import DollarMessage as __
>>> print(__('Message with $num $what', num=2, what='placeholders'))
Message with 2 placeholders
```

While the above examples use `print()` to show how the formatting works, you would of course use `logger.debug()` or similar to actually log using this approach.

One thing to note is that you pay no significant performance penalty with this approach: the actual formatting happens not when you make the logging call, but when (and if) the logged message is actually about to be output to a log by a handler. So the only slightly unusual thing which might trip you up is that the parentheses go around the format string and the arguments, not just the format string. That's because the __ notation is just syntax sugar for a constructor call to one of the XXXMessage classes.

If you prefer, you can use a `LoggerAdapter` to achieve a similar effect to the above, as in the following example:

```python
import logging

class Message(object):
```
```python
def __init__(self, fmt, args):
    self.fmt = fmt
    self.args = args

def __str__(self):
    return self.fmt.format(*self.args)

class StyleAdapter(logging.LoggerAdapter):
    def __init__(self, logger, extra=None):
        super(StyleAdapter, self).__init__(logger, extra)

    def log(self, level, msg, *args, **kwargs):
        if self.isEnabledFor(level):
            msg, kwargs = self.process(msg, kwargs)
            self.logger._log(level, Message(msg, args, kwargs))

logger = StyleAdapter(logging.getLogger(__name__))

def main():
    logger.debug('Hello, {}', 'world!')

if __name__ == '__main__':
    logging.basicConfig(level=logging.DEBUG)
    main()
```

The above script should log the message Hello, world! when run with Python 3.2 or later.
Customizing LogRecord

Every logging event is represented by a LogRecord instance. When an event is logged and not filtered out by a logger's level, a LogRecord is created, populated with information about the event and then passed to the handlers for that logger (and its ancestors, up to and including the logger where further propagation up the hierarchy is disabled). Before Python 3.2, there were only two places where this creation was done:

- `Logger.makeRecord()`, which is called in the normal process of logging an event. This invoked LogRecord directly to create an instance.
- `makeLogRecord()`, which is called with a dictionary containing attributes to be added to the LogRecord. This is typically invoked when a suitable dictionary has been received over the network (e.g. in pickle form via a SocketHandler, or in JSON form via an HTTPHandler).

This has usually meant that if you need to do anything special with a LogRecord, you've had to do one of the following.

- Create your own Logger subclass, which overrides `Logger.makeRecord()`, and set it using `setLoggerClass()` before any loggers that you care about are instantiated.
- Add a Filter to a logger or handler, which does the necessary special manipulation you need when its `filter()` method is called.

The first approach would be a little unwieldy in the scenario where (say) several different libraries wanted to do different things. Each would attempt to set its own Logger subclass, and the one which did
this last would win.

The second approach works reasonably well for many cases, but does not allow you to e.g. use a specialized subclass of `LogRecord`. Library developers can set a suitable filter on their loggers, but they would have to remember to do this every time they introduced a new logger (which they would do simply by adding new packages or modules and doing

```python
logger = logging.getLogger(__name__)
```

at module level). It’s probably one too many things to think about. Developers could also add the filter to a `NullHandler` attached to their top-level logger, but this would not be invoked if an application developer attached a handler to a lower-level library logger – so output from that handler would not reflect the intentions of the library developer.

In Python 3.2 and later, `LogRecord` creation is done through a factory, which you can specify. The factory is just a callable you can set with `setLogRecordFactory()`, and interrogate with `getLogRecordFactory()`. The factory is invoked with the same signature as the `LogRecord` constructor, as `LogRecord` is the default setting for the factory.

This approach allows a custom factory to control all aspects of `LogRecord` creation. For example, you could return a subclass, or just add some additional attributes to the record once created, using a pattern similar to this:

```python
old_factory = logging.getLogRecordFactory()

def record_factory(*args, **kwargs):
```
```python
record = old_factory(*args, **kwargs)
record.custom_attribute = 0xdeadbeef
return record
```

logging.setLogRecordFactory(record_factory)

This pattern allows different libraries to chain factories together, and as long as they don't overwrite each other's attributes or unintentionally overwrite the attributes provided as standard, there should be no surprises. However, it should be borne in mind that each link in the chain adds run-time overhead to all logging operations, and the technique should only be used when the use of a Filter does not provide the desired result.
Subclassing QueueHandler - a ZeroMQ example

You can use a QueueHandler subclass to send messages to other kinds of queues, for example a ZeroMQ ‘publish’ socket. In the example below, the socket is created separately and passed to the handler (as its ‘queue’):

```python
import zmq # using pyzmq, the Python binding for ZeroMQ
import json # for serializing records portably

ctx = zmq.Context()
sock = zmq.Socket(ctx, zmq.PUB) # or zmq.PUSH, or other
sock.bind('tcp://*:5556') # or wherever

class ZeroMQSocketHandler(QueueHandler):
    def enqueue(self, record):
        data = json.dumps(record.__dict__)
        self.queue.send(data)

handler = ZeroMQSocketHandler(sock)
```

Of course there are other ways of organizing this, for example passing in the data needed by the handler to create the socket:

```python
class ZeroMQSocketHandler(QueueHandler):
    def __init__(self, uri, socktype=zmq.PUB, ctx=None):
        super().__init__(ctx or zmq.Context())
        socket = zmq.Socket(self.ctx, socktype)
        socket.bind(uri)
        self.queue = QueueHandler.__init__(self, socket)

    def enqueue(self, record):
```
data = json.dumps(record.__dict__)
self.queue.send(data)

def close(self):
    self.queue.close()
Subclassing QueueListener - a ZeroMQ example

You can also subclass QueueListener to get messages from other kinds of queues, for example a ZeroMQ ‘subscribe’ socket. Here’s an example:

class ZeroMQSocketListener(QueueListener):
    def __init__(self, uri, *handlers, **kwargs):
        self.ctx = kwargs.get('ctx') or zmq.Context()
        socket = zmq.Socket(self.ctx, zmq.SUB)
        socket.setsockopt(zmq.SUBSCRIBE, '')  # subscribe to everything
        socket.connect(uri)

    def dequeue(self):
        msg = self.queue.recv()
        return logging.makeLogRecord(json.loads(msg))

See also:

Module logging
   API reference for the logging module.

Module logging.config
   Configuration API for the logging module.

Module logging.handlers
   Useful handlers included with the logging module.

A basic logging tutorial

A more advanced logging tutorial
An example dictionary-based configuration

Below is an example of a logging configuration dictionary - it's taken from the documentation on the Django project. This dictionary is passed to `dictConfig()` to put the configuration into effect:

```python
LOGGING = {
    'version': 1,
    'disable_existing_loggers': True,
    'formatters': {
        'verbose': {
            'format': '%(levelname)s %(asctime)s %(module)s %(process)d %(thread)d %(message)s'
        },
        'simple': {
            'format': '%(levelname)s %(message)s'
        },
    },
    'filters': {
        'special': {
            'foo': 'bar',
        },
    },
    'handlers': {
        'null': {
            'level': 'DEBUG',
            'class': 'django.utils.log.NullHandler',
        },
        'console':{
            'level': 'DEBUG',
            'class': 'logging.StreamHandler',
            'formatter': 'simple'
        },
        'mail_admins': {  
            'level': 'ERROR',
```
For more information about this configuration, you can see the relevant section of the Django documentation.
Using a rotator and namer to customize log rotation processing

An example of how you can define a namer and rotator is given in the following snippet, which shows zlib-based compression of the log file:

```python
def namer(name):
    return name + " .gz"

def rotator(source, dest):
    with open(source, "rb") as sf:
        data = sf.read()
        compressed = zlib.compress(data, 9)
    with open(dest, "wb") as df:
        df.write(compressed)
    os.remove(source)

rh = logging.handlers.RotatingFileHandler(...)  
rh.rotator = rotator  
rh.namer = namer
```

These are not "true" .gz files, as they are bare compressed data, with no "container" such as you’d find in an actual gzip file. This snippet is just for illustration purposes.
A more elaborate multiprocessing example

The following working example shows how logging can be used with multiprocessing using configuration files. The configurations are fairly simple, but serve to illustrate how more complex ones could be implemented in a real multiprocessing scenario.

In the example, the main process spawns a listener process and some worker processes. Each of the main process, the listener and the workers have three separate configurations (the workers all share the same configuration). We can see logging in the main process, how the workers log to a QueueHandler and how the listener implements a QueueListener and a more complex logging configuration, and arranges to dispatch events received via the queue to the handlers specified in the configuration. Note that these configurations are purely illustrative, but you should be able to adapt this example to your own scenario.

Here’s the script - the docstrings and the comments hopefully explain how it works:

```python
import logging
import logging.config
import logging.handlers
from multiprocessing import.Process, Queue, Event,
import os
import random
import time

class MyHandler:
    """
    A simple handler for logging events. It runs in
    dispatches events to loggers based on the name in
```
which then get dispatched, by the logging system configured for those loggers.

```python
def handle(self, record):
    logger = logging.getLogger(record.name)
    # The process name is transformed just to show it's the listener doing the logging to files and console
    record.processName = '%s (for %s)' % (current_process, record.processName)
    logger.handle(record)
```

```python
def listener_process(q, stop_event, config):
    """
    This could be done in the main process, but is just done in a separate process for illustrative purposes.

    This initialises logging according to the specified configuration, starts the listener and waits for the main process to signal completion via the event. The listener is then stopped, and the process exits.
    """
    logging.config.dictConfig(config)
    listener = logging.handlers.QueueListener(q, MyHandler)
    listener.start()
    if os.name == 'posix':
        # On POSIX, the setup logger will have been
        # parent process, but should have been disabled
        # dictConfig call.  # On Windows, since fork isn't used, the setup
        # exist in the child, so it would be created
        # would appear - hence the "if posix" clause
        logger = logging.getLogger('setup')
        logger.critical('Should not appear, because stop_event.wait()')
        listener.stop()

    def worker_process(config):
        """
        A number of these are spawned for the purpose of
        """
```
practice, they could be a heterogeneous bunch of ones which are identical to each other.

This initialises logging according to the specified configuration and logs a hundred messages with random levels to randomly selected loggers.

A small sleep is added to allow other processes a chance to run. This is not strictly needed, but it mixes the output from the different processes a bit more than if it's left out.

```
logging.config.dictConfig(config)
levels = [logging.DEBUG, logging.INFO, logging.WARN, logging.CRITICAL]
loggers = ['foo', 'foo.bar', 'foo.bar.baz', 'spam', 'spam.ham', 'spam.ham.eggs']
if os.name == 'posix':
    # On POSIX, the setup logger will have been configured in the parent process, but should have been disabled following the dictConfig call.
    # On Windows, since fork isn't used, the setup logger won't exist in the child, so it would be created and would appear - hence the "if posix" clause.
    logger = logging.getLogger('setup')
    logger.critical('Should not appear, because

for i in range(100):
    lvl = random.choice(levels)
    logger = logging.getLogger(random.choice(loggers))
    logger.log(lvl, 'Message no. %d', i)
    time.sleep(0.01)
```

def main():
    q = Queue()
    # The main process gets a simple configuration
    config_initial = {
        'version': 1,
        'formatters': {
'detailed': {
    'class': 'logging.Formatter',
    'format': '%(asctime)s	%(name)-15s	%(levelname)-8s	%(processName)-10s	%(message)s'
},

'handlers': {
    'console': {
        'class': 'logging.StreamHandler',
        'level': 'INFO',
    },
},

'root': {
    'level': 'DEBUG',
    'handlers': ['console']
},

# The worker process configuration is just a QueueHandler attached to the
# root logger, which allows all messages to be sent to the queue.
# We disable existing loggers to disable the "setup" logger used in the
# parent process. This is needed on POSIX because the logger will
# be there in the child following a fork().
config_worker = {
    'version': 1,
    'disable_existing_loggers': True,
    'handlers': {
        'queue': {
            'class': 'logging.handlers.QueueHandler',
            'queue': q,
        },
    },
    'root': {
        'level': 'DEBUG',
        'handlers': ['queue']
    },
}

# The listener process configuration shows that the full flexibility of
# logging configuration is available to dispatch events to handlers however
# you want.
# We disable existing loggers to disable the "setup" logger used in the
# parent process. This is needed on POSIX because the logger will
# be there in the child following a fork().

config_listener = {
    'version': 1,
    'disable_existing_loggers': True,
    'formatters': {
        'detailed': {
            'class': 'logging.Formatter',
            'format': '%(asctime)s %(name)-15s %(levelname)-8s %(processName)-10s %(message)s'
        },
        'simple': {
            'class': 'logging.Formatter',
            'format': '%(name)-15s %(levelname)-8s %(processName)-10s %(message)s'
        }
    },
    'handlers': {
        'console': {
            'class': 'logging.StreamHandler',
            'level': 'INFO',
            'formatter': 'simple',
        },
        'file': {
            'class': 'logging.FileHandler',
            'filename': 'mplog.log',
            'mode': 'w',
            'formatter': 'detailed',
        },
        'foofile': {
            'class': 'logging.FileHandler',
            'filename': 'mplog-foo.log',
            'mode': 'w',
            'formatter': 'detailed',
        },
        'errors': {
            'class': 'logging.FileHandler',
        },
    }
}
'filename': 'mplog-errors.log',
'mode': 'w',
'level': 'ERROR',
'formatter': 'detailed',
},
},
'loggers': {
'foo': {
'handlers': ['foofile']
}
},
'root': {
'level': 'DEBUG',
'handlers': ['console', 'file', 'errors'
}
},
}

# Log some initial events, just to show that logging normally.
logging.config.dictConfig(config_initial)
logger = logging.getLogger('setup')
logger.info('About to create workers ...')
workers = []
for i in range(5):
    wp = Process(target=worker_process, name='worker%d' args=(config_worker,))
    workers.append(wp)
    wp.start()
    logger.info('Started worker: %s', wp.name)
logger.info('About to create listener ...')
stop_event = Event()
lp = Process(target=listener_process, name='listener'
    args=(q, stop_event, config_listener)
lp.start()
logger.info('Started listener')
# We now hang around for the workers to finish their work.
for wp in workers:
    wp.join()
# Workers all done, listening can now stop.
# Logging in the parent still works normally.
logger.info('Telling listener to stop ...')
stop_event.set()
lp.join()
logger.info('All done.')

if __name__ == '__main__':
    main()
Inserting a BOM into messages sent to a SysLogHandler

RFC 5424 requires that a Unicode message be sent to a syslog daemon as a set of bytes which have the following structure: an optional pure-ASCII component, followed by a UTF-8 Byte Order Mark (BOM), followed by Unicode encoded using UTF-8. (See the relevant section of the specification.)

In Python 3.1, code was added to SysLogHandler to insert a BOM into the message, but unfortunately, it was implemented incorrectly, with the BOM appearing at the beginning of the message and hence not allowing any pure-ASCII component to appear before it.

As this behaviour is broken, the incorrect BOM insertion code is being removed from Python 3.2.4 and later. However, it is not being replaced, and if you want to produce RFC 5424-compliant messages which include a BOM, an optional pure-ASCII sequence before it and arbitrary Unicode after it, encoded using UTF-8, then you need to do the following:

1. Attach a Formatter instance to your SysLogHandler instance, with a format string such as:

   "ASCII section\uFEFFUnicode section"

   The Unicode code point U+FEFF, when encoded using UTF-8, will be encoded as a UTF-8 BOM – the byte-string b'\xef\xbb\xbf'.

2. Replace the ASCII section with whatever placeholders you like, but make sure that the data that appears in there after substitution
is always ASCII (that way, it will remain unchanged after UTF-8 encoding).

3. Replace the Unicode section with whatever placeholders you like; if the data which appears there after substitution contains characters outside the ASCII range, that’s fine – it will be encoded using UTF-8.

The formatted message will be encoded using UTF-8 encoding by SysLogHandler. If you follow the above rules, you should be able to produce RFC 5424-compliant messages. If you don’t, logging may not complain, but your messages will not be RFC 5424-compliant, and your syslog daemon may complain.
Implementing structured logging

Although most logging messages are intended for reading by humans, and thus not readily machine-parseable, there might be circumstances where you want to output messages in a structured format which is capable of being parsed by a program (without needing complex regular expressions to parse the log message). This is straightforward to achieve using the logging package. There are a number of ways in which this could be achieved, but the following is a simple approach which uses JSON to serialise the event in a machine-parseable manner:

```python
import json
import logging

class StructuredMessage(object):
    def __init__(self, message, **kwargs):
        self.message = message
        self.kwargs = kwargs

    def __str__(self):
        return '%s >>> %s' % (self.message, json.dumps(self.kwargs))

_ = StructuredMessage  # optional, to improve readability

logging.basicConfig(level=logging.INFO, format='%(message)s')
logging.info(_('message 1', foo='bar', bar='baz', num=123, fnum=123.456))
```

If the above script is run, it prints:
Note that the order of items might be different according to the version of Python used.

If you need more specialised processing, you can use a custom JSON encoder, as in the following complete example:

```python
from __future__ import unicode_literals

import json
import logging

# This next bit is to ensure the script runs unchanged
try:
    unicode
except NameError:
    unicode = str

class Encoder(json.JSONEncoder):
    def default(self, o):
        if isinstance(o, set):
            return tuple(o)
        elif isinstance(o, unicode):
            return o.encode('unicode_escape').decode()
        return super(Encoder, self).default(o)

class StructuredMessage(object):
    def __init__(self, message, **kwargs):
        self.message = message
        self.kwargs = kwargs

        def __str__(self):
            s = Encoder().encode(self.kwargs)
            return '%s >>> %s' % (self.message, s)

_ = StructuredMessage  # optional, to improve readability
```
```python
def main():
    logging.basicConfig(level=logging.INFO, format='%(message)s')
    logging.info(_('message 1', set_value={1, 2, 3}),
    if __name__ == '__main__':
        main()
```

When the above script is run, it prints:

```bash
message 1 >>> {'snowman': '\u2603', 'set_value': [1,
```

Note that the order of items might be different according to the version of Python used.
Customizing handlers with `dictConfig()`

There are times when you want to customize logging handlers in particular ways, and if you use `dictConfig()` you may be able to do this without subclassing. As an example, consider that you may want to set the ownership of a log file. On POSIX, this is easily done using `shutil.chown()`, but the file handlers in the stdlib don’t offer built-in support. You can customize handler creation using a plain function such as:

```python
def owned_file_handler(filename, mode='a', encoding=None):
    if owner:
        if not os.path.exists(filename):
            open(filename, 'a').close()
            shutil.chown(filename, *owner)
    return logging.FileHandler(filename, mode, encoding)
```

You can then specify, in a logging configuration passed to `dictConfig()`, that a logging handler be created by calling this function:

```python
LOGGING = {
    'version': 1,
    'disable_existing_loggers': False,
    'formatters': {
        'default': {
            'format': '%(asctime)s %(levelname)s %(name)s %(message)s',
        },
    },
    'handlers': {
        'file':{
```
In this example I am setting the ownership using the pulse user and group, just for the purposes of illustration. Putting it together into a working script, chowntest.py:

```python
import logging, logging.config, os, shutil

def owned_file_handler(filename, mode='a', encoding='utf-8', owner=None):
    if owner:
        if not os.path.exists(filename):
            open(filename, 'a').close()
        shutil.chown(filename, *owner)
    return logging.FileHandler(filename, mode, encoding)

LOGGING = {
    'version': 1,
    'disable_existing_loggers': False,
    'root': {
        'handlers': ['file'],
        'level': 'DEBUG',
    },
}
```
'formatters': { 
    'default': { 
        'format': '%(asctime)s (%(levelname)s)s (%(name)s)s %(message)s',
    },
},
'handlers': { 
    'file': { 
        # The values below are popped from this 
        # used to create the handler, set the ha 
        # its formatter.
        '()': owned_file_handler,
        'level': 'DEBUG',
        'formatter': 'default',
        # The values below are passed to the han 
        # as keyword arguments.
        'owner': ['pulse', 'pulse'],
        'filename': 'chowntest.log',
        'mode': 'w',
        'encoding': 'utf-8',
    },
},
'root': { 
    'handlers': ['file'],
    'level': 'DEBUG',
},
}

logging.config.dictConfig(LOGGING)
logger = logging.getLogger('mylogger')
logger.debug('A debug message')

To run this, you will probably need to run as root:

$ sudo python3.3 chowntest.py
$ cat chowntest.log
2013-11-05 09:34:51,128 DEBUG mylogger A debug message
Note that this example uses Python 3.3 because that's where `shutil.chown()` makes an appearance. This approach should work with any Python version that supports `dictConfig()` - namely, Python 2.7, 3.2 or later. With pre-3.3 versions, you would need to implement the actual ownership change using e.g. `os.chown()`.

In practice, the handler-creating function may be in a utility module somewhere in your project. Instead of the line in the configuration:

```python
'(\): owned_file_handler,
```

you could use e.g.:

```python
'(\): 'ext://project.util.owned_file_handler',
```

where `project.util` can be replaced with the actual name of the package where the function resides. In the above working script, using `'ext://__main___.owned_file_handler'` should work. Here, the actual callable is resolved by `dictConfig()` from the `ext://` specification.

This example hopefully also points the way to how you could implement other types of file change - e.g. setting specific POSIX permission bits - in the same way, using `os.chmod()`.

Of course, the approach could also be extended to types of handler other than a `FileHandler` - for example, one of the rotating file handlers, or a different type of handler altogether.
Using particular formatting styles throughout your application

In Python 3.2, the `Formatter` gained a style keyword parameter which, while defaulting to `%` for backward compatibility, allowed the specification of `{` or `$` to support the formatting approaches supported by `str.format()` and `string.Template`. Note that this governs the formatting of logging messages for final output to logs, and is completely orthogonal to how an individual logging message is constructed.

Logging calls (`debug()`, `info()` etc.) only take positional parameters for the actual logging message itself, with keyword parameters used only for determining options for how to handle the logging call (e.g. the `exc_info` keyword parameter to indicate that traceback information should be logged, or the `extra` keyword parameter to indicate additional contextual information to be added to the log). So you cannot directly make logging calls using `str.format()` or `string.Template` syntax, because internally the logging package uses %-formatting to merge the format string and the variable arguments. There would no changing this while preserving backward compatibility, since all logging calls which are out there in existing code will be using %-format strings.

There have been suggestions to associate format styles with specific loggers, but that approach also runs into backward compatibility problems because any existing code could be using a given logger name and using %-formatting.

For logging to work interoperably between any third-party libraries and your code, decisions about formatting need to be made at the level of
the individual logging call. This opens up a couple of ways in which alternative formatting styles can be accommodated.

**Using LogRecord factories**

In Python 3.2, along with the `Formatter` changes mentioned above, the logging package gained the ability to allow users to set their own `LogRecord` subclasses, using the `setLogRecordFactory()` function. You can use this to set your own subclass of `LogRecord`, which does the Right Thing by overriding the `getMessage()` method. The base class implementation of this method is where the msg % args formatting happens, and where you can substitute your alternate formatting; however, you should be careful to support all formatting styles and allow %-formatting as the default, to ensure interoperability with other code. Care should also be taken to call `str(self.msg)`, just as the base implementation does.

Refer to the reference documentation on `setLogRecordFactory()` and `LogRecord` for more information.

**Using custom message objects**

There is another, perhaps simpler way that you can use {}- and $-formatting to construct your individual log messages. You may recall (from Using arbitrary objects as messages) that when logging you can use an arbitrary object as a message format string, and that the logging package will call `str()` on that object to get the actual format string. Consider the following two classes:

```python
class BraceMessage(object):
    def __init__(self, fmt, *args, **kwargs):
```
Either of these can be used in place of a format string, to allow {}- or $-formatting to be used to build the actual “message” part which appears in the formatted log output in place of “%(message)s” or “{message}” or “$message”. If you find it a little unwieldy to use the class names whenever you want to log something, you can make it more palatable if you use an alias such as M or _ for the message (or perhaps __, if you are using _ for localization).

Examples of this approach are given below. Firstly, formatting with str.format():

```python
>>> __ = BraceMessage
>>> print(__('Message with {0} {1}', 2, 'placeholders'))
Message with 2 placeholders
```
>>> print('Message with coordinates: ({point.x:.2f}, {point.y:.2f})
Message with coordinates: (0.50, 0.50)

Secondly, formatting with `string.Template`:

```python
>>> __ = DollarMessage
>>> print('Message with $num $what', num=2, what=
Message with 2 placeholders
```  

One thing to note is that you pay no significant performance penalty with this approach: the actual formatting happens not when you make the logging call, but when (and if) the logged message is actually about to be output to a log by a handler. So the only slightly unusual thing which might trip you up is that the parentheses go around the format string and the arguments, not just the format string. That's because the `__` notation is just syntax sugar for a constructor call to one of the XXXMessage classes shown above.
Configuring filters with `dictConfig()`

You can configure filters using `dictConfig()`, though it might not be obvious at first glance how to do it (hence this recipe). Since `Filter` is the only filter class included in the standard library, and it is unlikely to cater to many requirements (it's only there as a base class), you will typically need to define your own `Filter` subclass with an overridden `filter()` method. To do this, specify the `()` key in the configuration dictionary for the filter, specifying a callable which will be used to create the filter (a class is the most obvious, but you can provide any callable which returns a `Filter` instance). Here is a complete example:

```python
import logging
import logging.config
import sys

class MyFilter(logging.Filter):
    def __init__(self, param=None):
        self.param = param

    def filter(self, record):
        if self.param is None:
            allow = True
        else:
            allow = self.param not in record.msg
        if allow:
            record.msg = 'changed: ' + record.msg
        return allow

LOGGING = {
    'version': 1,
    'filters': {
```
This example shows how you can pass configuration data to the callable which constructs the instance, in the form of keyword parameters. When run, the above script will print:

```
changed: hello
```

which shows that the filter is working as configured.

A couple of extra points to note:

- If you can't refer to the callable directly in the configuration (e.g. if it lives in a different module, and you can't import it directly where the configuration dictionary is), you can use the form `ext://...` as described in [Access to external objects](#). For example, you
could have used the text 'ext://__main___.MyFilter' instead of MyFilter in the above example.

- As well as for filters, this technique can also be used to configure custom handlers and formatters. See User-defined objects for more information on how logging supports using user-defined objects in its configuration, and see the other cookbook recipe Customizing handlers with dictConfig() above.
Customized exception formatting

There might be times when you want to do customized exception formatting - for argument's sake, let's say you want exactly one line per logged event, even when exception information is present. You can do this with a custom formatter class, as shown in the following example:

```python
import logging

class OneLineExceptionFormatter(logging.Formatter):
    def formatException(self, exc_info):
        """
        Format an exception so that it prints on a single line.
        """
        result = super(OneLineExceptionFormatter, self).formatException(exc_info)
        return repr(result)  # or format into one line however you want to

    def format(self, self, record):
        s = super(OneLineExceptionFormatter, self).format(record)
        if record.exc_text:
            s = s.replace('\n', '') + '|
        return s

def configure_logging():
    fh = logging.FileHandler('output.txt', 'w')
    f = OneLineExceptionFormatter('%(asctime)s|%(levelname)s|%(message)s|%(d/%m/%Y %H:%M:%S')
    fh.setFormatter(f)
    root = logging.getLogger()
    root.setLevel(logging.DEBUG)
    root.addHandler(fh)

def main():
    configure_logging()
```
```python
logging.info('Sample message')
try:
    x = 1 / 0
except ZeroDivisionError as e:
    logging.exception('ZeroDivisionError: %s', e)
if __name__ == '__main__':
    main()
```

When run, this produces a file with exactly two lines:

```
28/01/2015 07:21:23|INFO|Sample message|
28/01/2015 07:21:23|ERROR|ZeroDivisionError: integer
```

While the above treatment is simplistic, it points the way to how exception information can be formatted to your liking. The `traceback` module may be helpful for more specialized needs.
Speaking logging messages

There might be situations when it is desirable to have logging messages rendered in an audible rather than a visible format. This is easy to do if you have text-to-speech (TTS) functionality available in your system, even if it doesn’t have a Python binding. Most TTS systems have a command line program you can run, and this can be invoked from a handler using `subprocess`. It’s assumed here that TTS command line programs won’t expect to interact with users or take a long time to complete, and that the frequency of logged messages will be not so high as to swamp the user with messages, and that it’s acceptable to have the messages spoken one at a time rather than concurrently. The example implementation below waits for one message to be spoken before the next is processed, and this might cause other handlers to be kept waiting. Here is a short example showing the approach, which assumes that the espeak TTS package is available:

```python
import logging
import subprocess
import sys

class TTSHandler(logging.Handler):
    def emit(self, record):
        msg = self.format(record)
        # Speak slowly in a female English voice
        cmd = ['espeak', '-s150', '-ven+f3', msg]
        p = subprocess.Popen(cmd, stdout=subprocess.STDOUT,
                             stderr=subprocess.STDOUT)
        # wait for the program to finish
        p.communicate()

    def configure_logging():
```
When run, this script should say “Hello” and then “Goodbye” in a female voice.

The above approach can, of course, be adapted to other TTS systems and even other systems altogether which can process messages via external programs run from a command line.
Buffering logging messages and outputting them conditionally

There might be situations where you want to log messages in a temporary area and only output them if a certain condition occurs. For example, you may want to start logging debug events in a function, and if the function completes without errors, you don’t want to clutter the log with the collected debug information, but if there is an error, you want all the debug information to be output as well as the error.

Here is an example which shows how you could do this using a decorator for your functions where you want logging to behave this way. It makes use of the `logging.handlers.MemoryHandler`, which allows buffering of logged events until some condition occurs, at which point the buffered events are flushed - passed to another handler (the target handler) for processing. By default, the MemoryHandler flushed when its buffer gets filled up or an event whose level is greater than or equal to a specified threshold is seen. You can use this recipe with a more specialised subclass of MemoryHandler if you want custom flushing behavior.

The example script has a simple function, `foo`, which just cycles through all the logging levels, writing to `sys.stderr` to say what level it’s about to log at, and then actually logging a message that that level. You can pass a parameter to `foo` which, if true, will log at ERROR and CRITICAL levels - otherwise, it only logs at DEBUG, INFO and WARNING levels.

The script just arranges to decorate `foo` with a decorator which will do the conditional logging that’s required. The decorator takes a logger as a parameter and attaches a memory handler for the duration of the call
to the decorated function. The decorator can be additionally parameterised using a target handler, a level at which flushing should occur, and a capacity for the buffer. These default to a StreamHandler which writes to sys.stderr, logging.ERROR and 100 respectively.

Here’s the script:

```python
import logging
from logging.handlers import MemoryHandler
import sys

logger = logging.getLogger(__name__)
logger.addHandler(logging.NullHandler())

def log_if_errors(logger, target_handler=None, flush_level=None, capacity=None):
    if target_handler is None:
        target_handler = logging.StreamHandler()
    if flush_level is None:
        flush_level = logging.ERROR
    if capacity is None:
        capacity = 100
    handler = MemoryHandler(capacity, flushLevel=flush_level)

def decorator(fn):
    def wrapper(*args, **kwargs):
        logger.addHandler(handler)
        try:
            return fn(*args, **kwargs)
        except Exception:
            logger.exception('call failed')
        raise
    finally:
        super(MemoryHandler, handler).flush()
        logger.removeHandler(handler)
    return wrapper
```
**return** decorator

```python
def write_line(s):
    sys.stderr.write('%s
' % s)

def foo(fail=False):
    write_line('about to log at DEBUG ...')
    logger.debug('Actually logged at DEBUG')
    write_line('about to log at INFO ...')
    logger.info('Actually logged at INFO')
    write_line('about to log at WARNING ...')
    logger.warning('Actually logged at WARNING')
    if fail:
        write_line('about to log at ERROR ...')
        logger.error('Actually logged at ERROR')
        write_line('about to log at CRITICAL ...')
        logger.critical('Actually logged at CRITICAL')
    return fail
```

decorated_foo = log_if_errors(logger)(foo)

```python
if __name__ == '__main__':
    logger.setLevel(logging.DEBUG)
    write_line('Calling undecorated foo with False')
    assert not foo(False)
    write_line('Calling undecorated foo with True')
    assert foo(True)
    write_line('Calling decorated foo with False')
    assert not decorated_foo(False)
    write_line('Calling decorated foo with True')
    assert decorated_foo(True)
```

When this script is run, the following output should be observed:

**Calling undecorated foo with False**
As you can see, actual logging output only occurs when an event is logged whose severity is ERROR or greater, but in that case, any previous events at lower severities are also logged.

You can of course use the conventional means of decoration:

```python
@log_if_errors(logger)
def foo(fail=False):
    ...
```
Formatting times using UTC (GMT) via configuration

Sometimes you want to format times using UTC, which can be done using a class such as `UTCFormatter`, shown below:

```python
import logging
import time

class UTCFormatter(logging.Formatter):
    converter = time.gmtime
```

and you can then use the UTCFormatter in your code instead of `Formatter`. If you want to do that via configuration, you can use the `dictConfig()` API with an approach illustrated by the following complete example:

```python
import logging
import logging.config
import time

class UTCFormatter(logging.Formatter):
    converter = time.gmtime

LOGGING = {
    'version': 1,
    'disable_existing_loggers': False,
    'formatters': {
        'utc': {
            '()': UTCFormatter,
            'format': '%(asctime)s %(message)s',
        },
        'local': {
            'format': '%(asctime)s %(message)s',
        },
    },
    'handlers': {
        'null': {
            'level': 'DEBUG',
            'class': 'logging.NullHandler',
        },
    },
    'loggers': {
        '__main__': {
            'level': 'DEBUG',
            'handlers': ['null'],
        },
    },
}

logging.config.dictConfig(LOGGING)
```
if __name__ == '__main__':
    logging.config.dictConfig(LOGGING)
    logging.warning('The local time is %s', time.asctime(time.gmtime()))

When this script is run, it should print something like:

```
2015-10-17 12:53:29,501 The local time is Sat Oct 17
2015-10-17 13:53:29,501 The local time is Sat Oct 17
```

showing how the time is formatted both as local time and UTC, one for each handler.
Regular Expression HOWTO

Author: A.M. Kuchling <amk@amk.ca>

Abstract

This document is an introductory tutorial to using regular expressions in Python with the re module. It provides a gentler introduction than the corresponding section in the Library Reference.
Introduction

Regular expressions (called REs, or regexes, or regex patterns) are essentially a tiny, highly specialized programming language embedded inside Python and made available through the `re` module. Using this little language, you specify the rules for the set of possible strings that you want to match; this set might contain English sentences, or e-mail addresses, or TeX commands, or anything you like. You can then ask questions such as “Does this string match the pattern?”, or “Is there a match for the pattern anywhere in this string?”. You can also use REs to modify a string or to split it apart in various ways.

Regular expression patterns are compiled into a series of bytecodes which are then executed by a matching engine written in C. For advanced use, it may be necessary to pay careful attention to how the engine will execute a given RE, and write the RE in a certain way in order to produce bytecode that runs faster. Optimization isn’t covered in this document, because it requires that you have a good understanding of the matching engine’s internals.

The regular expression language is relatively small and restricted, so not all possible string processing tasks can be done using regular expressions. There are also tasks that can be done with regular expressions, but the expressions turn out to be very complicated. In these cases, you may be better off writing Python code to do the processing; while Python code will be slower than an elaborate regular expression, it will also probably be more understandable.
Simple Patterns

We'll start by learning about the simplest possible regular expressions. Since regular expressions are used to operate on strings, we'll begin with the most common task: matching characters.

For a detailed explanation of the computer science underlying regular expressions (deterministic and non-deterministic finite automata), you can refer to almost any textbook on writing compilers.

Matching Characters

Most letters and characters will simply match themselves. For example, the regular expression test will match the string test exactly. (You can enable a case-insensitive mode that would let this RE match Test or TEST as well; more about this later.)

There are exceptions to this rule; some characters are special metacharacters, and don't match themselves. Instead, they signal that some out-of-the-ordinary thing should be matched, or they affect other portions of the RE by repeating them or changing their meaning. Much of this document is devoted to discussing various metacharacters and what they do.

Here's a complete list of the metacharacters; their meanings will be discussed in the rest of this HOWTO.

. ^ $ * + ? { } [ ] \ | ( )

The first metacharacters we'll look at are [ and ]. They're used for specifying a character class, which is a set of characters that you wish to match. Characters can be listed individually, or a range of
characters can be indicated by giving two characters and separating them by a ' - '. For example, [abc] will match any of the characters a, b, or c; this is the same as [a-c], which uses a range to express the same set of characters. If you wanted to match only lowercase letters, your RE would be [a-z].

Metacharacters are not active inside classes. For example, [akm$] will match any of the characters 'a', 'k', 'm', or '$'; '$' is usually a metacharacter, but inside a character class it's stripped of its special nature.

You can match the characters not listed within the class by complementing the set. This is indicated by including a ' ^ ' as the first character of the class; ' ^ ' outside a character class will simply match the ' ^ ' character. For example, [ ^ 5 ] will match any character except ' 5 '.

Perhaps the most important metacharacter is the backslash, \ . As in Python string literals, the backslash can be followed by various characters to signal various special sequences. It's also used to escape all the metacharacters so you can still match them in patterns; for example, if you need to match a [ or \ , you can precede them with a backslash to remove their special meaning: \[ or \ \ .

Some of the special sequences beginning with ' \ ' represent predefined sets of characters that are often useful, such as the set of digits, the set of letters, or the set of anything that isn't whitespace.

Let's take an example: \w matches any alphanumeric character. If the regex pattern is expressed in bytes, this is equivalent to the class [a-zA-Z0-9_]. If the regex pattern is a string, \w will match all the characters marked as letters in the Unicode database provided by the
unicode data module. You can use the more restricted definition of \w in a string pattern by supplying the re.ASCII flag when compiling the regular expression.

The following list of special sequences isn’t complete. For a complete list of sequences and expanded class definitions for Unicode string patterns, see the last part of Regular Expression Syntax in the Standard Library reference. In general, the Unicode versions match any character that’s in the appropriate category in the Unicode database.

\d

Matches any decimal digit; this is equivalent to the class [0-9].

\D

Matches any non-digit character; this is equivalent to the class [^0-9].

\s

Matches any whitespace character; this is equivalent to the class [\t\n\r\f\v].

\S

Matches any non-whitespace character; this is equivalent to the class [^ \t\n\r\f\v].

\w

Matches any alphanumeric character; this is equivalent to the class [a-zA-Z0-9_].

\W

Matches any non-alphanumeric character; this is equivalent to the class [^a-zA-Z0-9_].

These sequences can be included inside a character class. For example, [\s,.] is a character class that will match any whitespace
character, or ',', or '. '

The final metacharacter in this section is .. It matches anything except a newline character, and there’s an alternate mode (re.DOTALL) where it will match even a newline. '.' is often used where you want to match “any character”.

**Repeating Things**

Being able to match varying sets of characters is the first thing regular expressions can do that isn’t already possible with the methods available on strings. However, if that was the only additional capability of regexes, they wouldn’t be much of an advance. Another capability is that you can specify that portions of the RE must be repeated a certain number of times.

The first metacharacter for repeating things that we’ll look at is *. * doesn’t match the literal character *; instead, it specifies that the previous character can be matched zero or more times, instead of exactly once.

For example, ca*t will match ct (0 a characters), cat (1 a), caaat (3 a characters), and so forth. The RE engine has various internal limitations stemming from the size of C’s int type that will prevent it from matching over 2 billion a characters; patterns are usually not written to match that much data.

Repetitions such as * are greedy; when repeating a RE, the matching engine will try to repeat it as many times as possible. If later portions of the pattern don’t match, the matching engine will then back up and try again with few repetitions.
A step-by-step example will make this more obvious. Let’s consider the expression `a[bcd]*b`. This matches the letter 'a', zero or more letters from the class `[bcd]`, and finally ends with a 'b'. Now imagine matching this RE against the string `abcbd`.

<table>
<thead>
<tr>
<th>Step</th>
<th>Matched</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a</td>
<td>The a in the RE matches.</td>
</tr>
<tr>
<td>2</td>
<td>abcbd</td>
<td>The engine matches <code>[bcd]*</code>, going as far as it can, which is to the end of the string.</td>
</tr>
<tr>
<td>3</td>
<td>Failure</td>
<td>The engine tries to match b, but the current position is at the end of the string, so it fails.</td>
</tr>
<tr>
<td>4</td>
<td>abcb</td>
<td>Back up, so that <code>[bcd]*</code> matches one less character.</td>
</tr>
<tr>
<td>5</td>
<td>Failure</td>
<td>Try b again, but the current position is at the last character, which is a 'd'.</td>
</tr>
<tr>
<td>6</td>
<td>abc</td>
<td>Back up again, so that <code>[bcd]*</code> is only matching bc.</td>
</tr>
<tr>
<td>6</td>
<td>abcb</td>
<td>Try b again. This time the character at the current position is 'b', so it succeeds.</td>
</tr>
</tbody>
</table>

The end of the RE has now been reached, and it has matched `abcb`. This demonstrates how the matching engine goes as far as it can at first, and if no match is found it will then progressively back up and retry the rest of the RE again and again. It will back up until it has tried zero matches for `[bcd]*`, and if that subsequently fails, the engine will conclude that the string doesn’t match the RE at all.

Another repeating metacharacter is +, which matches one or more times. Pay careful attention to the difference between * and +; * matches zero or more times, so whatever’s being repeated may not be
present at all, while + requires at least one occurrence. To use a similar example, ca+t will match cat (1 a), caaat (3 a's), but won't match ct.

There are two more repeating qualifiers. The question mark character, ?, matches either once or zero times; you can think of it as marking something as being optional. For example, home-?brew matches either homebrew or home-brew.

The most complicated repeated qualifier is \{m, n\}, where m and n are decimal integers. This qualifier means there must be at least m repetitions, and at most n. For example, a/{1,3}b will match a/b, a///b, and a///b. It won’t match ab, which has no slashes, or a/////b, which has four.

You can omit either m or n; in that case, a reasonable value is assumed for the missing value. Omitting m is interpreted as a lower limit of 0, while omitting n results in an upper bound of infinity — actually, the upper bound is the 2-billion limit mentioned earlier, but that might as well be infinity.

Readers of a reductionist bent may notice that the three other qualifiers can all be expressed using this notation. \{0,\} is the same as *, \{1,\} is equivalent to +, and \{0,1\} is the same as ?. It's better to use *, +, or ? when you can, simply because they're shorter and easier to read.
Using Regular Expressions

Now that we’ve looked at some simple regular expressions, how do we actually use them in Python? The `re` module provides an interface to the regular expression engine, allowing you to compile REs into objects and then perform matches with them.

Compiling Regular Expressions

Regular expressions are compiled into pattern objects, which have methods for various operations such as searching for pattern matches or performing string substitutions.

```python
>>> import re
>>> p = re.compile('ab*')
>>> p
re.compile('ab*')
```

`re.compile()` also accepts an optional `flags` argument, used to enable various special features and syntax variations. We’ll go over the available settings later, but for now a single example will do:

```python
>>> p = re.compile('ab*', re.IGNORECASE)
```

The RE is passed to `re.compile()` as a string. REs are handled as strings because regular expressions aren’t part of the core Python language, and no special syntax was created for expressing them. (There are applications that don’t need REs at all, so there’s no need to bloat the language specification by including them.) Instead, the `re` module is simply a C extension module included with Python, just like the `socket` or `zlib` modules.
Putting REs in strings keeps the Python language simpler, but has one disadvantage which is the topic of the next section.

The Backslash Plague

As stated earlier, regular expressions use the backslash character (\') to indicate special forms or to allow special characters to be used without invoking their special meaning. This conflicts with Python’s usage of the same character for the same purpose in string literals.

Let’s say you want to write a RE that matches the string \section, which might be found in a LaTeX file. To figure out what to write in the program code, start with the desired string to be matched. Next, you must escape any backslashes and other metacharacters by preceding them with a backslash, resulting in the string \\section. The resulting string that must be passed to re.compile() must be \\section. However, to express this as a Python string literal, both backslashes must be escaped again.

<table>
<thead>
<tr>
<th>Characters</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>\section</td>
<td>Text string to be matched</td>
</tr>
<tr>
<td>\section</td>
<td>Escaped backslash for re.compile()</td>
</tr>
<tr>
<td>&quot;\\section&quot;</td>
<td>Escaped backslashes for a string literal</td>
</tr>
</tbody>
</table>

In short, to match a literal backslash, one has to write '\\\' as the RE string, because the regular expression must be \, and each backslash must be expressed as \ inside a regular Python string literal. In REs that feature backslashes repeatedly, this leads to lots of repeated backslashes and makes the resulting strings difficult to understand.
The solution is to use Python's raw string notation for regular expressions; backslashes are not handled in any special way in a string literal prefixed with 'r', so r"\n" is a two-character string containing '\\' and 'n', while "\n" is a one-character string containing a newline. Regular expressions will often be written in Python code using this raw string notation.

<table>
<thead>
<tr>
<th>Regular String</th>
<th>Raw string</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;ab*&quot;</td>
<td>r&quot;ab*&quot;</td>
</tr>
<tr>
<td>&quot;\\section&quot;</td>
<td>r&quot;\section&quot;</td>
</tr>
<tr>
<td>&quot;\w+\s+\1&quot;</td>
<td>r&quot;\w+\s+\1&quot;</td>
</tr>
</tbody>
</table>

Performing Matches

Once you have an object representing a compiled regular expression, what do you do with it? Pattern objects have several methods and attributes. Only the most significant ones will be covered here; consult the re docs for a complete listing.

<table>
<thead>
<tr>
<th>Method/Attribute</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>match()</td>
<td>Determine if the RE matches at the beginning of the string.</td>
</tr>
<tr>
<td>search()</td>
<td>Scan through a string, looking for any location where this RE matches.</td>
</tr>
<tr>
<td>findall()</td>
<td>Find all substrings where the RE matches, and returns them as a list.</td>
</tr>
<tr>
<td>finditer()</td>
<td>Find all substrings where the RE matches, and returns them as an iterator.</td>
</tr>
</tbody>
</table>

match() and search() return None if no match can be found. If
they're successful, a **match object** instance is returned, containing information about the match: where it starts and ends, the substring it matched, and more.

You can learn about this by interactively experimenting with the `re` module. If you have `tkinter` available, you may also want to look at `Tools/demo/redemo.py`, a demonstration program included with the Python distribution. It allows you to enter REs and strings, and displays whether the RE matches or fails. `redemo.py` can be quite useful when trying to debug a complicated RE. Phil Schwartz's *Kodos* is also an interactive tool for developing and testing RE patterns.

This HOWTO uses the standard Python interpreter for its examples. First, run the Python interpreter, import the `re` module, and compile a RE:

```python
>>> import re
>>> p = re.compile('[a-z]+')
>>> p
re.compile('[a-z]+')
```

Now, you can try matching various strings against the RE `[a-z]+`. An empty string shouldn’t match at all, since `+` means ‘one or more repetitions’. `match()` should return `None` in this case, which will cause the interpreter to print no output. You can explicitly print the result of `match()` to make this clear.

```python
>>> p.match('')
>>> print(p.match(''))
None
```

Now, let’s try it on a string that it should match, such as `tempo`. In this case, `match()` will return a **match object**, so you should store the
result in a variable for later use.

```python
>>> m = p.match('tempo')
>>> m
<_sre.SRE_Match object; span=(0, 5), match='tempo'>
```

Now you can query the `match object` for information about the matching string. `match object` instances also have several methods and attributes; the most important ones are:

<table>
<thead>
<tr>
<th>Method/Attribute</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>group()</td>
<td>Return the string matched by the RE</td>
</tr>
<tr>
<td>start()</td>
<td>Return the starting position of the match</td>
</tr>
<tr>
<td>end()</td>
<td>Return the ending position of the match</td>
</tr>
<tr>
<td>span()</td>
<td>Return a tuple containing the (start, end) positions of the match</td>
</tr>
</tbody>
</table>

Trying these methods will soon clarify their meaning:

```python
>>> m.group()
'tempo'
>>> m.start(), m.end()
(0, 5)
>>> m.span()
(0, 5)
```

`group()` returns the substring that was matched by the RE. `start()` and `end()` return the starting and ending index of the match. `span()` returns both start and end indexes in a single tuple. Since the `match()` method only checks if the RE matches at the start of a string, `start()` will always be zero. However, the `search()` method of patterns scans through the string, so the match may not start at
zero in that case.

```python
>>> print(p.match('::: message'))
None
>>> m = p.search('::: message'); print(m)
<_sre.SRE_Match object; span=(4, 11), match='message'>
>>> m.group()
'message'
>>> m.span()
(4, 11)
```

In actual programs, the most common style is to store the match object in a variable, and then check if it was None. This usually looks like:

```python
p = re.compile( ... )
m = p.match( 'string goes here' )
if m:
    print('Match found: ', m.group())
else:
    print('No match')
```

Two pattern methods return all of the matches for a pattern. `findall()` returns a list of matching strings:

```python
>>> p = re.compile('\d+')
>>> p.findall('12 drummers drumming, 11 pipers piping, 10 lords a-leaping')
['12', '11', '10']
```

`findall()` has to create the entire list before it can be returned as the result. The `finditer()` method returns a sequence of match object instances as an iterator:
Module-Level Functions

You don’t have to create a pattern object and call its methods; the `re` module also provides top-level functions called `match()`, `search()`, `findall()`, `sub()`, and so forth. These functions take the same arguments as the corresponding pattern method with the RE string added as the first argument, and still return either None or a `match` object instance.

```python
>>> print(re.match(r'From\s+', 'Fromage amk'))
None
>>> re.match(r'From\s+', 'From amk Thu May 14 19:12:10 1998')
<_sre.SRE_Match object; span=(0, 5), match='From '>
```

Under the hood, these functions simply create a pattern object for you and call the appropriate method on it. They also store the compiled object in a cache, so future calls using the same RE won’t need to parse the pattern again and again.

Should you use these module-level functions, or should you get the pattern and call its methods yourself? If you’re accessing a regex within a loop, pre-compiling it will save a few function calls. Outside of
loops, there’s not much difference thanks to the internal cache.

Compilation Flags

Compilation flags let you modify some aspects of how regular expressions work. Flags are available in the `re` module under two names, a long name such as `IGNORECASE` and a short, one-letter form such as `I`. (If you're familiar with Perl's pattern modifiers, the one-letter forms use the same letters; the short form of `re.VERBOSE` is `re.X`, for example.) Multiple flags can be specified by bitwise OR-ing them; `re.I | re.M` sets both the `I` and `M` flags, for example.

Here’s a table of the available flags, followed by a more detailed explanation of each one.

<table>
<thead>
<tr>
<th>Flag</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCII, A</td>
<td>Makes several escapes like <code>\w</code>, <code>\b</code>, <code>\s</code> and <code>\d</code> match only on ASCII characters with the respective property.</td>
</tr>
<tr>
<td>DOTALL, S</td>
<td>Make . match any character, including newlines</td>
</tr>
<tr>
<td>IGNORECASE, I</td>
<td>Do case-insensitive matches</td>
</tr>
<tr>
<td>LOCALE, L</td>
<td>Do a locale-aware match</td>
</tr>
<tr>
<td>MULTILINE, M</td>
<td>Multi-line matching, affecting <code>^</code> and <code>$</code></td>
</tr>
<tr>
<td>VERBOSE, X (for ‘extended’)</td>
<td>Enable verbose REs, which can be organized more cleanly and understandably.</td>
</tr>
</tbody>
</table>

I

`IGNORECASE`
Perform case-insensitive matching; character class and literal strings will match letters by ignoring case. For example, [A-Z] will match lowercase letters, too, and Spam will match Spam, spam, or spAM. This lowercasing doesn’t take the current locale into account; it will if you also set the LOCALE flag.

L

LOCALE

Make \w, \W, \b, and \B, dependent on the current locale instead of the Unicode database.

Locales are a feature of the C library intended to help in writing programs that take account of language differences. For example, if you’re processing French text, you’d want to be able to write \w+ to match words, but \w only matches the character class [A-Za-z]; it won’t match 'é' or 'ç'. If your system is configured properly and a French locale is selected, certain C functions will tell the program that 'é' should also be considered a letter. Setting the LOCALE flag when compiling a regular expression will cause the resulting compiled object to use these C functions for \w; this is slower, but also enables \w+ to match French words as you’d expect.

M

MULTILINE

(\^ and $ haven’t been explained yet; they’ll be introduced in section More Metacharacters.)

Usually \^ matches only at the beginning of the string, and $ matches only at the end of the string and immediately before the newline (if any) at the end of the string. When this flag is specified, \^ matches at the beginning of the string and at the beginning of
each line within the string, immediately following each newline. Similarly, the $ metacharacter matches either at the end of the string and at the end of each line (immediately preceding each newline).

S

DOTALL

Makes the '.' special character match any character at all, including a newline; without this flag, '.' will match anything except a newline.

A

ASCII

Make \w, \W, \b, \B, \s and \S perform ASCII-only matching instead of full Unicode matching. This is only meaningful for Unicode patterns, and is ignored for byte patterns.

X

VERBOSE

This flag allows you to write regular expressions that are more readable by granting you more flexibility in how you can format them. When this flag has been specified, whitespace within the RE string is ignored, except when the whitespace is in a character class or preceded by an unescaped backslash; this lets you organize and indent the RE more clearly. This flag also lets you put comments within a RE that will be ignored by the engine; comments are marked by a '#' that's neither in a character class or preceded by an unescaped backslash.

For example, here's a RE that uses re.VERBOSE; see how much easier it is to read?
charref = re.compile(r""
&[#]  # Start of a numeric entity
  (  
    0[0-7]+  # Octal form
    | [0-9]+  # Decimal form
    | x[0-9a-fA-F]+  # Hexadecimal form
  )
);  # Trailing semicolon
""", re.VERBOSE)

Without the verbose setting, the RE would look like this:

charref = re.compile("&#(0[0-7]+"
                   "|[0-9]+"
                   "|x[0-9a-fA-F]+);")

In the above example, Python's automatic concatenation of string literals has been used to break up the RE into smaller pieces, but it's still more difficult to understand than the version using re.VERBOSE.
More Pattern Power

So far we’ve only covered a part of the features of regular expressions. In this section, we’ll cover some new metacharacters, and how to use groups to retrieve portions of the text that was matched.

More Metacharacters

There are some metacharacters that we haven’t covered yet. Most of them will be covered in this section.

Some of the remaining metacharacters to be discussed are zero-width assertions. They don’t cause the engine to advance through the string; instead, they consume no characters at all, and simply succeed or fail. For example, \b is an assertion that the current position is located at a word boundary; the position isn’t changed by the \b at all. This means that zero-width assertions should never be repeated, because if they match once at a given location, they can obviously be matched an infinite number of times.

| Alternation, or the “or” operator. If A and B are regular expressions, A | B will match any string that matches either A or B. | has very low precedence in order to make it work reasonably when you’re alternating multi-character strings. Crow|Servo will match either Crow or Servo, not Cro, a 'w' or an 'S', and ervo.

To match a literal '|', use \|, or enclose it inside a character class, as in [|].
Matches at the beginning of lines. Unless the MULTILINE flag has been set, this will only match at the beginning of the string. In MULTILINE mode, this also matches immediately after each newline within the string.

For example, if you wish to match the word From only at the beginning of a line, the RE to use is ^From.

```python
>>> print(re.search('^From', 'From Here to Eternity')
<_sre.SRE_Match object; span=(0, 4), match='From'>
>>> print(re.search('^From', 'Reciting From Memory'))
None
```

Matches at the end of a line, which is defined as either the end of the string, or any location followed by a newline character.

```python
>>> print(re.search('}$', '{block}'))
<_sre.SRE_Match object; span=(6, 7), match='}'>
>>> print(re.search('}$', '{block} '))
None
>>> print(re.search('}$', '{block}\n'))
<_sre.SRE_Match object; span=(6, 7), match='}'>
```

To match a literal '\$', use \\ or enclose it inside a character class, as in [\$].

\A

Matches only at the start of the string. When not in MULTILINE mode, \A and ^ are effectively the same. In MULTILINE mode, they’re different: \A still matches only at the beginning of the string, but ^ may match at any location inside the string that follows a newline character.
\z
  Matches only at the end of the string.
\b
  Word boundary. This is a zero-width assertion that matches only at the beginning or end of a word. A word is defined as a sequence of alphanumeric characters, so the end of a word is indicated by whitespace or a non-alphanumeric character.

The following example matches class only when it's a complete word; it won't match when it's contained inside another word.

```
>>> p = re.compile(r'\bclass\b')
>>> print(p.search('no class at all'))
<_sre.SRE_Match object; span=(3, 8), match='class'>
>>> print(p.search('the declassified algorithm'))
None
>>> print(p.search('one subclass is'))
None
```

There are two subtleties you should remember when using this special sequence. First, this is the worst collision between Python’s string literals and regular expression sequences. In Python’s string literals, \b is the backspace character, ASCII value 8. If you’re not using raw strings, then Python will convert the \b to a backspace, and your RE won’t match as you expect it to. The following example looks the same as our previous RE, but omits the 'r' in front of the RE string.

```
>>> p = re.compile('\\bclass\\b')
>>> print(p.search('no class at all'))
None
>>> print(p.search('\\b + 'class' + '\\b'))
<_sre.SRE_Match object; span=(0, 7), match='\x08c
```
Second, inside a character class, where there’s no use for this assertion, \b represents the backspace character, for compatibility with Python’s string literals.

\B

Another zero-width assertion, this is the opposite of \b, only matching when the current position is not at a word boundary.

**Grouping**

Frequently you need to obtain more information than just whether the RE matched or not. Regular expressions are often used to dissect strings by writing a RE divided into several subgroups which match different components of interest. For example, an RFC-822 header line is divided into a header name and a value, separated by a ':', like this:

<table>
<thead>
<tr>
<th>From: <a href="mailto:author@example.com">author@example.com</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>User-Agent: Thunderbird 1.5.0.9 (X11/20061227)</td>
</tr>
<tr>
<td>MIME-Version: 1.0</td>
</tr>
<tr>
<td>To: <a href="mailto:editor@example.com">editor@example.com</a></td>
</tr>
</tbody>
</table>

This can be handled by writing a regular expression which matches an entire header line, and has one group which matches the header name, and another group which matches the header’s value.

Groups are marked by the '(', ')' metacharacters. '(' and ')' have much the same meaning as they do in mathematical expressions; they group together the expressions contained inside them, and you can repeat the contents of a group with a repeating qualifier, such as *, +, ?, or \{m,n\}. For example, (ab)* will match zero or more repetitions of ab.
>>> p = re.compile('(ab)*')
>>> print(p.match('ababababab').span())
(0, 10)

Groups indicated with '( , )' also capture the starting and ending index of the text that they match; this can be retrieved by passing an argument to group(), start(), end(), and span(). Groups are numbered starting with 0. Group 0 is always present; it’s the whole RE, so match object methods all have group 0 as their default argument. Later we’ll see how to express groups that don’t capture the span of text that they match.

>>> p = re.compile('(a)b')
>>> m = p.match('ab')
>>> m.group()  
'ab'
>>> m.group(0)  
'ab'

Subgroups are numbered from left to right, from 1 upward. Groups can be nested; to determine the number, just count the opening parenthesis characters, going from left to right.

>>> p = re.compile('(a(b)c)d')
>>> m = p.match('abcd')
>>> m.group(0)  
'abcd'
>>> m.group(1)  
'abc'
>>> m.group(2)  
'b'

group() can be passed multiple group numbers at a time, in which case it will return a tuple containing the corresponding values for those
The `groups()` method returns a tuple containing the strings for all the subgroups, from 1 up to however many there are.

```python
m.group(2,1,2)
('b', 'abc', 'b')
```

Backreferences in a pattern allow you to specify that the contents of an earlier capturing group must also be found at the current location in the string. For example, `\1` will succeed if the exact contents of group 1 can be found at the current position, and fails otherwise. Remember that Python’s string literals also use a backslash followed by numbers to allow including arbitrary characters in a string, so be sure to use a raw string when incorporating backreferences in a RE.

For example, the following RE detects doubled words in a string.

```python
p = re.compile(r'\b\w+\s+\1')
p.search('Paris in the the spring').group()
'the the'
```

Backreferences like this aren’t often useful for just searching through a string — there are few text formats which repeat data in this way — but you’ll soon find out that they’re very useful when performing string substitutions.

**Non-capturing and Named Groups**

Elaborate REs may use many groups, both to capture substrings of
interest, and to group and structure the RE itself. In complex REs, it becomes difficult to keep track of the group numbers. There are two features which help with this problem. Both of them use a common syntax for regular expression extensions, so we'll look at that first.

Perl 5 is well known for its powerful additions to standard regular expressions. For these new features the Perl developers couldn't choose new single-keystroke metacharacters or new special sequences beginning with \ without making Perl's regular expressions confusingly different from standard REs. If they chose & as a new metacharacter, for example, old expressions would be assuming that & was a regular character and wouldn't have escaped it by writing \& or [\&].

The solution chosen by the Perl developers was to use (? . . . ) as the extension syntax. ? immediately after a parenthesis was a syntax error because the ? would have nothing to repeat, so this didn't introduce any compatibility problems. The characters immediately after the ? indicate what extension is being used, so (? =foo) is one thing (a positive lookahead assertion) and (? : foo) is something else (a non-capturing group containing the subexpression foo).

Python supports several of Perl's extensions and adds an extension syntax to Perl's extension syntax. If the first character after the question mark is a P, you know that it's an extension that's specific to Python.

Now that we've looked at the general extension syntax, we can return to the features that simplify working with groups in complex REs.

Sometimes you'll want to use a group to denote a part of a regular expression, but aren't interested in retrieving the group's contents. You
can make this fact explicit by using a non-capturing group: (?:...), where you can replace the ... with any other regular expression.

```python
>>> m = re.match("\([abc]\)+", "abc")
>>> m.groups()
('c',)
>>> m = re.match("(?:[abc])+", "abc")
>>> m.groups()
()
```

Except for the fact that you can’t retrieve the contents of what the group matched, a non-capturing group behaves exactly the same as a capturing group; you can put anything inside it, repeat it with a repetition metacharacter such as *, and nest it within other groups (capturing or non-capturing). (?:...) is particularly useful when modifying an existing pattern, since you can add new groups without changing how all the other groups are numbered. It should be mentioned that there’s no performance difference in searching between capturing and non-capturing groups; neither form is any faster than the other.

A more significant feature is named groups: instead of referring to them by numbers, groups can be referenced by a name.

The syntax for a named group is one of the Python-specific extensions: (?P<name>...). name is, obviously, the name of the group. Named groups behave exactly like capturing groups, and additionally associate a name with a group. The match object methods that deal with capturing groups all accept either integers that refer to the group by number or strings that contain the desired group’s name. Named groups are still given numbers, so you can retrieve information about a group in two ways:
Named groups are handy because they let you use easily-remembered names, instead of having to remember numbers. Here's an example RE from the `imaplib` module:

```python
InternalDate = re.compile(r'\INTERNALDATE "\
  r'(?P<day>[ 123][0-9])-(?P<mon>[A-Z][a-z][a-z]-
  r'(?P<year>[0-9][0-9][0-9][0-9])
  r' (?P<hour>[0-9][0-9]):(?P<min>[0-9][0-9]):(?P<sec>[0-9][0-9])
  r' (?P<zonen>[-+])(?P<zoneh>[0-9][0-9])(?P<zonem>[0-9][0-9])"')
```

It's obviously much easier to retrieve `m.group('zonem')`, instead of having to remember to retrieve group 9.

The syntax for backreferences in an expression such as `( ... )\1` refers to the number of the group. There's naturally a variant that uses the group name instead of the number. This is another Python extension: `( ?P=name )` indicates that the contents of the group called `name` should again be matched at the current point. The regular expression for finding doubled words, `(?bw+)\s+\1` can also be written as `(?P<word>\bw+)\s+(?P=word)`:  

```python
>>> p = re.compile(r'( ?P<word>\bw+)\s+(?P=word)')
>>> p.search('Paris in the the spring').group()
'the the'
```
Lookahead Assertions

Another zero-width assertion is the lookahead assertion. Lookahead assertions are available in both positive and negative form, and look like this:

(?=...)  
Positive lookahead assertion. This succeeds if the contained regular expression, represented here by . . . , successfully matches at the current location, and fails otherwise. But, once the contained expression has been tried, the matching engine doesn’t advance at all; the rest of the pattern is tried right where the assertion started.

(?!...)  
Negative lookahead assertion. This is the opposite of the positive assertion; it succeeds if the contained expression doesn’t match at the current position in the string.

To make this concrete, let’s look at a case where a lookahead is useful. Consider a simple pattern to match a filename and split it apart into a base name and an extension, separated by a . . For example, in news.rc, news is the base name, and rc is the filename’s extension.

The pattern to match this is quite simple:

.*[.].*$

Notice that the . needs to be treated specially because it’s a metacharacter, so it’s inside a character class to only match that specific character. Also notice the trailing $; this is added to ensure that all the rest of the string must be included in the extension. This regular expression matches foo.bar and autoexec.bat and sendmail.cf and printers.conf.
Now, consider complicating the problem a bit; what if you want to match filenames where the extension is not bat? Some incorrect attempts:

`.*[^b].*$` The first attempt above tries to exclude bat by requiring that the first character of the extension is not a b. This is wrong, because the pattern also doesn’t match foo.bar.

`.*[^b].[^a].[^t]` The expression gets messier when you try to patch up the first solution by requiring one of the following cases to match: the first character of the extension isn’t b; the second character isn’t a; or the third character isn’t t. This accepts foo.bar and rejects autoexec.bat, but it requires a three-letter extension and won’t accept a filename with a two-letter extension such as sendmail.cf. We’ll complicate the pattern again in an effort to fix it.

`.*[^b].[^a].[^t]` In the third attempt, the second and third letters are all made optional in order to allow matching extensions shorter than three characters, such as sendmail.cf.

The pattern’s getting really complicated now, which makes it hard to read and understand. Worse, if the problem changes and you want to exclude both bat and exe as extensions, the pattern would get even more complicated and confusing.

A negative lookahead cuts through all this confusion:

`.*[^b].*bat$` The negative lookahead means: if the expression bat doesn’t match at this point, try the rest of the pattern; if
bat$ does match, the whole pattern will fail. The trailing $ is required to ensure that something like sample.bat, where the extension only starts with bat, will be allowed.

Excluding another filename extension is now easy; simply add it as an alternative inside the assertion. The following pattern excludes filenames that end in either bat or exe:

.*[.](?!bat$|exe$).*$
Modifying Strings

Up to this point, we’ve simply performed searches against a static string. Regular expressions are also commonly used to modify strings in various ways, using the following pattern methods:

<table>
<thead>
<tr>
<th>Method/Attribute</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>split()</td>
<td>Split the string into a list, splitting it wherever the RE matches</td>
</tr>
<tr>
<td>sub()</td>
<td>Find all substrings where the RE matches, and replace them with a different string</td>
</tr>
<tr>
<td>subn()</td>
<td>Does the same thing as sub(), but returns the new string and the number of replacements</td>
</tr>
</tbody>
</table>

Splitting Strings

The `split()` method of a pattern splits a string apart wherever the RE matches, returning a list of the pieces. It’s similar to the `split()` method of strings but provides much more generality in the delimiters that you can split by; string `split()` only supports splitting by whitespace or by a fixed string. As you’d expect, there’s a module-level `re.split()` function, too.

```
.split(string[, maxsplit=0])
```

Split `string` by the matches of the regular expression. If capturing parentheses are used in the RE, then their contents will also be returned as part of the resulting list. If `maxsplit` is nonzero, at most `maxsplit` splits are performed.

You can limit the number of splits made, by passing a value for `maxsplit`. When `maxsplit` is nonzero, at most `maxsplit` splits will be
made, and the remainder of the string is returned as the final element of the list. In the following example, the delimiter is any sequence of non-alphanumeric characters.

```python
>>> p = re.compile(r'\W+')
>>> p.split('This is a test, short and sweet, of split()')
['This', 'is', 'a', 'test', 'short', 'and', 'sweet', '', 'of split()']
```

Sometimes you're not only interested in what the text between delimiters is, but also need to know what the delimiter was. If capturing parentheses are used in the RE, then their values are also returned as part of the list. Compare the following calls:

```python
>>> p = re.compile(r'\W+')
>>> p2 = re.compile(r'([^\W]+)')
>>> p.split('This... is a test.')
['This', 'is', 'a', 'test', '']
>>> p2.split('This... is a test.')
['This', '...', 'is', '', 'a', '', 'test', '.', '']
```

The module-level function `re.split()` adds the RE to be used as the first argument, but is otherwise the same.

```python
>>> re.split('([^\W])+', 'Words, words, words.')
['Words', 'words', 'words', '']
>>> re.split('([^\W])+', 'Words, words, words.')
['Words', '', '', 'words', '', 'words', '.', '', '']
>>> re.split('([^\W]+)', 'Words, words, words.', 1)
['Words', 'words, words.']
```

Search and Replace
Another common task is to find all the matches for a pattern, and replace them with a different string. The `sub()` method takes a replacement value, which can be either a string or a function, and the string to be processed.

\[
\texttt{.sub}(\textit{replacement}, \textit{string}[, \textit{count}=0])
\]

Returns the string obtained by replacing the leftmost non-overlapping occurrences of the RE in \textit{string} by the replacement \textit{replacement}. If the pattern isn’t found, \textit{string} is returned unchanged.

The optional argument \textit{count} is the maximum number of pattern occurrences to be replaced; \textit{count} must be a non-negative integer. The default value of 0 means to replace all occurrences.

Here’s a simple example of using the `sub()` method. It replaces colour names with the word colour:

```python
>>> p = re.compile(' (blue|white|red) ')
>>> p.sub( 'colour', 'blue socks and red shoes')
'colour socks and colour shoes'
>>> p.sub( 'colour', 'blue socks and red shoes', count=2)
'colour socks and red shoes'
```

The `subn()` method does the same work, but returns a 2-tuple containing the new string value and the number of replacements that were performed:

```python
>>> p = re.compile(' (blue|white|red) ')
>>> p.subn( 'colour', 'blue socks and red shoes')
('colour socks and colour shoes', 2)
>>> p.subn( 'colour', 'no colours at all')
```
Empty matches are replaced only when they're not adjacent to a previous match.

```python
>>> p = re.compile('x*')
>>> p.sub('-', 'abxd')
'-a-b-d-
```

If *replacement* is a string, any backslash escapes in it are processed. That is, \n is converted to a single newline character, \r is converted to a carriage return, and so forth. Unknown escapes such as \& are left alone. Backreferences, such as \6, are replaced with the substring matched by the corresponding group in the RE. This lets you incorporate portions of the original text in the resulting replacement string.

This example matches the word section followed by a string enclosed in {}, and changes section to subsection:

```python
>>> p = re.compile('section{ ( [^}]*) }', re.VERBOSE)
>>> p.sub(r'subsection{\1}', 'section{First} section{second}
subsection{First} subsection{second}'
```

There's also a syntax for referring to named groups as defined by the (?P<name>...) syntax. \g<name> will use the substring matched by the group named name, and \g<number> uses the corresponding group number. \g<2> is therefore equivalent to \2, but isn't ambiguous in a replacement string such as \g<2>0. (\20 would be interpreted as a reference to group 20, not a reference to group 2 followed by the literal character '0'.) The following substitutions are all equivalent, but use all three variations of the replacement string.
replacement can also be a function, which gives you even more control. If replacement is a function, the function is called for every
non-overlapping occurrence of pattern. On each call, the function is
passed a match object argument for the match and can use this
information to compute the desired replacement string and return it.

In the following example, the replacement function translates decimals
into hexadecimal:

```python
def hexrepl(match):
    ...  "Return the hex string for a decimal number"
    ...  value = int(match.group())
    ...  return hex(value)
...  p = re.compile(r'\d+')
...  p.sub(hexrepl, 'Call 65490 for printing, 49152 for
  Call 0xffd2 for printing, 0xc000 for user code.')
```

When using the module-level re.sub() function, the pattern is
passed as the first argument. The pattern may be provided as an
object or as a string; if you need to specify regular expression flags,
you must either use a pattern object as the first parameter, or use
embedded modifiers in the pattern string, e.g. sub("(?i)b+", "x",
"bbbb BBBB") returns 'x x'.

Common Problems

Regular expressions are a powerful tool for some applications, but in some ways their behaviour isn’t intuitive and at times they don’t behave the way you may expect them to. This section will point out some of the most common pitfalls.

Use String Methods

Sometimes using the re module is a mistake. If you’re matching a fixed string, or a single character class, and you’re not using any re features such as the IGNORECASE flag, then the full power of regular expressions may not be required. Strings have several methods for performing operations with fixed strings and they’re usually much faster, because the implementation is a single small C loop that’s been optimized for the purpose, instead of the large, more generalized regular expression engine.

One example might be replacing a single fixed string with another one; for example, you might replace word with deed. re.sub() seems like the function to use for this, but consider the replace() method. Note that replace() will also replace word inside words, turning swordfish into sdeedfish, but the naive RE word would have done that, too. (To avoid performing the substitution on parts of words, the pattern would have to be \bword\b, in order to require that word have a word boundary on either side. This takes the job beyond replace()‘s abilities.)

Another common task is deleting every occurrence of a single character from a string or replacing it with another single character.
You might do this with something like `re.sub(\n', ' ', S)`, but `translate()` is capable of doing both tasks and will be faster than any regular expression operation can be.

In short, before turning to the `re` module, consider whether your problem can be solved with a faster and simpler string method.

**match() versus search()**

The `match()` function only checks if the RE matches at the beginning of the string while `search()` will scan forward through the string for a match. It's important to keep this distinction in mind. Remember, `match()` will only report a successful match which will start at 0; if the match wouldn't start at zero, `match()` will *not* report it.

```python
>>> print(re.match('super', 'superstition').span())
(0, 5)
>>> print(re.match('super', 'insuperable'))
None
```

On the other hand, `search()` will scan forward through the string, reporting the first match it finds.

```python
>>> print(re.search('super', 'superstition').span())
(0, 5)
>>> print(re.search('super', 'insuperable').span())
(2, 7)
```

Sometimes you'll be tempted to keep using `re.match()`, and just add `.*` to the front of your RE. Resist this temptation and use `re.search()` instead. The regular expression compiler does some analysis of REs in order to speed up the process of looking for a
match. One such analysis figures out what the first character of a match must be; for example, a pattern starting with Crow must match starting with a 'C'. The analysis lets the engine quickly scan through the string looking for the starting character, only trying the full match if a 'C' is found.

Adding .* defeats this optimization, requiring scanning to the end of the string and then backtracking to find a match for the rest of the RE. Use re.search() instead.

**Greedy versus Non-Greedy**

When repeating a regular expression, as in a*, the resulting action is to consume as much of the pattern as possible. This fact often bites you when you're trying to match a pair of balanced delimiters, such as the angle brackets surrounding an HTML tag. The naive pattern for matching a single HTML tag doesn't work because of the greedy nature of .*.

```python
>>> s = '<html><head><title>Title</title>'
>>> len(s)
32
>>> print(re.match('<.*>', s).span())
(0, 32)
>>> print(re.match('<.*>', s).group())
<html><head><title>Title</title>
```

The RE matches the '<' in <html>, and the .* consumes the rest of the string. There's still more left in the RE, though, and the > can't match at the end of the string, so the regular expression engine has to backtrack character by character until it finds a match for the >. The final match extends from the '<' in <html> to the '>' in </title>,
which isn’t what you want.

In this case, the solution is to use the non-greedy qualifiers *?, +?, ??, or \{m,n}\?, which match as little text as possible. In the above example, the ']' is tried immediately after the first '<' matches, and when it fails, the engine advances a character at a time, retrying the ']' at every step. This produces just the right result:

```python
>>> print(re.match('<.*?>', s).group())
<html>
```

(Note that parsing HTML or XML with regular expressions is painful. Quick-and-dirty patterns will handle common cases, but HTML and XML have special cases that will break the obvious regular expression; by the time you’ve written a regular expression that handles all of the possible cases, the patterns will be very complicated. Use an HTML or XML parser module for such tasks.)

**Using re.VERBOSE**

By now you’ve probably noticed that regular expressions are a very compact notation, but they’re not terribly readable. REs of moderate complexity can become lengthy collections of backslashes, parentheses, and metacharacters, making them difficult to read and understand.

For such REs, specifying the re.VERBOSE flag when compiling the regular expression can be helpful, because it allows you to format the regular expression more clearly.

The re.VERBOSE flag has several effects. Whitespace in the regular expression that isn’t inside a character class is ignored. This means
that an expression such as dog | cat is equivalent to the less readable dog|cat, but [a b] will still match the characters 'a', 'b', or a space. In addition, you can also put comments inside a RE; comments extend from a # character to the next newline. When used with triple-quoted strings, this enables REs to be formatted more neatly:

```python
pat = re.compile(r""
    \s*    # Skip leading whitespace
    (?P<header>[^:]+)  # Header name
    \s* :  # Whitespace, and a colon
    (?P<value>.*?)  # The header's value -- *? used to lose the following trailing whitespace
    \s*$  # Trailing whitespace to end-of-line
""", re.VERBOSE)
```

This is far more readable than:

```python
pat = re.compile(r"\s*(?P<header>[^:]+)\s*: (?P<value>.*?)\s*$"
```
Feedback

Regular expressions are a complicated topic. Did this document help you understand them? Were there parts that were unclear, or Problems you encountered that weren't covered here? If so, please send suggestions for improvements to the author.

The most complete book on regular expressions is almost certainly Jeffrey Friedl’s Mastering Regular Expressions, published by O’Reilly. Unfortunately, it exclusively concentrates on Perl and Java’s flavours of regular expressions, and doesn't contain any Python material at all, so it won't be useful as a reference for programming in Python. (The first edition covered Python’s now-removed regex module, which won't help you much.) Consider checking it out from your library.
Socket Programming HOWTO

Author: Gordon McMillan

Abstract

Sockets are used nearly everywhere, but are one of the most severely misunderstood technologies around. This is a 10,000 foot overview of sockets. It’s not really a tutorial - you’ll still have work to do in getting things operational. It doesn’t cover the fine points (and there are a lot of them), but I hope it will give you enough background to begin using them decently.
Sockets

I’m only going to talk about INET (i.e. IPv4) sockets, but they account for at least 99% of the sockets in use. And I’ll only talk about STREAM (i.e. TCP) sockets - unless you really know what you’re doing (in which case this HOWTO isn’t for you!), you’ll get better behavior and performance from a STREAM socket than anything else. I will try to clear up the mystery of what a socket is, as well as some hints on how to work with blocking and non-blocking sockets. But I’ll start by talking about blocking sockets. You’ll need to know how they work before dealing with non-blocking sockets.

Part of the trouble with understanding these things is that “socket” can mean a number of subtly different things, depending on context. So first, let’s make a distinction between a “client” socket - an endpoint of a conversation, and a “server” socket, which is more like a switchboard operator. The client application (your browser, for example) uses “client” sockets exclusively; the web server it’s talking to uses both “server” sockets and “client” sockets.

History

Of the various forms of IPC, sockets are by far the most popular. On any given platform, there are likely to be other forms of IPC that are faster, but for cross-platform communication, sockets are about the only game in town.

They were invented in Berkeley as part of the BSD flavor of Unix. They spread like wildfire with the Internet. With good reason — the combination of sockets with INET makes talking to arbitrary machines around the world unbelievably easy (at least compared to other
schemes).
Creating a Socket

Roughly speaking, when you clicked on the link that brought you to this page, your browser did something like the following:

```python
# create an INET, STREAMing socket
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
# now connect to the web server on port 80 - the normal http port
s.connect(('www.python.org', 80))
```

When the connect completes, the socket `s` can be used to send in a request for the text of the page. The same socket will read the reply, and then be destroyed. That's right, destroyed. Client sockets are normally only used for one exchange (or a small set of sequential exchanges).

What happens in the web server is a bit more complex. First, the web server creates a "server socket":

```python
# create an INET, STREAMing socket
serversocket = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
# bind the socket to a public host, and a well-known port
serversocket.bind((socket.gethostname(), 80))
# become a server socket
serversocket.listen(5)
```

A couple things to notice: we used `socket.gethostname()` so that the socket would be visible to the outside world. If we had used `s.bind(('localhost', 80))` or `s.bind(('127.0.0.1', 80))` we would still have a "server" socket, but one that was only visible within the same machine. `s.bind(('', 80))` specifies that
the socket is reachable by any address the machine happens to have.

A second thing to note: low number ports are usually reserved for “well known” services (HTTP, SNMP etc). If you’re playing around, use a nice high number (4 digits).

Finally, the argument to listen tells the socket library that we want it to queue up as many as 5 connect requests (the normal max) before refusing outside connections. If the rest of the code is written properly, that should be plenty.

Now that we have a “server” socket, listening on port 80, we can enter the mainloop of the web server:

```python
while True:
    # accept connections from outside
    (clientsocket, address) = serversocket.accept()
    # now do something with the clientsocket
    # in this case, we'll pretend this is a threaded
    ct = client_thread(clientsocket)
    ct.run()
```

There's actually 3 general ways in which this loop could work - dispatching a thread to handle clientsocket, create a new process to handle clientsocket, or restructure this app to use non-blocking sockets, and multplex between our “server” socket and any active clientsockets using select. More about that later. The important thing to understand now is this: this is all a “server” socket does. It doesn't send any data. It doesn't receive any data. It just produces “client” sockets. Each clientsocket is created in response to some other “client” socket doing a connect() to the host and port we're bound to. As soon as we've created that clientsocket, we go back to listening for more connections. The two “clients” are free to chat it
up - they are using some dynamically allocated port which will be recycled when the conversation ends.

**IPC**

If you need fast IPC between two processes on one machine, you should look into pipes or shared memory. If you do decide to use AF_INET sockets, bind the “server” socket to 'localhost'. On most platforms, this will take a shortcut around a couple of layers of network code and be quite a bit faster.

**See also:** The `multiprocessing` integrates cross-platform IPC into a higher-level API.
Using a Socket

The first thing to note, is that the web browser’s “client” socket and the web server’s “client” socket are identical beasts. That is, this is a “peer to peer” conversation. Or to put it another way, as the designer, you will have to decide what the rules of etiquette are for a conversation. Normally, the connecting socket starts the conversation, by sending in a request, or perhaps a signon. But that’s a design decision - it’s not a rule of sockets.

Now there are two sets of verbs to use for communication. You can use send and recv, or you can transform your client socket into a file-like beast and use read and write. The latter is the way Java presents its sockets. I’m not going to talk about it here, except to warn you that you need to use flush on sockets. These are buffered “files”, and a common mistake is to write something, and then read for a reply. Without a flush in there, you may wait forever for the reply, because the request may still be in your output buffer.

Now we come to the major stumbling block of sockets - send and recv operate on the network buffers. They do not necessarily handle all the bytes you hand them (or expect from them), because their major focus is handling the network buffers. In general, they return when the associated network buffers have been filled (send) or emptied (recv). They then tell you how many bytes they handled. It is your responsibility to call them again until your message has been completely dealt with.

When a recv returns 0 bytes, it means the other side has closed (or is in the process of closing) the connection. You will not receive any more data on this connection. Ever. You may be able to send data
successfully; I'll talk more about this later.

A protocol like HTTP uses a socket for only one transfer. The client sends a request, then reads a reply. That's it. The socket is discarded. This means that a client can detect the end of the reply by receiving 0 bytes.

But if you plan to reuse your socket for further transfers, you need to realize that there is no EOT on a socket. I repeat: if a socket send or recv returns after handling 0 bytes, the connection has been broken. If the connection has not been broken, you may wait on a recv forever, because the socket will not tell you that there's nothing more to read (for now). Now if you think about that a bit, you'll come to realize a fundamental truth of sockets: messages must either be fixed length (yuck), or be delimited (shrug), or indicate how long they are (much better), or end by shutting down the connection. The choice is entirely yours, (but some ways are righter than others).

Assuming you don't want to end the connection, the simplest solution is a fixed length message:

```python
class MySocket:
    """demonstration class only
    - coded for clarity, not efficiency
    ""

    def __init__(self, sock=\None):
        if sock is \None:
            self.sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
        else:
            self.sock = sock

    def connect(self, host, port):
```
self.sock.connect((host, port))

def mysend(self, msg):
    totalsent = 0
    while totalsent < MSGLEN:
        sent = self.sock.send(msg[totalsent:])
        if sent == 0:
            raise RuntimeError("socket connection broken")
        totalsent = totalsent + sent

def myreceive(self):
    chunks = []
    bytes_recd = 0
    while bytes_recd < MSGLEN:
        chunk = self.sock.recv(min(MSGLEN - bytes_recd, 2048))
        if chunk == b'':
            raise RuntimeError("socket connection broken")
        chunks.append(chunk)
        bytes_recd = bytes_recd + len(chunk)
    return b''.join(chunks)

The sending code here is usable for almost any messaging scheme - in Python you send strings, and you can use len() to determine its length (even if it has embedded \0 characters). It's mostly the receiving code that gets more complex. (And in C, it's not much worse, except you can't use strlen if the message has embedded \0s.)

The easiest enhancement is to make the first character of the message an indicator of message type, and have the type determine the length. Now you have two recv's - the first to get (at least) that first character so you can look up the length, and the second in a loop to get the rest. If you decide to go the delimited route, you'll be receiving in some arbitrary chunk size, (4096 or 8192 is frequently a good match for network buffer sizes), and scanning what you've received for a
delimiter.

One complication to be aware of: if your conversational protocol allows multiple messages to be sent back to back (without some kind of reply), and you pass recv an arbitrary chunk size, you may end up reading the start of a following message. You'll need to put that aside and hold onto it, until it's needed.

Prefixing the message with its length (say, as 5 numeric characters) gets more complex, because (believe it or not), you may not get all 5 characters in one recv. In playing around, you'll get away with it; but in high network loads, your code will very quickly break unless you use two recv loops - the first to determine the length, the second to get the data part of the message. Nasty. This is also when you'll discover that send does not always manage to get rid of everything in one pass. And despite having read this, you will eventually get bit by it!

In the interests of space, building your character, (and preserving my competitive position), these enhancements are left as an exercise for the reader. Lets move on to cleaning up.

**Binary Data**

It is perfectly possible to send binary data over a socket. The major problem is that not all machines use the same formats for binary data. For example, a Motorola chip will represent a 16 bit integer with the value 1 as the two hex bytes 00 01. Intel and DEC, however, are byte-reversed - that same 1 is 01 00. Socket libraries have calls for converting 16 and 32 bit integers - ntohl, htonl, ntohs, htons where “n” means network and “h” means host, “s” means short and “l” means long. Where network order is host order, these do nothing, but where the machine is byte-reversed, these swap the bytes around
appropriately.

In these days of 32 bit machines, the ascii representation of binary data is frequently smaller than the binary representation. That's because a surprising amount of the time, all those longs have the value 0, or maybe 1. The string "0" would be two bytes, while binary is four. Of course, this doesn't fit well with fixed-length messages. Decisions, decisions.
Disconnecting

Strictly speaking, you're supposed to use shutdown on a socket before you close it. The shutdown is an advisory to the socket at the other end. Depending on the argument you pass it, it can mean “I’m not going to send anymore, but I’ll still listen”, or “I’m not listening, good riddance!”. Most socket libraries, however, are so used to programmers neglecting to use this piece of etiquette that normally a close is the same as shutdown(); close(). So in most situations, an explicit shutdown is not needed.

One way to use shutdown effectively is in an HTTP-like exchange. The client sends a request and then does a shutdown(1). This tells the server “This client is done sending, but can still receive.” The server can detect “EOF” by a receive of 0 bytes. It can assume it has the complete request. The server sends a reply. If the send completes successfully then, indeed, the client was still receiving.

Python takes the automatic shutdown a step further, and says that when a socket is garbage collected, it will automatically do a close if it’s needed. But relying on this is a very bad habit. If your socket just disappears without doing a close, the socket at the other end may hang indefinitely, thinking you’re just being slow. Please close your sockets when you’re done.

When Sockets Die

Probably the worst thing about using blocking sockets is what happens when the other side comes down hard (without doing a close). Your socket is likely to hang. TCP is a reliable protocol, and it will wait a
long, long time before giving up on a connection. If you’re using threads, the entire thread is essentially dead. There's not much you can do about it. As long as you aren't doing something dumb, like holding a lock while doing a blocking read, the thread isn’t really consuming much in the way of resources. Do not try to kill the thread - part of the reason that threads are more efficient than processes is that they avoid the overhead associated with the automatic recycling of resources. In other words, if you do manage to kill the thread, your whole process is likely to be screwed up.
Non-blocking Sockets

If you've understood the preceding, you already know most of what you need to know about the mechanics of using sockets. You'll still use the same calls, in much the same ways. It's just that, if you do it right, your app will be almost inside-out.

In Python, you use `socket.setblocking(0)` to make it non-blocking. In C, it's more complex, (for one thing, you'll need to choose between the BSD flavor `0_NONBLOCK` and the almost indistinguishable Posix flavor `0_NDELAY`, which is completely different from `TCP_NODELAY`), but it's the exact same idea. You do this after creating the socket, but before using it. (Actually, if you're nuts, you can switch back and forth.)

The major mechanical difference is that send, recv, connect and accept can return without having done anything. You have (of course) a number of choices. You can check return code and error codes and generally drive yourself crazy. If you don't believe me, try it sometime. Your app will grow large, buggy and suck CPU. So let's skip the brain-dead solutions and do it right.

Use select.

In C, coding select is fairly complex. In Python, it's a piece of cake, but it's close enough to the C version that if you understand select in Python, you'll have little trouble with it in C:

```python
ready_to_read, ready_to_write, in_error = \
    select.select(\n        potential_readers, \n        potential_writers, \n        potential_writers,
```
You pass select three lists: the first contains all sockets that you might want to try reading; the second all the sockets you might want to try writing to, and the last (normally left empty) those that you want to check for errors. You should note that a socket can go into more than one list. The select call is blocking, but you can give it a timeout. This is generally a sensible thing to do - give it a nice long timeout (say a minute) unless you have good reason to do otherwise.

In return, you will get three lists. They contain the sockets that are actually readable, writable and in error. Each of these lists is a subset (possibly empty) of the corresponding list you passed in.

If a socket is in the output readable list, you can be as-close-to-certain-as-we-ever-get-in-this-business that a recv on that socket will return something. Same idea for the writable list. You’ll be able to send something. Maybe not all you want to, but something is better than nothing. (Actually, any reasonably healthy socket will return as writable - it just means outbound network buffer space is available.)

If you have a “server” socket, put it in the potential_readers list. If it comes out in the readable list, your accept will (almost certainly) work. If you have created a new socket to connect to someone else, put it in the potential_writers list. If it shows up in the writable list, you have a decent chance that it has connected.

Actually, select can be handy even with blocking sockets. It’s one way of determining whether you will block - the socket returns as readable when there’s something in the buffers. However, this still doesn’t help with the problem of determining whether the other end is done, or just busy with something else.
**Portability alert:** On Unix, `select` works both with the sockets and files. Don’t try this on Windows. On Windows, `select` works with sockets only. Also note that in C, many of the more advanced socket options are done differently on Windows. In fact, on Windows I usually use threads (which work very, very well) with my sockets.
Sorting HOW TO

<table>
<thead>
<tr>
<th>Author:</th>
<th>Andrew Dalke and Raymond Hettinger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Release:</td>
<td>0.1</td>
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Python lists have a built-in `list.sort()` method that modifies the list in-place. There is also a `sorted()` built-in function that builds a new sorted list from an iterable.

In this document, we explore the various techniques for sorting data using Python.
Sorting Basics

A simple ascending sort is very easy: just call the `sorted()` function. It returns a new sorted list:

```python
>>> sorted([5, 2, 3, 1, 4])
[1, 2, 3, 4, 5]
```

You can also use the `list.sort()` method. It modifies the list in-place (and returns `None` to avoid confusion). Usually it’s less convenient than `sorted()` - but if you don’t need the original list, it’s slightly more efficient.

```python
>>> a = [5, 2, 3, 1, 4]
>>> a.sort()
>>> a
[1, 2, 3, 4, 5]
```

Another difference is that the `list.sort()` method is only defined for lists. In contrast, the `sorted()` function accepts any iterable.

```python
[1, 2, 3, 4, 5]
```
Key Functions

Both `list.sort()` and `sorted()` have a `key` parameter to specify a function to be called on each list element prior to making comparisons.

For example, here's a case-insensitive string comparison:

```python
>>> sorted("This is a test string from Andrew".split,['a', 'Andrew', 'from', 'is', 'string', 'test', 'This'])
```

The value of the `key` parameter should be a function that takes a single argument and returns a key to use for sorting purposes. This technique is fast because the key function is called exactly once for each input record.

A common pattern is to sort complex objects using some of the object's indices as keys. For example:

```python
>>> student_tuples = [('john', 'A', 15),
                     ('jane', 'B', 12),
                     ('dave', 'B', 10),
                     ]
>>> sorted(student_tuples, key=lambda student: student)
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A',
```

The same technique works for objects with named attributes. For example:

```python
>>> class Student:
    def __init__(self, name, grade, age):
        self.name = name
```
```python
self.grade = grade
self.age = age
def __repr__(self):
    return repr((self.name, self.grade, self.age))

>>> student_objects = [
    Student('john', 'A', 15),
    Student('jane', 'B', 12),
    Student('dave', 'B', 10),
]

>>> sorted(student_objects, key=lambda student: student[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A',]
Operator Module Functions

The key-function patterns shown above are very common, so Python provides convenience functions to make accessor functions easier and faster. The operator module has `itemgetter()`, `attrgetter()`, and a `methodcaller()` function.

Using those functions, the above examples become simpler and faster:

```python
>>> from operator import itemgetter, attrgetter

>>> sorted(student_tuples, key=itemgetter(2))
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]

>>> sorted(student_objects, key=attrgetter('age'))
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]

The operator module functions allow multiple levels of sorting. For example, to sort by `grade` then by `age`:

```python
>>> sorted(student_tuples, key=itemgetter(1, 2))
[('john', 'A', 15), ('dave', 'B', 10), ('jane', 'B', 12)]

>>> sorted(student_objects, key=attrgetter('grade', 'age'))
[('john', 'A', 15), ('dave', 'B', 10), ('jane', 'B', 12)]
```
Ascending and Descending

Both `list.sort()` and `sorted()` accept a `reverse` parameter with a boolean value. This is used to flag descending sorts. For example, to get the student data in reverse *age* order:

```python
>>> sorted(student_tuples, key=itemgetter(2), reverse=True)
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

```python
>>> sorted(student_objects, key=attrgetter('age'), reverse=True)
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```
Sort Stability and Complex Sorts

Sorts are guaranteed to be stable. That means that when multiple records have the same key, their original order is preserved.

```python
>>> data = [('red', 1), ('blue', 1), ('red', 2), ('blue', 2), ('red', 1), ('red', 2)]
```

Notice how the two records for blue retain their original order so that ('blue', 1) is guaranteed to precede ('blue', 2).

This wonderful property lets you build complex sorts in a series of sorting steps. For example, to sort the student data by descending grade and then ascending age, do the age sort first and then sort again using grade:

```python
>>> s = sorted(student_objects, key=attrgetter('age'))
>>> sorted(s, key=attrgetter('grade'), reverse=True)
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

The Timsort algorithm used in Python does multiple sorts efficiently because it can take advantage of any ordering already present in a dataset.
The Old Way Using Decorate-Sort-Undecorate

This idiom is called Decorate-Sort-Undecorate after its three steps:

- First, the initial list is decorated with new values that control the sort order.
- Second, the decorated list is sorted.
- Finally, the decorations are removed, creating a list that contains only the initial values in the new order.

For example, to sort the student data by grade using the DSU approach:

```python
>>> decorated = [(student.grade, i, student) for i, student in decorated]
>>> decorated.sort()
>>> [student for grade, i, student in decorated]
[('john', 'A', 15), ('jane', 'B', 12), ('dave', 'B', 10)]
```

This idiom works because tuples are compared lexicographically; the first items are compared; if they are the same then the second items are compared, and so on.

It is not strictly necessary in all cases to include the index i in the decorated list, but including it gives two benefits:

- The sort is stable – if two items have the same key, their order will be preserved in the sorted list.
- The original items do not have to be comparable because the ordering of the decorated tuples will be determined by at most the first two items. So for example the original list could contain complex numbers which cannot be sorted directly.
Another name for this idiom is **Schwartzian transform**, after Randal L. Schwartz, who popularized it among Perl programmers.

Now that Python sorting provides key-functions, this technique is not often needed.
The Old Way Using the *cmp* Parameter

Many constructs given in this HOWTO assume Python 2.4 or later. Before that, there was no *sorted()* builtin and *list.sort()* took no keyword arguments. Instead, all of the Py2.x versions supported a *cmp* parameter to handle user specified comparison functions.

In Py3.0, the *cmp* parameter was removed entirely (as part of a larger effort to simplify and unify the language, eliminating the conflict between rich comparisons and the *__cmp__()* magic method).

In Py2.x, sort allowed an optional function which can be called for doing the comparisons. That function should take two arguments to be compared and then return a negative value for less-than, return zero if they are equal, or return a positive value for greater-than. For example, we can do:

```python
>>> def numeric_compare(x, y):
    return x - y
>>> sorted([5, 2, 4, 1, 3], cmp=numeric_compare)
[1, 2, 3, 4, 5]
```

Or you can reverse the order of comparison with:

```python
>>> def reverse_numeric(x, y):
    return y - x
>>> sorted([5, 2, 4, 1, 3], cmp=reverse_numeric)
[5, 4, 3, 2, 1]
```

When porting code from Python 2.x to 3.x, the situation can arise when you have the user supplying a comparison function and you need to convert that to a key function. The following wrapper makes that easy to do:
def cmp_to_key(mycmp):
    'Convert a cmp= function into a key= function'

class K:
    def __init__(self, obj, *args):
        self.obj = obj
    def __lt__(self, other):
        return mycmp(self.obj, other.obj) < 0
    def __gt__(self, other):
        return mycmp(self.obj, other.obj) > 0
    def __eq__(self, other):
        return mycmp(self.obj, other.obj) == 0
    def __le__(self, other):
        return mycmp(self.obj, other.obj) <= 0
    def __ge__(self, other):
        return mycmp(self.obj, other.obj) >= 0
    def __ne__(self, other):
        return mycmp(self.obj, other.obj) != 0

return K

To convert to a key function, just wrap the old comparison function:

```python
>>> sorted([5, 2, 4, 1, 3], key=cmp_to_key(reverse_numeric))
[5, 4, 3, 2, 1]
```

In Python 3.2, the `functools.cmp_to_key()` function was added to the `functools` module in the standard library.
Odd and Ends

- For locale aware sorting, use `locale.strxfrm()` for a key function or `locale.strcoll()` for a comparison function.

- The `reverse` parameter still maintains sort stability (so that records with equal keys retain the original order). Interestingly, that effect can be simulated without the parameter by using the builtin `reversed()` function twice:

```python
>>> data = [('red', 1), ('blue', 1), ('red', 2),
>>> assert sorted(data, reverse=True) == list(reversed(data))
```

- The sort routines are guaranteed to use `__lt__()` when making comparisons between two objects. So, it is easy to add a standard sort order to a class by defining an `__lt__()` method:

```python
>>> Student.__lt__ = lambda self, other: self.age
>>> sorted(student_objects)
[('dave', 'B', 10), ('jane', 'B', 12), ('john',
```

- Key functions need not depend directly on the objects being sorted. A key function can also access external resources. For instance, if the student grades are stored in a dictionary, they can be used to sort a separate list of student names:

```python
>>> students = ['dave', 'john', 'jane']
>>> newgrades = {'john': 'F', 'jane': 'A', 'dave'
>>> sorted(students, key=newgrades.__getitem__)
['jane', 'dave', 'john']
```
Unicode HOWTO

Release: 1.12

This HOWTO discusses Python support for Unicode, and explains various problems that people commonly encounter when trying to work with Unicode.
Introduction to Unicode

History of Character Codes

In 1968, the American Standard Code for Information Interchange, better known by its acronym ASCII, was standardized. ASCII defined numeric codes for various characters, with the numeric values running from 0 to 127. For example, the lowercase letter ‘a’ is assigned 97 as its code value.

ASCII was an American-developed standard, so it only defined unaccented characters. There was an ‘e’, but no ‘é’ or ‘Í’. This meant that languages which required accented characters couldn’t be faithfully represented in ASCII. (Actually the missing accents matter for English, too, which contains words such as ‘naïve’ and ‘café’, and some publications have house styles which require spellings such as ‘coöperate’.)

For a while people just wrote programs that didn’t display accents. In the mid-1980s an Apple II BASIC program written by a French speaker might have lines like these:

```basic
PRINT "MISE A JOUR TERMINEE"
PRINT "PARAMETRES ENREGISTRES"
```

Those messages should contain accents (terminée, paramètre, enregistrés) and they just look wrong to someone who can read French.

In the 1980s, almost all personal computers were 8-bit, meaning that bytes could hold values ranging from 0 to 255. ASCII codes only went up to 127, so some machines assigned values between 128 and 255.
to accented characters. Different machines had different codes, however, which led to problems exchanging files. Eventually various commonly used sets of values for the 128–255 range emerged. Some were true standards, defined by the International Standards Organization, and some were de facto conventions that were invented by one company or another and managed to catch on.

255 characters aren’t very many. For example, you can’t fit both the accented characters used in Western Europe and the Cyrillic alphabet used for Russian into the 128–255 range because there are more than 128 such characters.

You could write files using different codes (all your Russian files in a coding system called KOI8, all your French files in a different coding system called Latin1), but what if you wanted to write a French document that quotes some Russian text? In the 1980s people began to want to solve this problem, and the Unicode standardization effort began.

Unicode started out using 16-bit characters instead of 8-bit characters. 16 bits means you have $2^{16} = 65,536$ distinct values available, making it possible to represent many different characters from many different alphabets; an initial goal was to have Unicode contain the alphabets for every single human language. It turns out that even 16 bits isn’t enough to meet that goal, and the modern Unicode specification uses a wider range of codes, 0 through 1,114,111 (0x10FFFF in base 16).

There’s a related ISO standard, ISO 10646. Unicode and ISO 10646 were originally separate efforts, but the specifications were merged with the 1.1 revision of Unicode.

(This discussion of Unicode’s history is highly simplified. The precise
historical details aren’t necessary for understanding how to use Unicode effectively, but if you’re curious, consult the Unicode consortium site listed in the References or the Wikipedia entry for Unicode for more information.)

Definitions

A character is the smallest possible component of a text. ‘A’, ‘B’, ‘C’, etc., are all different characters. So are ‘È’ and ‘Í’. Characters are abstractions, and vary depending on the language or context you’re talking about. For example, the symbol for ohms (Ω) is usually drawn much like the capital letter omega (Ω) in the Greek alphabet (they may even be the same in some fonts), but these are two different characters that have different meanings.

The Unicode standard describes how characters are represented by code points. A code point is an integer value, usually denoted in base 16. In the standard, a code point is written using the notation U+12CA to mean the character with value 0x12ca (4,810 decimal). The Unicode standard contains a lot of tables listing characters and their corresponding code points:

```
0061 'a'; LATIN SMALL LETTER A
0062 'b'; LATIN SMALL LETTER B
0063 'c'; LATIN SMALL LETTER C
...
007B '{'; LEFT CURLY BRACKET
```

Strictly, these definitions imply that it’s meaningless to say ‘this is character U+12CA’. U+12CA is a code point, which represents some particular character; in this case, it represents the character ‘ETHIOPIAN SYLLABLE WI’. In informal contexts, this distinction
between code points and characters will sometimes be forgotten.

A character is represented on a screen or on paper by a set of graphical elements that's called a **glyph**. The glyph for an uppercase A, for example, is two diagonal strokes and a horizontal stroke, though the exact details will depend on the font being used. Most Python code doesn't need to worry about glyphs; figuring out the correct glyph to display is generally the job of a GUI toolkit or a terminal’s font renderer.

**Encodings**

To summarize the previous section: a Unicode string is a sequence of code points, which are numbers from 0 through \(0\times10FFFF\) (1,114,111 decimal). This sequence needs to be represented as a set of bytes (meaning, values from 0 through 255) in memory. The rules for translating a Unicode string into a sequence of bytes are called an **encoding**.

The first encoding you might think of is an array of 32-bit integers. In this representation, the string “Python” would look like this:

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>y</th>
<th>t</th>
<th>h</th>
<th>o</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0x50 00 00 00 79 00 00 00 74 00 00 00 68 00 00 00 6f 00 00 00 6e 00 00 00 6f 00 00 00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This representation is straightforward but using it presents a number of problems.

1. It's not portable; different processors order the bytes differently.
2. It's very wasteful of space. In most texts, the majority of the code points are less than 127, or less than 255, so a lot of space is
occupied by 0x00 bytes. The above string takes 24 bytes compared to the 6 bytes needed for an ASCII representation. Increased RAM usage doesn’t matter too much (desktop computers have gigabytes of RAM, and strings aren’t usually that large), but expanding our usage of disk and network bandwidth by a factor of 4 is intolerable.

3. It’s not compatible with existing C functions such as strlen(), so a new family of wide string functions would need to be used.

4. Many Internet standards are defined in terms of textual data, and can’t handle content with embedded zero bytes.

Generally people don’t use this encoding, instead choosing other encodings that are more efficient and convenient. UTF-8 is probably the most commonly supported encoding; it will be discussed below.

Encodings don’t have to handle every possible Unicode character, and most encodings don’t. The rules for converting a Unicode string into the ASCII encoding, for example, are simple; for each code point:

1. If the code point is < 128, each byte is the same as the value of the code point.
2. If the code point is 128 or greater, the Unicode string can’t be represented in this encoding. (Python raises a UnicodeEncodeError exception in this case.)

Latin-1, also known as ISO-8859-1, is a similar encoding. Unicode code points 0–255 are identical to the Latin-1 values, so converting to this encoding simply requires converting code points to byte values; if a code point larger than 255 is encountered, the string can’t be encoded into Latin-1.

Encodings don’t have to be simple one-to-one mappings like Latin-1. Consider IBM’s EBCDIC, which was used on IBM mainframes. Letter values weren’t in one block: ‘a’ through ‘i’ had values from 129 to 137,
but ‘j’ through ‘r’ were 145 through 153. If you wanted to use EBCDIC as an encoding, you’d probably use some sort of lookup table to perform the conversion, but this is largely an internal detail.

UTF-8 is one of the most commonly used encodings. UTF stands for “Unicode Transformation Format”, and the ‘8’ means that 8-bit numbers are used in the encoding. (There are also a UTF-16 and UTF-32 encodings, but they are less frequently used than UTF-8.) UTF-8 uses the following rules:

1. If the code point is < 128, it’s represented by the corresponding byte value.
2. If the code point is >= 128, it’s turned into a sequence of two, three, or four bytes, where each byte of the sequence is between 128 and 255.

UTF-8 has several convenient properties:

1. It can handle any Unicode code point.
2. A Unicode string is turned into a string of bytes containing no embedded zero bytes. This avoids byte-ordering issues, and means UTF-8 strings can be processed by C functions such as `strcpy()` and sent through protocols that can’t handle zero bytes.
3. A string of ASCII text is also valid UTF-8 text.
4. UTF-8 is fairly compact; the majority of commonly used characters can be represented with one or two bytes.
5. If bytes are corrupted or lost, it’s possible to determine the start of the next UTF-8-encoded code point and resynchronize. It’s also unlikely that random 8-bit data will look like valid UTF-8.

References

The Unicode Consortium site has character charts, a glossary, and
PDF versions of the Unicode specification. Be prepared for some difficult reading. A chronology of the origin and development of Unicode is also available on the site.

To help understand the standard, Jukka Korpela has written an introductory guide to reading the Unicode character tables.

Another good introductory article was written by Joel Spolsky. If this introduction didn’t make things clear to you, you should try reading this alternate article before continuing.

Wikipedia entries are often helpful; see the entries for “character encoding” and UTF-8, for example.
Python’s Unicode Support

Now that you’ve learned the rudiments of Unicode, we can look at Python’s Unicode features.

The String Type

Since Python 3.0, the language features a `str` type that contain Unicode characters, meaning any string created using "unicode rocks!", 'unicode rocks!', or the triple-quoted string syntax is stored as Unicode.

The default encoding for Python source code is UTF-8, so you can simply include a Unicode character in a string literal:

```python
try:
    with open('/tmp/input.txt', 'r') as f:
        ...
except OSError:
    # 'File not found' error message.
    print("Fichier non trouvé")
```

You can use a different encoding from UTF-8 by putting a specially-formatted comment as the first or second line of the source code:

```
# -*- coding: <encoding name> -*-
```

Side note: Python 3 also supports using Unicode characters in identifiers:

```python
répertoire = "/tmp/records.log"
with open(répertoire, "w") as f:
```
f.write("test\n")

If you can't enter a particular character in your editor or want to keep the source code ASCII-only for some reason, you can also use escape sequences in string literals. (Depending on your system, you may see the actual capital-delta glyph instead of a u escape.)

```python
>>> "\N{GREEK CAPITAL LETTER DELTA}"  # Using the character name
'\u0394'
>>> "\u0394"  # Using a 16-bit hex value
'\u0394'
>>> "\U00000394"  # Using a 32-bit hex value
'\u0394'
```

In addition, one can create a string using the `decode()` method of `bytes`. This method takes an `encoding` argument, such as UTF-8, and optionally an `errors` argument.

The `errors` argument specifies the response when the input string can't be converted according to the encoding's rules. Legal values for this argument are 'strict' (raise a `UnicodeDecodeError` exception), 'replace' (use U+FFFD, REPLACEMENT CHARACTER), 'ignore' (just leave the character out of the Unicode result), or 'backslashreplace' (inserts a \xNN escape sequence). The following examples show the differences:

```python
>>> b'\x80abc'.decode("utf-8", "strict")
Traceback (most recent call last):
  ...
UnicodeDecodeError: 'utf-8' codec can't decode byte invalid start byte
>>> b'\x80abc'.decode("utf-8", "replace")
'\ufffdabc'
```
(In this code example, the Unicode replacement character has been replaced by a question mark because it may not be displayed on some systems.)

Encodings are specified as strings containing the encoding’s name. Python 3.2 comes with roughly 100 different encodings; see the Python Library Reference at Standard Encodings for a list. Some encodings have multiple names; for example, 'latin-1', 'iso_8859_1' and '8859' are all synonyms for the same encoding.

One-character Unicode strings can also be created with the chr() built-in function, which takes integers and returns a Unicode string of length 1 that contains the corresponding code point. The reverse operation is the built-in ord() function that takes a one-character Unicode string and returns the code point value:

```python
>>> chr(57344)
'\ue000'
>>> ord('\ue000')
57344
```

**Converting to Bytes**

The opposite method of bytes.decode() is str.encode(), which returns a bytes representation of the Unicode string, encoded in the requested encoding.
The errors parameter is the same as the parameter of the `decode()` method but supports a few more possible handlers. As well as 'strict', 'ignore', and 'replace' (which in this case inserts a question mark instead of the unencodable character), there is also 'xmlcharrefreplace' (inserts an XML character reference), `backslashreplace` (inserts a \uNNNN escape sequence) and `namereplace` (inserts a \N{...} escape sequence).

The following example shows the different results:

```python
>>> u = chr(40960) + 'abcd' + chr(1972)
>>> u.encode('utf-8')
b'\xea\x80\x80abcd\xde\xb4'
>>> u.encode('ascii')
Traceback (most recent call last):
  ...  
UnicodeEncodeError: 'ascii' codec can't encode character 'ꀀ' in position 0: ordinal not in range(128)
>>> u.encode('ascii', 'ignore')
b'abcd'
>>> u.encode('ascii', 'replace')
b'?abcd?'
>>> u.encode('ascii', 'xmlcharrefreplace')
b'&#40960;abcd&amp;#1972;'  
>>> u.encode('ascii', 'backslashreplace')
b'\ua000abcd\u07b4'
>>> u.encode('ascii', 'namereplace')
b'\N{YI SYLLABLE IT}abcd\u07b4'
```

The low-level routines for registering and accessing the available encodings are found in the `codecs` module. Implementing new encodings also requires understanding the `codecs` module. However, the encoding and decoding functions returned by this module are usually more low-level than is comfortable, and writing new encodings
is a specialized task, so the module won’t be covered in this HOWTO.

**Unicode Literals in Python Source Code**

In Python source code, specific Unicode code points can be written using the \u escape sequence, which is followed by four hex digits giving the code point. The \U escape sequence is similar, but expects eight hex digits, not four:

```python
>>> s = "a\xac\u1234\u20ac\U00008000"
... # ^^^^ two-digit hex escape
... # ^^^^^^ four-digit Unicode escape
... # ^^^^^^^^^ eight-digit Unicode escape

>>> [ord(c) for c in s]
[97, 172, 4660, 8364, 32768]
```

Using escape sequences for code points greater than 127 is fine in small doses, but becomes an annoyance if you're using many accented characters, as you would in a program with messages in French or some other accent-using language. You can also assemble strings using the `chr()` built-in function, but this is even more tedious.

Ideally, you’d want to be able to write literals in your language’s natural encoding. You could then edit Python source code with your favorite editor which would display the accented characters naturally, and have the right characters used at runtime.

Python supports writing source code in UTF-8 by default, but you can use almost any encoding if you declare the encoding being used. This is done by including a special comment as either the first or second line of the source file:
The syntax is inspired by Emacs’s notation for specifying variables local to a file. Emacs supports many different variables, but Python only supports ‘coding’. The -*- symbols indicate to Emacs that the comment is special; they have no significance to Python but are a convention. Python looks for coding: name or coding=name in the comment.

If you don’t include such a comment, the default encoding used will be UTF-8 as already mentioned. See also PEP 263 for more information.

**Unicode Properties**

The Unicode specification includes a database of information about code points. For each defined code point, the information includes the character’s name, its category, the numeric value if applicable (Unicode has characters representing the Roman numerals and fractions such as one-third and four-fifths). There are also properties related to the code point’s use in bidirectional text and other display-related properties.

The following program displays some information about several characters, and prints the numeric value of one particular character:

```python
import unicodedata
u = chr(233) + chr(0x0bf2) + chr(3972) + chr(6000) +
```

```python
print(unicodedata.name(u[1]))
```
for i, c in enumerate(u):
    print(i, '%04x' % ord(c), unicodedata.category(c), unicodedata.name(c))

# Get numeric value of second character
print(unicodedata.numeric(u[1]))

When run, this prints:

0 00e9 Ll LATIN SMALL LETTER E WITH ACUTE
1 0bf2 No TAMIL NUMBER ONE THOUSAND
2 0f84 Mn TIBETAN MARK HALANTA
3 1770 Lo TAGBANWA LETTER SA
4 33af So SQUARE RAD OVER S SQUARED
1000.0

The category codes are abbreviations describing the nature of the character. These are grouped into categories such as “Letter”, “Number”, “Punctuation”, or “Symbol”, which in turn are broken up into subcategories. To take the codes from the above output, 'Ll' means ‘Letter, lowercase’, 'No' means “Number, other”, 'Mn' is “Mark, nonspacing”, and 'So' is “Symbol, other”. See the General Category Values section of the Unicode Character Database documentation for a list of category codes.

Unicode Regular Expressions

The regular expressions supported by the re module can be provided either as bytes or strings. Some of the special character sequences such as \d and \w have different meanings depending on whether the pattern is supplied as bytes or a string. For example, \d will match the characters \[0-9\] in bytes but in strings will match any character that's
in the 'Nd' category.

The string in this example has the number 57 written in both Thai and Arabic numerals:

```python
import re
p = re.compile('\d+)

s = "Over \u0e55\u0e57 57 flavours"
m = p.search(s)
print(repr(m.group()))
```

When executed, \d+ will match the Thai numerals and print them out. If you supply the re.ASCII flag to compile(), \d+ will match the substring “57” instead.

Similarly, \w matches a wide variety of Unicode characters but only [a-zA-Z0-9_] in bytes or if re.ASCII is supplied, and \s will match either Unicode whitespace characters or [ \t\n\r\f\v].

References

Some good alternative discussions of Python’s Unicode support are:

- Processing Text Files in Python 3, by Nick Coghlan.
- Pragmatic Unicode, a PyCon 2012 presentation by Ned Batchelder.

The str type is described in the Python library reference at Text Sequence Type — str.

The documentation for the unicodedata module.

The documentation for the codecs module.
Marc-André Lemburg gave a presentation titled “Python and Unicode” (PDF slides) at EuroPython 2002. The slides are an excellent overview of the design of Python 2’s Unicode features (where the Unicode string type is called unicode and literals start with u).
Reading and Writing Unicode Data

Once you’ve written some code that works with Unicode data, the next problem is input/output. How do you get Unicode strings into your program, and how do you convert Unicode into a form suitable for storage or transmission?

It’s possible that you may not need to do anything depending on your input sources and output destinations; you should check whether the libraries used in your application support Unicode natively. XML parsers often return Unicode data, for example. Many relational databases also support Unicode-valued columns and can return Unicode values from an SQL query.

Unicode data is usually converted to a particular encoding before it gets written to disk or sent over a socket. It’s possible to do all the work yourself: open a file, read an 8-bit bytes object from it, and convert the bytes with `bytes.decode(encoding)`. However, the manual approach is not recommended.

One problem is the multi-byte nature of encodings; one Unicode character can be represented by several bytes. If you want to read the file in arbitrary-sized chunks (say, 1024 or 4096 bytes), you need to write error-handling code to catch the case where only part of the bytes encoding a single Unicode character are read at the end of a chunk. One solution would be to read the entire file into memory and then perform the decoding, but that prevents you from working with files that are extremely large; if you need to read a 2 GiB file, you need 2 GiB of RAM. (More, really, since for at least a moment you’d need to have both the encoded string and its Unicode version in memory.)

The solution would be to use the low-level decoding interface to catch
the case of partial coding sequences. The work of implementing this has already been done for you: the built-in `open()` function can return a file-like object that assumes the file’s contents are in a specified encoding and accepts Unicode parameters for methods such as `read()` and `write()`. This works through `open()`’s `encoding` and `errors` parameters which are interpreted just like those in `str.encode()` and `bytes.decode()`.

Reading Unicode from a file is therefore simple:

```python
with open('unicode.txt', encoding='utf-8') as f:
    for line in f:
        print(repr(line))
```

It’s also possible to open files in update mode, allowing both reading and writing:

```python
with open('test', encoding='utf-8', mode='w+') as f:
    f.write('䔀 blah blah blah
    f.seek(0)
    print(repr(f.readline()[:1]))
```

The Unicode character U+FEFF is used as a byte-order mark (BOM), and is often written as the first character of a file in order to assist with autodetection of the file’s byte ordering. Some encodings, such as UTF-16, expect a BOM to be present at the start of a file; when such an encoding is used, the BOM will be automatically written as the first character and will be silently dropped when the file is read. There are variants of these encodings, such as ‘utf-16-le’ and ‘utf-16-be’ for little-endian and big-endian encodings, that specify one particular byte ordering and don’t skip the BOM.

In some areas, it is also convention to use a “BOM” at the start of
UTF-8 encoded files; the name is misleading since UTF-8 is not byte-order dependent. The mark simply announces that the file is encoded in UTF-8. Use the ‘utf-8-sig’ codec to automatically skip the mark if present for reading such files.

Unicode filenames

Most of the operating systems in common use today support filenames that contain arbitrary Unicode characters. Usually this is implemented by converting the Unicode string into some encoding that varies depending on the system. For example, Mac OS X uses UTF-8 while Windows uses a configurable encoding; on Windows, Python uses the name “mbcs” to refer to whatever the currently configured encoding is. On Unix systems, there will only be a filesystem encoding if you’ve set the LANG or LC_CTYPE environment variables; if you haven’t, the default encoding is UTF-8.

The `sys.getfilesystemencoding()` function returns the encoding to use on your current system, in case you want to do the encoding manually, but there’s not much reason to bother. When opening a file for reading or writing, you can usually just provide the Unicode string as the filename, and it will be automatically converted to the right encoding for you:

```python
filename = 'filename\u4500abc'
with open(filename, 'w') as f:
    f.write('blah\n')
```

Functions in the `os` module such as `os.stat()` will also accept Unicode filenames.

The `os.listdir()` function returns filenames and raises an issue:
should it return the Unicode version of filenames, or should it return bytes containing the encoded versions? `os.listdir()` will do both, depending on whether you provided the directory path as bytes or a Unicode string. If you pass a Unicode string as the path, filenames will be decoded using the filesystem's encoding and a list of Unicode strings will be returned, while passing a byte path will return the filenames as bytes. For example, assuming the default filesystem encoding is UTF-8, running the following program:

```python
def fn = 'filename\u4500abc'
f = open(fn, 'w')
f.close()

import os
print(os.listdir(b'.'))
print(os.listdir('.'))
```

will produce the following output:

```
$ python t.py
[b'filename\xe4\x94\x80abc', ...]
['filename\u4500abc', ...]
```

The first list contains UTF-8-encoded filenames, and the second list contains the Unicode versions.

Note that on most occasions, the Unicode APIs should be used. The bytes APIs should only be used on systems where undecodable file names can be present, i.e. Unix systems.

**Tips for Writing Unicode-aware Programs**

This section provides some suggestions on writing software that deals
with Unicode.

The most important tip is:

Software should only work with Unicode strings internally, decoding the input data as soon as possible and encoding the output only at the end.

If you attempt to write processing functions that accept both Unicode and byte strings, you will find your program vulnerable to bugs wherever you combine the two different kinds of strings. There is no automatic encoding or decoding: if you do e.g. `str + bytes`, a `TypeError` will be raised.

When using data coming from a web browser or some other untrusted source, a common technique is to check for illegal characters in a string before using the string in a generated command line or storing it in a database. If you're doing this, be careful to check the decoded string, not the encoded bytes data; some encodings may have interesting properties, such as not being bijective or not being fully ASCII-compatible. This is especially true if the input data also specifies the encoding, since the attacker can then choose a clever way to hide malicious text in the encoded bytestream.

Converting Between File Encodings

The `StreamRecoder` class can transparently convert between encodings, taking a stream that returns data in encoding #1 and behaving like a stream returning data in encoding #2.

For example, if you have an input file `f` that's in Latin-1, you can wrap it with a `StreamRecoder` to return bytes encoded in UTF-8:

```python
new_f = codecs.StreamRecoder(f, encoding='latin-1', new_encoding='utf-8')
```
Files in an Unknown Encoding

What can you do if you need to make a change to a file, but don’t know the file’s encoding? If you know the encoding is ASCII-compatible and only want to examine or modify the ASCII parts, you can open the file with the surrogateescape error handler:

```python
with open(fname, 'r', encoding="ascii", errors="surrogateescape") as f:
    data = f.read()

# make changes to the string 'data'
with open(fname + '.new', 'w', encoding="ascii", errors="surrogateescape") as f:
    f.write(data)
```

The surrogateescape error handler will decode any non-ASCII bytes as code points in the Unicode Private Use Area ranging from U+DC80 to U+DCFF. These private code points will then be turned back into the same bytes when the surrogateescape error handler is used when encoding the data and writing it back out.

References

One section of Mastering Python 3 Input/Output, a PyCon 2010 talk by
David Beazley, discusses text processing and binary data handling.

The PDF slides for Marc-André Lemburg’s presentation “Writing Unicode-aware Applications in Python” discuss questions of character encodings as well as how to internationalize and localize an application. These slides cover Python 2.x only.

The Guts of Unicode in Python is a PyCon 2013 talk by Benjamin Peterson that discusses the internal Unicode representation in Python 3.3.
Acknowledgements

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HOWTO Fetch Internet Resources Using The urllib Package

**Author:** Michael Foord

**Note:** There is a French translation of an earlier revision of this HOWTO, available at urllib2 - Le Manuel manquant.
Introduction

urllib.request is a Python module for fetching URLs (Uniform Resource Locators). It offers a very simple interface, in the form of the urlopen function. This is capable of fetching URLs using a variety of different protocols. It also offers a slightly more complex interface for handling common situations - like basic authentication, cookies, proxies and so on. These are provided by objects called handlers and openers.

urllib.request supports fetching URLs for many “URL schemes” (identified by the string before the “:” in URL - for example “ftp” is the URL scheme of “ftp://python.org/”) using their associated network protocols (e.g. FTP, HTTP). This tutorial focuses on the most common case, HTTP.

For straightforward situations urlopen is very easy to use. But as soon as you encounter errors or non-trivial cases when opening HTTP URLs, you will need some understanding of the HyperText Transfer Protocol. The most comprehensive and authoritative reference to HTTP is RFC 2616. This is a technical document and not intended to be easy to read. This HOWTO aims to illustrate using urllib, with enough detail about HTTP to help you through. It is not intended to replace the urllib.request docs, but is supplementary to them.
Fetching URLs

The simplest way to use urllib.request is as follows:

```python
import urllib.request
with urllib.request.urlopen('http://python.org/') as html:
    html = response.read()
```

If you wish to retrieve a resource via URL and store it in a temporary location, you can do so via the `urlretrieve()` function:

```python
import urllib.request
local_filename, headers = urllib.request.urlretrieve()
html = open(local_filename)
```

Many uses of urllib will be that simple (note that instead of an ‘http:’ URL we could have used an URL starting with ‘ftp:’, ‘file:’, etc.). However, it's the purpose of this tutorial to explain the more complicated cases, concentrating on HTTP.

HTTP is based on requests and responses - the client makes requests and servers send responses. urllib.request mirrors this with a `Request` object which represents the HTTP request you are making. In its simplest form you create a `Request` object that specifies the URL you want to fetch. Calling `urlopen` with this `Request` object returns a response object for the URL requested. This response is a file-like object, which means you can for example call `.read()` on the response:

```python
import urllib.request
```
req = urllib.request.Request(http://www.voidspace.org.uk)

with urllib.request.urlopen(req) as response:
    the_page = response.read()

Note that urllib.request makes use of the same Request interface to handle all URL schemes. For example, you can make an FTP request like so:

req = urllib.request.Request(ftp://example.com/)

In the case of HTTP, there are two extra things that Request objects allow you to do: First, you can pass data to be sent to the server. Second, you can pass extra information (“metadata”) about the data or the about request itself, to the server - this information is sent as HTTP “headers”. Let's look at each of these in turn.

Data

Sometimes you want to send data to a URL (often the URL will refer to a CGI (Common Gateway Interface) script or other web application). With HTTP, this is often done using what's known as a POST request. This is often what your browser does when you submit a HTML form that you filled in on the web. Not all POSTs have to come from forms: you can use a POST to transmit arbitrary data to your own application. In the common case of HTML forms, the data needs to be encoded in a standard way, and then passed to the Request object as the data argument. The encoding is done using a function from the urllib.parse library.

import urllib.parse
import urllib.request
url = 'http://www.someserver.com/cgi-bin/register.cgi'
values = { 'name' : 'Michael Foord',
            'location' : 'Northampton',
            'language' : 'Python' }

data = urllib.parse.urlencode(values)
data = data.encode('utf-8') # data should be bytes
req = urllib.request.Request(url, data)
with urllib.request.urlopen(req) as response:
    the_page = response.read()

Note that other encodings are sometimes required (e.g. for file upload from HTML forms - see HTML Specification, Form Submission for more details).

If you do not pass the data argument, urllib uses a **GET** request. One way in which GET and POST requests differ is that POST requests often have “side-effects”: they change the state of the system in some way (for example by placing an order with the website for a hundredweight of tinned spam to be delivered to your door). Though the HTTP standard makes it clear that POSTs are intended to **always** cause side-effects, and GET requests **never** to cause side-effects, nothing prevents a GET request from having side-effects, nor a POST requests from having no side-effects. Data can also be passed in an HTTP GET request by encoding it in the URL itself.

This is done as follows:

```python
>>> import urllib.request
>>> import urllib.parse
>>> data = {}
>>> data['name'] = 'Somebody Here'
>>> data['location'] = 'Northampton'
>>> data['language'] = 'Python'
```
Notice that the full URL is created by adding a ? to the URL, followed by the encoded values.

Headers

We'll discuss here one particular HTTP header, to illustrate how to add headers to your HTTP request.

Some websites [1] dislike being browsed by programs, or send different versions to different browsers [2]. By default urllib identifies itself as Python-urllib/x.y (where x and y are the major and minor version numbers of the Python release, e.g. Python-urllib/2.5), which may confuse the site, or just plain not work. The way a browser identifies itself is through the User-Agent header [3]. When you create a Request object you can pass a dictionary of headers in. The following example makes the same request as above, but identifies itself as a version of Internet Explorer [4].

```python
import urllib.parse
import urllib.request

url = 'http://www.someserver.com/cgi-bin/register.cgi'
user_agent = 'Mozilla/5.0 (Windows NT 6.1; Win64; x64)
values = {'name' : 'Michael Foord',
          'location' : 'Northampton',
          'language' : 'Python' }
```
headers = {'User-Agent': user_agent}

data = urllib.parse.urlencode(values)
data = data.encode('utf-8')
req = urllib.request.Request(url, data, headers)
with urllib.request.urlopen(req) as response:
    the_page = response.read()

The response also has two useful methods. See the section on info and geturl which comes after we have a look at what happens when things go wrong.
Handling Exceptions

`urlopen` raises `URLError` when it cannot handle a response (though as usual with Python APIs, built-in exceptions such as `ValueError`, `TypeError` etc. may also be raised).

HTTPError is the subclass of `URLError` raised in the specific case of HTTP URLs.

The exception classes are exported from the `urllib.error` module.

**URLError**

Often, `URLError` is raised because there is no network connection (no route to the specified server), or the specified server doesn’t exist. In this case, the exception raised will have a ‘reason’ attribute, which is a tuple containing an error code and a text error message.

e.g.

```python
>>> req = urllib.request.Request('http://www.pretend_server.org')
>>> try:
...     urllib.request.urlopen(req)
... except urllib.error.URLError as e:
...     print(e.reason)
... (4, 'getaddrinfo failed')
```

**HTTPError**

Every HTTP response from the server contains a numeric “status code”. Sometimes the status code indicates that the server is unable
to fulfil the request. The default handlers will handle some of these responses for you (for example, if the response is a “redirection” that requests the client fetch the document from a different URL, urllib will handle that for you). For those it can’t handle, urlopen will raise an HTTPError. Typical errors include ‘404’ (page not found), ‘403’ (request forbidden), and ‘401’ (authentication required).

See section 10 of RFC 2616 for a reference on all the HTTP error codes.

The HTTPError instance raised will have an integer ‘code’ attribute, which corresponds to the error sent by the server.

Error Codes

Because the default handlers handle redirects (codes in the 300 range), and codes in the 100-299 range indicate success, you will usually only see error codes in the 400-599 range.

`http.server.BaseHTTPRequestHandler.responses` is a useful dictionary of response codes in that shows all the response codes used by RFC 2616. The dictionary is reproduced here for convenience.

```
# Table mapping response codes to messages; entries # form {code: (shortmessage, longmessage)}.
responses = {
    100: ('Continue', 'Request received, please continue'),
    101: ('Switching Protocols', 'Switching to new protocol; obey Upgrade header'),
    200: ('OK', 'Request fulfilled, document follows'),
    201: ('Created', 'Document created, URL follows'),
    202: ('Accepted', 'Request accepted, processing continues of
```
203: (Non-Authoritative Information, Request fulfilled, nothing following)
204: (No Content, Request fulfilled, nothing follows)
205: (Reset Content, Clear input form for further input)
206: (Partial Content, Partial content follows)
300: (Multiple Choices, Object has several resources -- see URI list)
301: (Moved Permanently, Object moved permanently -- see URI list)
302: (Found, Object moved temporarily -- see URI list)
303: (See Other, Object moved -- see Method and URL list)
304: (Not Modified, Document has not changed since given time)
305: (Use Proxy, You must use proxy specified in Location resource.)
307: (Temporary Redirect, Object moved temporarily -- see URI list)
400: (Bad Request, Bad request syntax or unsupported method)
401: (Unauthorized, No permission -- see authorization schemes)
402: (Payment Required, No payment -- see charging schemes)
403: (Forbidden, Request forbidden -- authorization will not help)
404: (Not Found, Nothing matches the given URI)
405: (Method Not Allowed, Specified method is invalid for this server)
406: (Not Acceptable, URI not available in preferred format)
407: (Proxy Authentication Required, You must authenticate with this proxy before proceeding)
408: (Request Timeout, Request timed out; try again later)
409: (Conflict, Request conflict)
410: (Gone, URI no longer exists and has been permanently removed)
411: (Length Required, Client must specify Content-Length)
When an error is raised, the server responds by returning an HTTP error code and an error page. You can use the HTTPError instance as a response on the page returned. This means that as well as the code attribute, it also has read, geturl, and info, methods as returned by the urllib.response module:

```python
>>> req = urllib.request.Request('http://www.python.org/fish.html')
```
Wrapping it Up

So if you want to be prepared for HTTPError or URLError there are two basic approaches. I prefer the second approach.

Number 1

```python
from urllib.request import Request, urlopen
from urllib.error import URLError, HTTPError
req = Request(someurl)
try:
    response = urlopen(req)
except HTTPError as e:
    print('The server couldn’t fulfill the request.
    print('Error code: ', e.code)
except URLError as e:
    print('We failed to reach a server.
    print('Reason: ', e.reason)
else:
    # everything is fine
```

**Note:** The except HTTPError must come first, otherwise except URLError will also catch an HTTPError.

Number 2

```python
from urllib.request import Request, urlopen
```
from urllib.error import URLError
req = Request(someurl)
try:
    response = urlopen(req)
except URLError as e:
    if hasattr(e, 'reason'):
        print('We failed to reach a server.')
        print('Reason: ', e.reason)
    elif hasattr(e, 'code'):
        print('The server couldn\'t fulfill the request.')
        print('Error code: ', e.code)
else:
    # everything is fine
info and geturl

The response returned by urlopen (or the HTTPError instance) has two useful methods info() and geturl() and is defined in the module urllib.response.

geturl - this returns the real URL of the page fetched. This is useful because urlopen (or the opener object used) may have followed a redirect. The URL of the page fetched may not be the same as the URL requested.

info - this returns a dictionary-like object that describes the page fetched, particularly the headers sent by the server. It is currently an http.client.HTTPMessage instance.

Typical headers include ‘Content-length’, ‘Content-type’, and so on. See the Quick Reference to HTTP Headers for a useful listing of HTTP headers with brief explanations of their meaning and use.
Openers and Handlers

When you fetch a URL you use an opener (an instance of the perhaps confusingly-named `urllib.request.OpenerDirector`). Normally we have been using the default opener - via `urlopen` - but you can create custom openers. Openers use handlers. All the “heavy lifting” is done by the handlers. Each handler knows how to open URLs for a particular URL scheme (http, ftp, etc.), or how to handle an aspect of URL opening, for example HTTP redirections or HTTP cookies.

You will want to create openers if you want to fetch URLs with specific handlers installed, for example to get an opener that handles cookies, or to get an opener that does not handle redirections.

To create an opener, instantiate an `OpenerDirector`, and then call `add_handler(some_handler_instance)` repeatedly.

Alternatively, you can use `build_opener`, which is a convenience function for creating opener objects with a single function call. `build_opener` adds several handlers by default, but provides a quick way to add more and/or override the default handlers.

Other sorts of handlers you might want to can handle proxies, authentication, and other common but slightly specialised situations.

`install_opener` can be used to make an opener object the (global) default opener. This means that calls to `urlopen` will use the opener you have installed.

Opener objects have an open method, which can be called directly to fetch urls in the same way as the `urlopen` function: there’s no need to call `install_opener`, except as a convenience.
Basic Authentication

To illustrate creating and installing a handler we will use the HTTPBasicAuthHandler. For a more detailed discussion of this subject – including an explanation of how Basic Authentication works - see the Basic Authentication Tutorial.

When authentication is required, the server sends a header (as well as the 401 error code) requesting authentication. This specifies the authentication scheme and a ‘realm’. The header looks like: WWW-Authenticate: SCHEME realm="REALM".

e.g.

```text
WWW-Authenticate: Basic realm="cPanel Users"
```

The client should then retry the request with the appropriate name and password for the realm included as a header in the request. This is ‘basic authentication’. In order to simplify this process we can create an instance of HTTPBasicAuthHandler and an opener to use this handler.

The HTTPBasicAuthHandler uses an object called a password manager to handle the mapping of URLs and realms to passwords and usernames. If you know what the realm is (from the authentication header sent by the server), then you can use a HTTPPasswordMgr. Frequently one doesn’t care what the realm is. In that case, it is convenient to use HTTPPasswordMgrWithDefaultRealm. This allows you to specify a default username and password for a URL. This will be supplied in the absence of you providing an alternative combination for a specific realm. We indicate this by providing None
as the realm argument to the `add_password` method.

The top-level URL is the first URL that requires authentication. URLs “deeper” than the URL you pass to `.add_password()` will also match.

```python
# create a password manager
password_mgr = urllib.request.HTTPPasswordMgrWithDefaultRealm()

# Add the username and password.
# If we knew the realm, we could use it instead of None.
top_level_url = "http://example.com/foo/
password_mgr.add_password(None, top_level_url, username, password)

handler = urllib.request.HTTPBasicAuthHandler(password_mgr)

# create "opener" (OpenerDirector instance)
opener = urllib.request.build_opener(handler)

# use the opener to fetch a URL
opener.open(a_url)

# Install the opener.
# Now all calls to urllib.request.urlopen use our opener
urllib.request.install_opener(opener)
```

**Note:** In the above example we only supplied our `HTTPBasicAuthHandler` to build_opener. By default openers have the handlers for normal situations – `ProxyHandler` (if a proxy setting such as an `http_proxy` environment variable is set), `UnknownHandler`, `HTTPHandler`, `HTTPDefaultErrorHandler`, `HTTPRedirectHandler`, `FTPHandler`, `FileHandler`, `DataHandler`, `HTTPRedirectHandler`. 
top_level_url is in fact either a full URL (including the ‘http’ scheme component and the hostname and optionally the port number) e.g. “http://example.com/” or an “authority” (i.e. the hostname, optionally including the port number) e.g. “example.com” or “example.com:8080” (the latter example includes a port number). The authority, if present, must NOT contain the “userinfo” component - for example “joe@password:example.com” is not correct.
Proxies

**urllib** will auto-detect your proxy settings and use those. This is through the `ProxyHandler`, which is part of the normal handler chain when a proxy setting is detected. Normally that’s a good thing, but there are occasions when it may not be helpful [5]. One way to do this is to setup our own `ProxyHandler`, with no proxies defined. This is done using similar steps to setting up a **Basic Authentication** handler:

```python
>>> proxy_support = urllib.request.ProxyHandler({})
>>> opener = urllib.request.build_opener(proxy_support)
>>> urllib.request.install_opener(opener)
```

**Note:** Currently **urllib.request** *does not* support fetching of https locations through a proxy. However, this can be enabled by extending urllib.request as shown in the recipe [6].
Sockets and Layers

The Python support for fetching resources from the web is layered. `urllib` uses the `http.client` library, which in turn uses the socket library.

As of Python 2.3 you can specify how long a socket should wait for a response before timing out. This can be useful in applications which have to fetch web pages. By default the socket module has *no timeout* and can hang. Currently, the socket timeout is not exposed at the `http.client` or `urllib.request` levels. However, you can set the default timeout globally for all sockets using

```python
import socket
import urllib.request

# timeout in seconds
timeout = 10
socket.setdefaulttimeout(timeout)

# this call to urllib.request.urlopen now uses the default timeout we have set in the socket module
req = urllib.request.Request('http://www.voidspace.org.uk')
response = urllib.request.urlopen(req)
```
Footnotes

This document was reviewed and revised by John Lee.

[1] Google for example. Browser sniffing is a very bad practise for website design - building sites using web standards is much more sensible. Unfortunately a lot of sites still send different versions to different browsers.

[2] The user agent for MSIE 6 is ‘Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; SV1; .NET CLR 1.1.4322)’

[3] For details of more HTTP request headers, see Quick Reference to HTTP Headers.

[4] In my case I have to use a proxy to access the internet at work. If you attempt to fetch localhost URLs through this proxy it blocks them. IE is set to use the proxy, which urllib picks up on. In order to test scripts with a localhost server, I have to prevent urllib from using the proxy.

HOWTO Use Python in the web

Author: Marek Kubica

Abstract

This document shows how Python fits into the web. It presents some ways to integrate Python with a web server, and general practices useful for developing web sites.

Programming for the Web has become a hot topic since the rise of “Web 2.0”, which focuses on user-generated content on web sites. It has always been possible to use Python for creating web sites, but it was a rather tedious task. Therefore, many frameworks and helper tools have been created to assist developers in creating faster and more robust sites. This HOWTO describes some of the methods used to combine Python with a web server to create dynamic content. It is not meant as a complete introduction, as this topic is far too broad to be covered in one single document. However, a short overview of the most popular libraries is provided.

See also: While this HOWTO tries to give an overview of Python in the web, it cannot always be as up to date as desired. Web development in Python is rapidly moving forward, so the wiki page on Web Programming may be more in sync with recent development.
The Low-Level View

When a user enters a web site, their browser makes a connection to the site's web server (this is called the request). The server looks up the file in the file system and sends it back to the user's browser, which displays it (this is the response). This is roughly how the underlying protocol, HTTP, works.

Dynamic web sites are not based on files in the file system, but rather on programs which are run by the web server when a request comes in, and which generate the content that is returned to the user. They can do all sorts of useful things, like display the postings of a bulletin board, show your email, configure software, or just display the current time. These programs can be written in any programming language the server supports. Since most servers support Python, it is easy to use Python to create dynamic web sites.

Most HTTP servers are written in C or C++, so they cannot execute Python code directly – a bridge is needed between the server and the program. These bridges, or rather interfaces, define how programs interact with the server. There have been numerous attempts to create the best possible interface, but there are only a few worth mentioning.

Not every web server supports every interface. Many web servers only support old, now-obsolete interfaces; however, they can often be extended using third-party modules to support newer ones.

Common Gateway Interface

This interface, most commonly referred to as “CGI”, is the oldest, and is supported by nearly every web server out of the box. Programs
using CGI to communicate with their web server need to be started by the server for every request. So, every request starts a new Python interpreter – which takes some time to start up – thus making the whole interface only usable for low load situations.

The upside of CGI is that it is simple – writing a Python program which uses CGI is a matter of about three lines of code. This simplicity comes at a price: it does very few things to help the developer.

Writing CGI programs, while still possible, is no longer recommended. With WSGI, a topic covered later in this document, it is possible to write programs that emulate CGI, so they can be run as CGI if no better option is available.

See also: The Python standard library includes some modules that are helpful for creating plain CGI programs:

- **cgi** – Handling of user input in CGI scripts
- **cgitb** – Displays nice tracebacks when errors happen in CGI applications, instead of presenting a “500 Internal Server Error” message

The Python wiki features a page on CGI scripts with some additional information about CGI in Python.

Simple script for testing CGI

To test whether your web server works with CGI, you can use this short and simple CGI program:

```
#!/usr/bin/env python
#
# -*- coding: UTF-8 -*-

# enable debugging
```
import cgitb

```python
cgitb.enable()

print("Content-Type: text/plain;charset=utf-8")
print()
print("Hello World!")
```

Depending on your web server configuration, you may need to save this code with a .py or .cgi extension. Additionally, this file may also need to be in a cgi-bin folder, for security reasons.

You might wonder what the cgitb line is about. This line makes it possible to display a nice traceback instead of just crashing and displaying an “Internal Server Error” in the user’s browser. This is useful for debugging, but it might risk exposing some confidential data to the user. You should not use cgitb in production code for this reason. You should *always* catch exceptions, and display proper error pages – end-users don’t like to see nondescript “Internal Server Errors” in their browsers.

**Setting up CGI on your own server**

If you don’t have your own web server, this does not apply to you. You can check whether it works as-is, and if not you will need to talk to the administrator of your web server. If it is a big host, you can try filing a ticket asking for Python support.

If you are your own administrator or want to set up CGI for testing purposes on your own computers, you have to configure it by yourself. There is no single way to configure CGI, as there are many web servers with different configuration options. Currently the most widely used free web server is **Apache HTTPd**, or Apache for short. Apache
can be easily installed on nearly every system using the system's package management tool. **lighttpd** is another alternative and is said to have better performance. On many systems this server can also be installed using the package management tool, so manually compiling the web server may not be needed.

- On Apache you can take a look at the [Dynamic Content with CGI](https://httpd.apache.org/docs/2.4/howto/dynamic.html) tutorial, where everything is described. Most of the time it is enough just to set +ExecCGI. The tutorial also describes the most common gotchas that might arise.
- On lighttpd you need to use the **CGI module**, which can be configured in a straightforward way. It boils down to setting `cgi.assign` properly.

**Common problems with CGI scripts**

Using CGI sometimes leads to small annoyances while trying to get these scripts to run. Sometimes a seemingly correct script does not work as expected, the cause being some small hidden problem that's difficult to spot.

Some of these potential problems are:

- The Python script is not marked as executable. When CGI scripts are not executable most web servers will let the user download it, instead of running it and sending the output to the user. For CGI scripts to run properly on Unix-like operating systems, the +x bit needs to be set. Using `chmod a+x your_script.py` may solve this problem.
- On a Unix-like system, the line endings in the program file must be Unix style line endings. This is important because the web server checks the first line of the script (called shebang) and tries to run the program specified there. It gets easily confused by Windows line endings (Carriage Return & Line Feed, also called
CRLF), so you have to convert the file to Unix line endings (only Line Feed, LF). This can be done automatically by uploading the file via FTP in text mode instead of binary mode, but the preferred way is just telling your editor to save the files with Unix line endings. Most editors support this.

- Your web server must be able to read the file, and you need to make sure the permissions are correct. On unix-like systems, the server often runs as user and group www-data, so it might be worth a try to change the file ownership, or making the file world readable by using chmod a+r your_script.py.

- The web server must know that the file you're trying to access is a CGI script. Check the configuration of your web server, as it may be configured to expect a specific file extension for CGI scripts.

- On Unix-like systems, the path to the interpreter in the shebang (#!/usr/bin/env python) must be correct. This line calls /usr/bin/env to find Python, but it will fail if there is no /usr/bin/env, or if Python is not in the web server's path. If you know where your Python is installed, you can also use that full path. The commands whereis python and type -p python could help you find where it is installed. Once you know the path, you can change the shebang accordingly: #!/usr/bin/python.

- The file must not contain a BOM (Byte Order Mark). The BOM is meant for determining the byte order of UTF-16 and UTF-32 encodings, but some editors write this also into UTF-8 files. The BOM interferes with the shebang line, so be sure to tell your editor not to write the BOM.

- If the web server is using mod_python, mod_python may be having problems. mod_python is able to handle CGI scripts by itself, but it can also be a source of issues.

mod_python
People coming from PHP often find it hard to grasp how to use Python in the web. Their first thought is mostly mod_python, because they think that this is the equivalent to mod_php. Actually, there are many differences. What mod_python does is embed the interpreter into the Apache process, thus speeding up requests by not having to start a Python interpreter for each request. On the other hand, it is not “Python intermixed with HTML” in the way that PHP is often intermixed with HTML. The Python equivalent of that is a template engine. mod_python itself is much more powerful and provides more access to Apache internals. It can emulate CGI, work in a “Python Server Pages” mode (similar to JSP) which is “HTML intermingled with Python”, and it has a “Publisher” which designates one file to accept all requests and decide what to do with them.

mod_python does have some problems. Unlike the PHP interpreter, the Python interpreter uses caching when executing files, so changes to a file will require the web server to be restarted. Another problem is the basic concept – Apache starts child processes to handle the requests, and unfortunately every child process needs to load the whole Python interpreter even if it does not use it. This makes the whole web server slower. Another problem is that, because mod_python is linked against a specific version of libpython, it is not possible to switch from an older version to a newer (e.g. 2.4 to 2.5) without recompiling mod_python. mod_python is also bound to the Apache web server, so programs written for mod_python cannot easily run on other web servers.

These are the reasons why mod_python should be avoided when writing new programs. In some circumstances it still might be a good idea to use mod_python for deployment, but WSGI makes it possible to run WSGI programs under mod_python as well.
FastCGI and SCGI

FastCGI and SCGI try to solve the performance problem of CGI in another way. Instead of embedding the interpreter into the web server, they create long-running background processes. There is still a module in the web server which makes it possible for the web server to “speak” with the background process. As the background process is independent of the server, it can be written in any language, including Python. The language just needs to have a library which handles the communication with the webservers.

The difference between FastCGI and SCGI is very small, as SCGI is essentially just a “simpler FastCGI”. As the web server support for SCGI is limited, most people use FastCGI instead, which works the same way. Almost everything that applies to SCGI also applies to FastCGI as well, so we'll only cover the latter.

These days, FastCGI is never used directly. Just like mod_python, it is only used for the deployment of WSGI applications.

Setting up FastCGI

Each web server requires a specific module.

- Apache has both mod_fastcgi and mod_fcgid. mod_fastcgi is the original one, but it has some licensing issues, which is why it is sometimes considered non-free. mod_fcgid is a smaller, compatible alternative. One of these modules needs to be loaded by Apache.
- lighttpd ships its own FastCGI module as well as an SCGI module.
- nginx also supports FastCGI.
Once you have installed and configured the module, you can test it with the following WSGI-application:

```python
#!/usr/bin/env python
# -*- coding: UTF-8 -*-

import sys, os
from html import escape
from flup.server.fcgi import WSGIServer

def app(environ, start_response):
    start_response('200 OK', [('Content-Type', 'text/html')])
    yield '<h1>FastCGI Environment</h1>'
    yield '<table>'
    for k, v in sorted(environ.items()):
        yield '<tr><th>{0}</th><td>{1}</td></tr>'.format(escape(k), escape(v))
    yield '</table>'

WSGIServer(app).run()
```

This is a simple WSGI application, but you need to install flup first, as flup handles the low level FastCGI access.

**See also:** There is some documentation on setting up Django with FastCGI, most of which can be reused for other WSGI-compliant frameworks and libraries. Only the manage.py part has to be changed, the example used here can be used instead. Django does more or less the exact same thing.

**mod_wsgi**

**mod_wsgi** is an attempt to get rid of the low level gateways. Given that
FastCGI, SCGI, and mod_python are mostly used to deploy WSGI applications, mod_wsgi was started to directly embed WSGI applications into the Apache web server. mod_wsgi is specifically designed to host WSGI applications. It makes the deployment of WSGI applications much easier than deployment using other low level methods, which need glue code. The downside is that mod_wsgi is limited to the Apache web server; other servers would need their own implementations of mod_wsgi.

mod_wsgi supports two modes: embedded mode, in which it integrates with the Apache process, and daemon mode, which is more FastCGI-like. Unlike FastCGI, mod_wsgi handles the worker-processes by itself, which makes administration easier.
Step back: WSGI

WSGI has already been mentioned several times, so it has to be something important. In fact it really is, and now it is time to explain it.

The Web Server Gateway Interface, or WSGI for short, is defined in PEP 333 and is currently the best way to do Python web programming. While it is great for programmers writing frameworks, a normal web developer does not need to get in direct contact with it. When choosing a framework for web development it is a good idea to choose one which supports WSGI.

The big benefit of WSGI is the unification of the application programming interface. When your program is compatible with WSGI – which at the outer level means that the framework you are using has support for WSGI – your program can be deployed via any web server interface for which there are WSGI wrappers. You do not need to care about whether the application user uses mod_python or FastCGI or mod_wsgi – with WSGI your application will work on any gateway interface. The Python standard library contains its own WSGI server, wsgiref, which is a small web server that can be used for testing.

A really great WSGI feature is middleware. Middleware is a layer around your program which can add various functionality to it. There is quite a bit of middleware already available. For example, instead of writing your own session management (HTTP is a stateless protocol, so to associate multiple HTTP requests with a single user your application must create and manage such state via a session), you can just download middleware which does that, plug it in, and get on with coding the unique parts of your application. The same thing with compression – there is existing middleware which handles compressing your HTML using gzip to save on your server's
bandwidth. Authentication is another a problem easily solved using existing middleware.

Although WSGI may seem complex, the initial phase of learning can be very rewarding because WSGI and the associated middleware already have solutions to many problems that might arise while developing web sites.

WSGI Servers

The code that is used to connect to various low level gateways like CGI or mod_python is called a WSGI server. One of these servers is flup, which supports FastCGI and SCGI, as well as AJP. Some of these servers are written in Python, as flup is, but there also exist others which are written in C and can be used as drop-in replacements.

There are many servers already available, so a Python web application can be deployed nearly anywhere. This is one big advantage that Python has compared with other web technologies.

See also: A good overview of WSGI-related code can be found in the WSGI homepage, which contains an extensive list of WSGI servers which can be used by any application supporting WSGI.

You might be interested in some WSGI-supporting modules already contained in the standard library, namely:

- wsgiref – some tiny utilities and servers for WSGI

Case study: MoinMoin
What does WSGI give the web application developer? Let’s take a look at an application that’s been around for a while, which was written in Python without using WSGI.

One of the most widely used wiki software packages is MoinMoin. It was created in 2000, so it predates WSGI by about three years. Older versions needed separate code to run on CGI, mod_python, FastCGI and standalone.

It now includes support for WSGI. Using WSGI, it is possible to deploy MoinMoin on any WSGI compliant server, with no additional glue code. Unlike the pre-WSGI versions, this could include WSGI servers that the authors of MoinMoin know nothing about.
Model-View-Controller

The term MVC is often encountered in statements such as “framework foo supports MVC”. MVC is more about the overall organization of code, rather than any particular API. Many web frameworks use this model to help the developer bring structure to their program. Bigger web applications can have lots of code, so it is a good idea to have an effective structure right from the beginning. That way, even users of other frameworks (or even other languages, since MVC is not Python-specific) can easily understand the code, given that they are already familiar with the MVC structure.

MVC stands for three components:

- The **model**. This is the data that will be displayed and modified. In Python frameworks, this component is often represented by the classes used by an object-relational mapper.
- The **view**. This component’s job is to display the data of the model to the user. Typically this component is implemented via templates.
- The **controller**. This is the layer between the user and the model. The controller reacts to user actions (like opening some specific URL), tells the model to modify the data if necessary, and tells the view code what to display.

While one might think that MVC is a complex design pattern, in fact it is not. It is used in Python because it has turned out to be useful for creating clean, maintainable web sites.

**Note:** While not all Python frameworks explicitly support MVC, it is often trivial to create a web site which uses the MVC pattern by separating the data logic (the model) from the user interaction logic.
(the controller) and the templates (the view). That's why it is important not to write unnecessary Python code in the templates – it works against the MVC model and creates chaos in the code base, making it harder to understand and modify.

**See also:** The English Wikipedia has an article about the Model-View-Controller pattern. It includes a long list of web frameworks for various programming languages.
Ingredients for Websites

Websites are complex constructs, so tools have been created to help web developers make their code easier to write and more maintainable. Tools like these exist for all web frameworks in all languages. Developers are not forced to use these tools, and often there is no “best” tool. It is worth learning about the available tools because they can greatly simplify the process of developing a website.

See also: There are far more components than can be presented here. The Python wiki has a page about these components, called Web Components.

Templates

Mixing of HTML and Python code is made possible by a few libraries. While convenient at first, it leads to horribly unmaintainable code. That’s why templates exist. Templates are, in the simplest case, just HTML files with placeholders. The HTML is sent to the user’s browser after filling in the placeholders.

Python already includes a way to build simple templates:

```python
# a simple template
template = "<html><body><h1>Hello {who}!</h1></body>
print(template.format(who="Reader"))
```

To generate complex HTML based on non-trivial model data, conditional and looping constructs like Python’s for and if are generally needed. Template engines support templates of this complexity.
There are a lot of template engines available for Python which can be used with or without a framework. Some of these define a plain-text programming language which is easy to learn, partly because it is limited in scope. Others use XML, and the template output is guaranteed to be always be valid XML. There are many other variations.

Some frameworks ship their own template engine or recommend one in particular. In the absence of a reason to use a different template engine, using the one provided by or recommended by the framework is a good idea.

Popular template engines include:

- Mako
- Genshi
- Jinja

See also: There are many template engines competing for attention, because it is pretty easy to create them in Python. The page Templating in the wiki lists a big, ever-growing number of these. The three listed above are considered “second generation” template engines and are a good place to start.

Data persistence

Data persistence, while sounding very complicated, is just about storing data. This data might be the text of blog entries, the postings on a bulletin board or the text of a wiki page. There are, of course, a number of different ways to store information on a web server.

Often, relational database engines like MySQL or PostgreSQL are used because of their good performance when handling very large
databases consisting of millions of entries. There is also a small database engine called SQLite, which is bundled with Python in the sqlite3 module, and which uses only one file. It has no other dependencies. For smaller sites SQLite is just enough.

Relational databases are queried using a language called SQL. Python programmers in general do not like SQL too much, as they prefer to work with objects. It is possible to save Python objects into a database using a technology called ORM (Object Relational Mapping). ORM translates all object-oriented access into SQL code under the hood, so the developer does not need to think about it. Most frameworks use ORMs, and it works quite well.

A second possibility is storing data in normal, plain text files (sometimes called “flat files”). This is very easy for simple sites, but can be difficult to get right if the web site is performing many updates to the stored data.

A third possibility are object oriented databases (also called “object databases”). These databases store the object data in a form that closely parallels the way the objects are structured in memory during program execution. (By contrast, ORMs store the object data as rows of data in tables and relations between those rows.) Storing the objects directly has the advantage that nearly all objects can be saved in a straightforward way, unlike in relational databases where some objects are very hard to represent.

Frameworks often give hints on which data storage method to choose. It is usually a good idea to stick to the data store recommended by the framework unless the application has special requirements better satisfied by an alternate storage mechanism.

See also:
• **Persistence Tools** lists possibilities on how to save data in the file system. Some of these modules are part of the standard library

• **Database Programming** helps with choosing a method for saving data

• **SQLAlchemy**, the most powerful OR-Mapper for Python, and **Elixir**, which makes SQLAlchemy easier to use

• **SQLObject**, another popular OR-Mapper

• **ZODB** and **Durus**, two object oriented databases
Frameworks

The process of creating code to run web sites involves writing code to provide various services. The code to provide a particular service often works the same way regardless of the complexity or purpose of the web site in question. Abstracting these common solutions into reusable code produces what are called “frameworks” for web development. Perhaps the most well-known framework for web development is Ruby on Rails, but Python has its own frameworks. Some of these were partly inspired by Rails, or borrowed ideas from Rails, but many existed a long time before Rails.

Originally Python web frameworks tended to incorporate all of the services needed to develop web sites as a giant, integrated set of tools. No two web frameworks were interoperable: a program developed for one could not be deployed on a different one without considerable re-engineering work. This led to the development of “minimalist” web frameworks that provided just the tools to communicate between the Python code and the http protocol, with all other services to be added on top via separate components. Some ad hoc standards were developed that allowed for limited interoperability between frameworks, such as a standard that allowed different template engines to be used interchangeably.

Since the advent of WSGI, the Python web framework world has been evolving toward interoperability based on the WSGI standard. Now many web frameworks, whether “full stack” (providing all the tools one needs to deploy the most complex web sites) or minimalist, or anything in between, are built from collections of reusable components that can be used with more than one framework.

The majority of users will probably want to select a “full stack”
framework that has an active community. These frameworks tend to be well documented, and provide the easiest path to producing a fully functional web site in minimal time.

Some notable frameworks

There are an incredible number of frameworks, so they cannot all be covered here. Instead we will briefly touch on some of the most popular.

Django

**Django** is a framework consisting of several tightly coupled elements which were written from scratch and work together very well. It includes an ORM which is quite powerful while being simple to use, and has a great online administration interface which makes it possible to edit the data in the database with a browser. The template engine is text-based and is designed to be usable for page designers who cannot write Python. It supports template inheritance and filters (which work like Unix pipes). Django has many handy features bundled, such as creation of RSS feeds or generic views, which make it possible to create web sites almost without writing any Python code.

It has a big, international community, the members of which have created many web sites. There are also a lot of add-on projects which extend Django’s normal functionality. This is partly due to Django’s well written online documentation and the **Django book**.

**Note:** Although Django is an MVC-style framework, it names the elements differently, which is described in the **Django FAQ**.

TurboGears
Another popular web framework for Python is TurboGears. TurboGears takes the approach of using already existing components and combining them with glue code to create a seamless experience. TurboGears gives the user flexibility in choosing components. For example, the ORM and template engine can be changed to use packages different from those used by default.

The documentation can be found in the TurboGears wiki, where links to screencasts can be found. TurboGears has also an active user community which can respond to most related questions. There is also a TurboGears book published, which is a good starting point.

The newest version of TurboGears, version 2.0, moves even further in direction of WSGI support and a component-based architecture. TurboGears 2 is based on the WSGI stack of another popular component-based web framework, Pylons.

Zope

The Zope framework is one of the “old original” frameworks. Its current incarnation in Zope2 is a tightly integrated full-stack framework. One of its most interesting feature is its tight integration with a powerful object database called the ZODB (Zope Object Database). Because of its highly integrated nature, Zope wound up in a somewhat isolated ecosystem: code written for Zope wasn’t very usable outside of Zope, and vice-versa. To solve this problem the Zope 3 effort was started. Zope 3 re-engineers Zope as a set of more cleanly isolated components. This effort was started before the advent of the WSGI standard, but there is WSGI support for Zope 3 from the Repoze project. Zope components have many years of production use behind them, and the Zope 3 project gives access to these components to the wider Python community. There is even a separate framework based
on the Zope components: Grok.

Zope is also the infrastructure used by the Plone content management system, one of the most powerful and popular content management systems available.

Other notable frameworks

Of course these are not the only frameworks that are available. There are many other frameworks worth mentioning.

Another framework that's already been mentioned is Pylons. Pylons is much like TurboGears, but with an even stronger emphasis on flexibility, which comes at the cost of being more difficult to use. Nearly every component can be exchanged, which makes it necessary to use the documentation of every single component, of which there are many. Pylons builds upon Paste, an extensive set of tools which are handy for WSGI.

And that’s still not everything. The most up-to-date information can always be found in the Python wiki.

See also: The Python wiki contains an extensive list of web frameworks.

Most frameworks also have their own mailing lists and IRC channels, look out for these on the projects’ web sites.
Argparse Tutorial

**author:** Tshepang Lekhonkhobe

This tutorial is intended to be a gentle introduction to **argparse**, the recommended command-line parsing module in the Python standard library.

**Note:** There are two other modules that fulfill the same task, namely **getopt** (an equivalent for getopt() from the C language) and the deprecated **optparse**. Note also that **argparse** is based on **optparse**, and therefore very similar in terms of usage.
Concepts

Let's show the sort of functionality that we are going to explore in this introductory tutorial by making use of the `ls` command:

$ ls
cpython devguide prog.py pypy rm-unused-function
$ ls pypy
ctypes_configure demo dotviewer include lib_pypy
$ ls -l
total 20
  drwxr-xr-x 19 wena wena 4096 Feb 18 18:51 cpython
drwxr-xr-x  4 wena wena 4096 Feb 8 12:04 devguide
-rwxr-xr-x  1 wena wena  535 Feb 19  00:05 prog.py
drwxr-xr-x 14 wena wena 4096 Feb  7  00:59 pypy
-rw-r--r--  1 wena wena  741 Feb 18  01:01 rm-unused-function
$ ls --help
Usage: ls [OPTION]... [FILE]...
List information about the FILEs (the current directory by default)
Sort entries alphabetically if none of -cftuvSUX nor --sort is specified.

A few concepts we can learn from the four commands:

- The `ls` command is useful when run without any options at all. It defaults to displaying the contents of the current directory.
- If we want beyond what it provides by default, we tell it a bit more. In this case, we want it to display a different directory, pypy. What we did is specify what is known as a positional argument. It's named so because the program should know what to do with the value, solely based on where it appears on the command line. This concept is more relevant to a command like `cp`, whose most basic usage is `cp SRC DEST`. The first position is *what you want copied*, and the second position is *where you want it copied to*.
• Now, say we want to change behaviour of the program. In our example, we display more info for each file instead of just showing the file names. The `-l` in that case is known as an optional argument.

• That's a snippet of the help text. It's very useful in that you can come across a program you have never used before, and can figure out how it works simply by reading its help text.
The basics

Let us start with a very simple example which does (almost) nothing:

```python
import argparse
parser = argparse.ArgumentParser()
parsers.parse_args()
```

Following is a result of running the code:

```
$ python3 prog.py
$ python3 prog.py --help
usage: prog.py [-h]

optional arguments:
  -h, --help    show this help message and exit

$ python3 prog.py --verbose
usage: prog.py [-h]
prog.py: error: unrecognized arguments: --verbose

$ python3 prog.py foo
usage: prog.py [-h]
prog.py: error: unrecognized arguments: foo
```

Here is what is happening:

- Running the script without any options results in nothing displayed to stdout. Not so useful.
- The second one starts to display the usefulness of the `argparse` module. We have done almost nothing, but already we get a nice help message.
- The `--help` option, which can also be shortened to `-h`, is the only option we get for free (i.e. no need to specify it). Specifying anything else results in an error. But even then, we do get a useful usage message, also for free.
Introducing Positional arguments

An example:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("echo")
args = parser.parse_args()
print(args.echo)
```

And running the code:

```
$ python3 prog.py
usage: prog.py [-h] echo
prog.py: error: the following arguments are required
$ python3 prog.py --help
usage: prog.py [-h] echo

positional arguments:
  echo

optional arguments:
  -h, --help    show this help message and exit
$ python3 prog.py foo
foo
```

Here is what's happening:

- We've added the `add_argument()` method, which is what we use to specify which command-line options the program is willing to accept. In this case, I've named it `echo` so that it's in line with its function.
- Calling our program now requires us to specify an option.
- The `parse_arg` method actually returns some data from the
options specified, in this case, echo.

- The variable is some form of ‘magic’ that `argparse` performs for free (i.e. no need to specify which variable that value is stored in). You will also notice that its name matches the string argument given to the method, echo.

Note however that, although the help display looks nice and all, it currently is not as helpful as it can be. For example we see that we got `echo` as a positional argument, but we don’t know what it does, other than by guessing or by reading the source code. So, let’s make it a bit more useful:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("echo", help="echo the string you use here")
args = parser.parse_args()
print(args.echo)
```

And we get:

```
$ python3 prog.py -h
usage: prog.py [-h] echo

positional arguments:
  echo          echo the string you use here

optional arguments:
  -h, --help    show this help message and exit
```

Now, how about doing something even more useful:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", help="display a square")
```
```python
args = parser.parse_args()
print(args.square**2)
```

Following is a result of running the code:

```
$ python3 prog.py 4
Traceback (most recent call last):
  File "prog.py", line 5, in <module>
    print(args.square**2)
TypeError: unsupported operand type(s) for ** or pow
```

That didn't go so well. That's because `argparse` treats the options we give it as strings, unless we tell it otherwise. So, let's tell `argparse` to treat that input as an integer:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", help="display a square of given number", type=int)
args = parser.parse_args()
print(args.square**2)
```

Following is a result of running the code:

```
$ python3 prog.py 4
16
$ python3 prog.py four
usage: prog.py [-h] square
prog.py: error: argument square: invalid int value:
```

That went well. The program now even helpfully quits on bad illegal input before proceeding.
Introducing Optional arguments

So far we have been playing with positional arguments. Let us have a look on how to add optional ones:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("--verbosity", help="increase output verbosity")
args = parser.parse_args()
if args.verbosity:
    print("verbosity turned on")
```

And the output:

```bash
$ python3 prog.py --verbosity 1
verbosity turned on
$ python3 prog.py
$ python3 prog.py --help
usage: prog.py [-h] [--verbosity VERBOSITY]
optional arguments:
  -h, --help              show this help message and exit
  --verbosity VERBOSITY   increase output verbosity
$ python3 prog.py --verbosity
usage: prog.py [-h] [--verbosity VERBOSITY]
prog.py: error: argument --verbosity: expected one argument
```

Here is what is happening:

- The program is written so as to display something when `--verbosity` is specified and display nothing when not.
- To show that the option is actually optional, there is no error when
running the program without it. Note that by default, if an optional argument isn't used, the relevant variable, in this case args.verbosity, is given None as a value, which is the reason it fails the truth test of the if statement.

- The help message is a bit different.
- When using the --verbosity option, one must also specify some value, any value.

The above example accepts arbitrary integer values for --verbosity, but for our simple program, only two values are actually useful, True or False. Let's modify the code accordingly:

```python
import argparse

parser = argparse.ArgumentParser()
parser.add_argument("--verbose", help="increase output verbosity", action="store_true")

args = parser.parse_args()
if args.verbose:
    print("verbosity turned on")
```

And the output:

```
$ python3 prog.py --verbose
verbosity turned on
$ python3 prog.py --verbose 1
usage: prog.py [-h] [--verbose]
prog.py: error: unrecognized arguments: 1
$ python3 prog.py --help
usage: prog.py [-h] [--verbose]

optional arguments:
  -h, --help    show this help message and exit
  --verbose     increase output verbosity
```
Here is what is happening:

- The option is now more of a flag than something that requires a value. We even changed the name of the option to match that idea. Note that we now specify a new keyword, action, and give it the value "store_true". This means that, if the option is specified, assign the value True to args.verbose. Not specifying it implies False.
- It complains when you specify a value, in true spirit of what flags actually are.
- Notice the different help text.

**Short options**

If you are familiar with command line usage, you will notice that I haven’t yet touched on the topic of short versions of the options. It’s quite simple:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("-v", "--verbose", help="increase output verbosity", action="store_true")
args = parser.parse_args()
if args.verbose:
    print("verbosity turned on")
```

And here goes:

```bash
$ python3 prog.py -v
verbosity turned on
$ python3 prog.py --help
usage: prog.py [-h] [-v]
onoptional arguments:
```
-h, --help   show this help message and exit
-v, --verbose  increase output verbosity

Note that the new ability is also reflected in the help text.
Combining Positional and Optional arguments

Our program keeps growing in complexity:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
    help="display a square of a given number")
parser.add_argument("-v", "--verbose", action="store_true",
    help="increase output verbosity")

args = parser.parse_args()
answer = args.square**2
if args.verbose:
    print("the square of {} equals {}".format(args.square, answer))
else:
    print(answer)
```

And now the output:

```
$ python3 prog.py
usage: prog.py [-h] [-v] square
prog.py: error: the following arguments are required
$ python3 prog.py 4
16
$ python3 prog.py 4 --verbose
the square of 4 equals 16
$ python3 prog.py --verbose 4
the square of 4 equals 16
```

- We’ve brought back a positional argument, hence the complaint.
- Note that the order does not matter.
How about we give this program of ours back the ability to have multiple verbosity values, and actually get to use them:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
    help="display a square of a given number")
parser.add_argument("-v", "--verbosity", type=int,
    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2
if args.verbosity == 2:
    print("the square of {} equals {}".format(args.square, answer))
elif args.verbosity == 1:
    print("{}^2 == {}".format(args.square, answer))
else:
    print(answer)
```

And the output:

```
$ python3 prog.py 4
16
$ python3 prog.py 4 -v
usage: prog.py [-h] [-v VERBOSITY] square
prog.py: error: argument -v/--verbosity: expected one argument
$ python3 prog.py 4 -v 1
4^2 == 16
$ python3 prog.py 4 -v 2
the square of 4 equals 16
$ python3 prog.py 4 -v 3
16
```

These all look good except the last one, which exposes a bug in our program. Let's fix it by restricting the values the --verbosity option can take.
can accept:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display a square of a given number")
parser.add_argument("-v", "--verbosity", type=int,
                    choices=[0,1,2],
                    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2
if args.verbosity == 2:
    print("the square of {} equals {}".format(args.square, answer))
elif args.verbosity == 1:
    print("{}^2 == {}".format(args.square, answer))
else:
    print(answer)
```

And the output:

```
$ python3 prog.py 4 -v 3
usage: prog.py [-h] [-v {0,1,2}] square
prog.py: error: argument -v/--verbosity: invalid choice: 3 (expected one of 0, 1, 2)
```

```
$ python3 prog.py 4 -h
usage: prog.py [-h] [-v {0,1,2}] square

positional arguments:
  square  display a square of a given number

optional arguments:
  -h, --help  show this help message and exit
  -v {0,1,2}, --verbosity {0,1,2}  increase output verbosity
```

Note that the change also reflects both in the error message as well as the help string.
Now, let's use a different approach of playing with verbosity, which is pretty common. It also matches the way the CPython executable handles its own verbosity argument (check the output of python --help):

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display the square of a given number")
parser.add_argument("-v", "--verbosity", action="count",
                    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2
if args.verbosity == 2:
    print("the square of {} equals {}".format(args.square, answer))
elif args.verbosity == 1:
    print("{}^2 == {}".format(args.square, answer))
else:
    print(answer)
```

We have introduced another action, “count”, to count the number of occurrences of a specific optional arguments:

```
$ python3 prog.py 4
16
$ python3 prog.py 4 -v
4^2 == 16
$ python3 prog.py 4 -vv
the square of 4 equals 16
$ python3 prog.py 4 --verbosity --verbosity
the square of 4 equals 16
$ python3 prog.py 4 -v 1
usage: prog.py [-h] [-v] square
prog.py: error: unrecognized arguments: 1
$ python3 prog.py 4 -h
```
usage: prog.py [-h] [-v] square

positional arguments:
  square          display a square of a given number

optional arguments:
  -h, --help      show this help message and exit
  -v, --verbosity increase output verbosity

$ python3 prog.py 4 -vvv
16

- Yes, it's now more of a flag (similar to action="store_true") in the previous version of our script. That should explain the complaint.
- It also behaves similar to “store_true” action.
- Now here's a demonstration of what the “count” action gives. You've probably seen this sort of usage before.
- And, just like the “store_true” action, if you don't specify the -v flag, that flag is considered to have None value.
- As should be expected, specifying the long form of the flag, we should get the same output.
- Sadly, our help output isn't very informative on the new ability our script has acquired, but that can always be fixed by improving the documentation for our script (e.g. via the help keyword argument).
- That last output exposes a bug in our program.

Let's fix:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                     help="display a square of a given number")
parser.add_argument("-v", "--verbosity", action="count",
                     help="increase output verbosity")
```
args = parser.parse_args()
answer = args.square**2

# bugfix: replace == with >=
if args.verbosity >= 2:
    print("the square of {} equals {}".format(args.square, answer))
elif args.verbosity >= 1:
    print("{}^2 == {}").format(args.square, answer))
else:
    print(answer)

And this is what it gives:

```bash
$ python3 prog.py 4 -vvv
the square of 4 equals 16
$ python3 prog.py 4 -vvvv
the square of 4 equals 16
$ python3 prog.py 4
Traceback (most recent call last):
  File "prog.py", line 11, in <module>
    if args.verbosity >= 2:
TypeError: unorderedable types: NoneType() >= int()
```

- First output went well, and fixes the bug we had before. That is, we want any value \( \geq 2 \) to be as verbose as possible.
- Third output not so good.

Let's fix that bug:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display a square of a given number")
parser.add_argument("-v", "--verbosity", action="count",
                    help="increase output verbosity")
args = parser.parse_args()
```
answer = args.square**2
if args.verbosity >= 2:
    print("the square of {} equals {}".format(args.square, answer))
elif args.verbosity >= 1:
    print("{}^2 == {}".format(args.square, answer))
else:
    print(answer)

We've just introduced yet another keyword, default. We've set it to 0 in order to make it comparable to the other int values. Remember that by default, if an optional argument isn't specified, it gets the None value, and that cannot be compared to an int value (hence the TypeError exception).

And:

$ python3 prog.py 4
16

You can go quite far just with what we've learned so far, and we have only scratched the surface. The argparse module is very powerful, and we'll explore a bit more of it before we end this tutorial.
Getting a little more advanced

What if we wanted to expand our tiny program to perform other powers, not just squares:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("x", type=int, help="the base")
parser.add_argument("y", type=int, help="the exponent")
parser.add_argument("-v", "--verbosity", action="count")
args = parser.parse_args()
answer = args.x**args.y
if args.verbosity >= 2:
    print("{} to the power {} equals {}".format(args.x, args.y, answer))
elif args.verbosity >= 1:
    print("{}^{} == {}".format(args.x, args.y, answer))
else:
    print(answer)
```

Output:

```
$ python3 prog.py
usage: prog.py [-h] [-v] x y
prog.py: error: the following arguments are required
$ python3 prog.py -h
usage: prog.py [-h] [-v] x y

positional arguments:
  x          the base
  y          the exponent

optional arguments:
  -h, --help  show this help message and exit
  -v, --verbosity
```
Notice that so far we've been using verbosity level to *change* the text that gets displayed. The following example instead uses verbosity level to display *more* text instead:

```python
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("x", type=int, help="the base")
parser.add_argument("y", type=int, help="the exponent")
parser.add_argument("-v", "--verbosity", action="count")
args = parser.parse_args()
answer = args.x**args.y
if args.verbosity >= 2:
    print("Running '{}'".format(__file__))
if args.verbosity >= 1:
    print("{}^{} == ".format(args.x, args.y), end=""
print(answer)
```

Output:

```
$ python3 prog.py 4 2
16
$ python3 prog.py 4 2 -v
4^2 == 16
$ python3 prog.py 4 2 -vv
Running 'prog.py'
4^2 == 16
```

**Conflicting options**

So far, we have been working with two methods of an
argparse.ArgumentParser instance. Let’s introduce a third one, add_mutually_exclusive_group(). It allows for us to specify options that conflict with each other. Let’s also change the rest of the program so that the new functionality makes more sense: we’ll introduce the --quiet option, which will be the opposite of the --verbose one:

```python
import argparse

parser = argparse.ArgumentParser()
group = parser.add_mutually_exclusive_group()
group.add_argument("-v", "--verbose", action="store_true")
group.add_argument("-q", "--quiet", action="store_true")
parser.add_argument("x", type=int, help="the base")
parser.add_argument("y", type=int, help="the exponent")
args = parser.parse_args()
answer = args.x**args.y

if args.quiet:
    print(answer)
elif args.verbose:
    print("{} to the power {} equals {}".format(args.x, args.y, answer))
else:
    print("{}^{} == {}".format(args.x, args.y, answer))
```

Our program is now simpler, and we’ve lost some functionality for the sake of demonstration. Anyways, here’s the output:

```bash
$ python3 prog.py 4 2
4^2 == 16
$ python3 prog.py 4 2 -q
16
$ python3 prog.py 4 2 -v
4 to the power 2 equals 16
```
That should be easy to follow. I’ve added that last output so you can see the sort of flexibility you get, i.e. mixing long form options with short form ones.

Before we conclude, you probably want to tell your users the main purpose of your program, just in case they don’t know:

```python
import argparse

parser = argparse.ArgumentParser(description="calculate \(X^Y\)")
group = parser.add_mutually_exclusive_group()
group.add_argument("-v", "--verbose", action="store_true")
group.add_argument("-q", "--quiet", action="store_true")
parser.add_argument("x", type=int, help="the base")
parsed.add_argument("y", type=int, help="the exponent")

args = parser.parse_args()

answer = args.x**args.y

if args.quiet:
    print(answer)
elif args.verbose:
    print("{} to the power {} equals {}".format(args.x, args.y, answer))
else:
    print("{}^{} == {}".format(args.x, args.y, answer))
```

Note that slight difference in the usage text. Note the [-v | -q], which tells us that we can either use -v or -q, but not both at the
same time:

```
$ python3 prog.py --help
usage: prog.py [-h] [-v | -q] x y

calculate X to the power of Y

positional arguments:
  x    the base
  y    the exponent

optional arguments:
  -h, --help    show this help message and exit
  -v, --verbose
  -q, --quiet
```
Conclusion

The argparse module offers a lot more than shown here. Its docs are quite detailed and thorough, and full of examples. Having gone through this tutorial, you should easily digest them without feeling overwhelmed.
An introduction to the ipaddress module

Overview

This document aims to provide a gentle introduction to the ipaddress module. It is aimed primarily at users that aren't already familiar with IP networking terminology, but may also be useful to network engineers wanting an overview of how ipaddress represents IP network addressing concepts.
Creating Address/Network/Interface objects

Since `ipaddress` is a module for inspecting and manipulating IP addresses, the first thing you'll want to do is create some objects. You can use `ipaddress` to create objects from strings and integers.

A Note on IP Versions

For readers that aren't particularly familiar with IP addressing, it's important to know that the Internet Protocol is currently in the process of moving from version 4 of the protocol to version 6. This transition is occurring largely because version 4 of the protocol doesn't provide enough addresses to handle the needs of the whole world, especially given the increasing number of devices with direct connections to the internet.

Explaining the details of the differences between the two versions of the protocol is beyond the scope of this introduction, but readers need to at least be aware that these two versions exist, and it will sometimes be necessary to force the use of one version or the other.

IP Host Addresses

Addresses, often referred to as “host addresses” are the most basic unit when working with IP addressing. The simplest way to create addresses is to use the `ipaddress.ip_address()` factory function, which automatically determines whether to create an IPv4 or IPv6 address based on the passed in value:
Addresses can also be created directly from integers. Values that will fit within 32 bits are assumed to be IPv4 addresses:

```python
>>> ipaddress.ip_address('192.0.2.1')
IPv4Address('192.0.2.1')
>>> ipaddress.ip_address('2001:db8::1')
IPv6Address('2001:db8::1')
```

To force the use of IPv4 or IPv6 addresses, the relevant classes can be invoked directly. This is particularly useful to force creation of IPv6 addresses for small integers:

```python
>>> ipaddress.ip_address(3221225985)
IPv4Address('192.0.2.1')
>>> ipaddress.ip_address(42540766411282592856903984951653826561)
IPv6Address('2001:db8::1')
```

Defining Networks

Host addresses are usually grouped together into IP networks, so `ipaddress` provides a way to create, inspect and manipulate network definitions. IP network objects are constructed from strings that define the range of host addresses that are part of that network. The simplest form for that information is a “network address/network prefix” pair, where the prefix defines the number of leading bits that are compared to determine whether or not an address is part of the network and the
network address defines the expected value of those bits.

As for addresses, a factory function is provided that determines the correct IP version automatically:

```python
>>> ipaddress.ip_network('192.0.2.0/24')
IPv4Network('192.0.2.0/24')
>>> ipaddress.ip_network('2001:db8::0/96')
IPv6Network('2001:db8::/96')
```

Network objects cannot have any host bits set. The practical effect of this is that 192.0.2.1/24 does not describe a network. Such definitions are referred to as interface objects since the ip-on-a-network notation is commonly used to describe network interfaces of a computer on a given network and are described further in the next section.

By default, attempting to create a network object with host bits set will result in `ValueError` being raised. To request that the additional bits instead be coerced to zero, the flag `strict=False` can be passed to the constructor:

```python
>>> ipaddress.ip_network('192.0.2.1/24')
Traceback (most recent call last):
...
ValueError: 192.0.2.1/24 has host bits set
>>> ipaddress.ip_network('192.0.2.1/24', strict=False)
IPv4Network('192.0.2.0/24')
```

While the string form offers significantly more flexibility, networks can also be defined with integers, just like host addresses. In this case, the network is considered to contain only the single address identified by the integer, so the network prefix includes the entire network address:
As with addresses, creation of a particular kind of network can be forced by calling the class constructor directly instead of using the factory function.

**Host Interfaces**

As mentioned just above, if you need to describe an address on a particular network, neither the address nor the network classes are sufficient. Notation like 192.0.2.1/24 is commonly used by network engineers and the people who write tools for firewalls and routers as shorthand for “the host 192.0.2.1 on the network 192.0.2.0/24”, Accordingly, *ipaddress* provides a set of hybrid classes that associate an address with a particular network. The interface for creation is identical to that for defining network objects, except that the address portion isn’t constrained to being a network address.

```python
>>> ipaddress.ip_interface('192.0.2.1/24')
IPv4Interface('192.0.2.1/24')
>>> ipaddress.ip_interface('2001:db8::1/96')
IPv6Interface('2001:db8::1/96')
```

Integer inputs are accepted (as with networks), and use of a particular IP version can be forced by calling the relevant constructor directly.
Inspecting Address/Network/Interface Objects

You’ve gone to the trouble of creating an IPv(4|6) (Address|Network|Interface) object, so you probably want to get information about it. `ipaddress` tries to make doing this easy and intuitive.

Extracting the IP version:

```python
>>> addr4 = ipaddress.ip_address('192.0.2.1')
>>> addr6 = ipaddress.ip_address('2001:db8::1')
>>> addr6.version
6
>>> addr4.version
4
```

Obtaining the network from an interface:

```python
>>> host4 = ipaddress.ip_interface('192.0.2.1/24')
>>> host4.network
IPv4Network('192.0.2.0/24')
>>> host6 = ipaddress.ip_interface('2001:db8::1/96')
>>> host6.network
IPv6Network('2001:db8::/96')
```

Finding out how many individual addresses are in a network:

```python
>>> net4 = ipaddress.ip_network('192.0.2.0/24')
>>> net4.num_addresses
256
>>> net6 = ipaddress.ip_network('2001:db8::/96')
>>> net6.num_addresses
```
Iterating through the “usable” addresses on a network:

```python
>>> net4 = ipaddress.ip_network('192.0.2.0/24')
>>> for x in net4.hosts():
...    print(x)
192.0.2.1
192.0.2.2
192.0.2.3
192.0.2.4
...
192.0.2.252
192.0.2.253
192.0.2.254
```

Obtaining the netmask (i.e. set bits corresponding to the network prefix) or the hostmask (any bits that are not part of the netmask):

```python
>>> net4 = ipaddress.ip_network('192.0.2.0/24')
>>> net4.netmask
IPv4Address('255.255.255.0')
>>> net4.hostmask
IPv4Address('0.0.0.255')
>>> net6 = ipaddress.ip_network('2001:db8::0/96')
>>> net6.netmask
IPv6Address('ffff:ffff:ffff:ffff:ffff::')
>>> net6.hostmask
IPv6Address('::ffff:ffff')
```

Exploding or compressing the address:

```python
>>> addr6.exploded
'2001:0db8:0000:0000:0000:0000:0000:0001'
>>> addr6.compressed
'2001:db8::1'
```
While IPv4 doesn't support explosion or compression, the associated objects still provide the relevant properties so that version neutral code can easily ensure the most concise or most verbose form is used for IPv6 addresses while still correctly handling IPv4 addresses.
Networks as lists of Addresses

It's sometimes useful to treat networks as lists. This means it is possible to index them like this:

```python
>>> net4[1]
IPv4Address('192.0.2.1')
>>> net4[-1]
IPv4Address('192.0.2.255')
>>> net6[1]
IPv6Address('2001:db8::1')
>>> net6[-1]
IPv6Address('2001:db8::ffff:ffff')
```

It also means that network objects lend themselves to using the list membership test syntax like this:

```python
if address in network:
    # do something
```

Containment testing is done efficiently based on the network prefix:

```python
>>> addr4 = ipaddress.ip_address('192.0.2.1')
>>> addr4 in ipaddress.ip_network('192.0.2.0/24')
True
>>> addr4 in ipaddress.ip_network('192.0.3.0/24')
False
```
Comparisons

`ipaddress` provides some simple, hopefully intuitive ways to compare objects, where it makes sense:

```python
>>> ipaddress.ip_address('192.0.2.1') < ipaddress.ip_address('192.0.2.2')
True
```

A `TypeError` exception is raised if you try to compare objects of different versions or different types.
Using IP Addresses with other modules

Other modules that use IP addresses (such as `socket`) usually won’t accept objects from this module directly. Instead, they must be coerced to an integer or string that the other module will accept:

```python
>>> addr4 = ipaddress.ip_address('192.0.2.1')
>>> str(addr4)
'192.0.2.1'
>>> int(addr4)
3221225985
```
Getting more detail when instance creation fails

When creating address/network/interface objects using the version-agnostic factory functions, any errors will be reported as `ValueError` with a generic error message that simply says the passed in value was not recognized as an object of that type. The lack of a specific error is because it's necessary to know whether the value is supposed to be IPv4 or IPv6 in order to provide more detail on why it has been rejected.

To support use cases where it is useful to have access to this additional detail, the individual class constructors actually raise the `ValueError` subclasses `ipaddress.AddressValueError` and `ipaddress.NetmaskValueError` to indicate exactly which part of the definition failed to parse correctly.

The error messages are significantly more detailed when using the class constructors directly. For example:

```python
>>> ipaddress.ip_address("192.168.0.256")
Traceback (most recent call last):
 ...
ValueError: '192.168.0.256' does not appear to be an IPv4 or IPv6 address
>>> ipaddress.IPv4Address("192.168.0.256")
Traceback (most recent call last):
 ...
ipaddress.AddressValueError: Octet 256 (> 255) not permitted in '192.168.0.256'

>>> ipaddress.ip_network("192.168.0.1/64")
Traceback (most recent call last):
 ...
ValueError: '192.168.0.1/64' does not appear to be an IPv4 or IPv6 network
```
>>> ipaddress.IPv4Network("192.168.0.1/64")
Traceback (most recent call last):
...
ipaddress.NetmaskValueError: '64' is not a valid net

However, both of the module specific exceptions have ValueError as their parent class, so if you’re not concerned with the particular type of error, you can still write code like the following:

```
try:
    network = ipaddress.IPv4Network(address)
except ValueError:
    print('address/netmask is invalid for IPv4:', address)
```
Argument Clinic How-To

Author: Larry Hastings

Abstract

Argument Clinic is a preprocessor for CPython C files. Its purpose is to automate all the boilerplate involved with writing argument parsing code for “builtins”. This document shows you how to convert your first C function to work with Argument Clinic, and then introduces some advanced topics on Argument Clinic usage.

Currently Argument Clinic is considered internal-only for CPython. Its use is not supported for files outside CPython, and no guarantees are made regarding backwards compatibility for future versions. In other words: if you maintain an external C extension for CPython, you're welcome to experiment with Argument Clinic in your own code. But the version of Argument Clinic that ships with CPython 3.5 could be totally incompatible and break all your code.
The Goals Of Argument Clinic

Argument Clinic's primary goal is to take over responsibility for all argument parsing code inside CPython. This means that, when you convert a function to work with Argument Clinic, that function should no longer do any of its own argument parsing—the code generated by Argument Clinic should be a “black box” to you, where CPython calls in at the top, and your code gets called at the bottom, with PyObject *args (and maybe PyObject *kwargs) magically converted into the C variables and types you need.

In order for Argument Clinic to accomplish its primary goal, it must be easy to use. Currently, working with CPython’s argument parsing library is a chore, requiring maintaining redundant information in a surprising number of places. When you use Argument Clinic, you don’t have to repeat yourself.

Obviously, no one would want to use Argument Clinic unless it’s solving their problem—and without creating new problems of its own. So it’s paramount that Argument Clinic generate correct code. It’d be nice if the code was faster, too, but at the very least it should not introduce a major speed regression. (Eventually Argument Clinic should make a major speedup possible—we could rewrite its code generator to produce tailor-made argument parsing code, rather than calling the general-purpose CPython argument parsing library. That would make for the fastest argument parsing possible!)

Additionally, Argument Clinic must be flexible enough to work with any approach to argument parsing. Python has some functions with some very strange parsing behaviors; Argument Clinic’s goal is to support all of them.
Finally, the original motivation for Argument Clinic was to provide introspection “signatures” for CPython builtins. It used to be, the introspection query functions would throw an exception if you passed in a builtin. With Argument Clinic, that’s a thing of the past!

One idea you should keep in mind, as you work with Argument Clinic: the more information you give it, the better job it’ll be able to do. Argument Clinic is admittedly relatively simple right now. But as it evolves it will get more sophisticated, and it should be able to do many interesting and smart things with all the information you give it.
Basic Concepts And Usage

Argument Clinic ships with CPython; you'll find it in Tools/clinic/clinic.py. If you run that script, specifying a C file as an argument:

```
% python3 Tools/clinic/clinic.py foo.c
```

Argument Clinic will scan over the file looking for lines that look exactly like this:

```
/*[clinic input]
```

When it finds one, it reads everything up to a line that looks exactly like this:

```
[clinic start generated code]*/
```

Everything in between these two lines is input for Argument Clinic. All of these lines, including the beginning and ending comment lines, are collectively called an Argument Clinic “block”.

When Argument Clinic parses one of these blocks, it generates output. This output is rewritten into the C file immediately after the block, followed by a comment containing a checksum. The Argument Clinic block now looks like this:

```
/*[clinic input]
... clinic input goes here ...
[clinic start generated code]*/
... clinic output goes here ...
/*[clinic end generated code: checksum=...]*/
```
If you run Argument Clinic on the same file a second time, Argument Clinic will discard the old output and write out the new output with a fresh checksum line. However, if the input hasn’t changed, the output won’t change either.

You should never modify the output portion of an Argument Clinic block. Instead, change the input until it produces the output you want. (That’s the purpose of the checksum—to detect if someone changed the output, as these edits would be lost the next time Argument Clinic writes out fresh output.)

For the sake of clarity, here’s the terminology we’ll use with Argument Clinic:

- The first line of the comment (/*[clinic input]) is the start line.
- The last line of the initial comment ([clinic start generated code]*) is the end line.
- The last line (/*[clinic end generated code: checksum=...]*/) is the checksum line.
- In between the start line and the end line is the input.
- In between the end line and the checksum line is the output.
- All the text collectively, from the start line to the checksum line inclusively, is the block. (A block that hasn’t been successfully processed by Argument Clinic yet doesn’t have output or a checksum line, but it’s still considered a block.)
Converting Your First Function

The best way to get a sense of how Argument Clinic works is to convert a function to work with it. Here, then, are the bare minimum steps you’d need to follow to convert a function to work with Argument Clinic. Note that for code you plan to check in to CPython, you really should take the conversion farther, using some of the advanced concepts you’ll see later on in the document (like “return converters” and “self converters”). But we’ll keep it simple for this walkthrough so you can learn.

Let’s dive in!

0. Make sure you’re working with a freshly updated checkout of the CPython trunk.

1. Find a Python builtin that calls either `PyArg_ParseTuple()` or `PyArg_ParseTupleAndKeywords()`, and hasn’t been converted to work with Argument Clinic yet. For my example I’m using `_pickle.Pickler.dump()`.

2. If the call to the PyArg_Parse function uses any of the following format units:

   ```
   0&
   0!
   es
   es#
   et
   et#
   ```

   or if it has multiple calls to `PyArg_ParseTuple()`, you should choose a different function. Argument Clinic does support all of
these scenarios. But these are advanced topics—let’s do something simpler for your first function.

Also, if the function has multiple calls to `PyArg_ParseTuple()` or `PyArg_ParseTupleAndKeywords()` where it supports different types for the same argument, or if the function uses something besides `PyArg_Parse` functions to parse its arguments, it probably isn’t suitable for conversion to Argument Clinic. Argument Clinic doesn’t support generic functions or polymorphic parameters.

3. Add the following boilerplate above the function, creating our block:

```c
/*[clinic input]
[clinic start generated code]*/
```

4. Cut the docstring and paste it in between the `[clinic]` lines, removing all the junk that makes it a properly quoted C string. When you’re done you should have just the text, based at the left margin, with no line wider than 80 characters. (Argument Clinic will preserve indents inside the docstring.)

If the old docstring had a first line that looked like a function signature, throw that line away. (The docstring doesn’t need it anymore—when you use `help()` on your builtin in the future, the first line will be built automatically based on the function’s signature.)

Sample:

```c
/*[clinic input]
Write a pickled representation of obj to the open
```
5. If your docstring doesn’t have a “summary” line, Argument Clinic will complain. So let’s make sure it has one. The “summary” line should be a paragraph consisting of a single 80-column line at the beginning of the docstring.

(Our example docstring consists solely of a summary line, so the sample code doesn’t have to change for this step.)

6. Above the docstring, enter the name of the function, followed by a blank line. This should be the Python name of the function, and should be the full dotted path to the function—it should start with the name of the module, include any sub-modules, and if the function is a method on a class it should include the class name too.

Sample:

```c
/*[clinic input]_pickle.Pickler.dump
Write a pickled representation of obj to the open [clinic start generated code]*/
```

7. If this is the first time that module or class has been used with Argument Clinic in this C file, you must declare the module and/or class. Proper Argument Clinic hygiene prefers declaring these in a separate block somewhere near the top of the C file, in the same way that include files and statics go at the top. (In our sample code we’ll just show the two blocks next to each other.)

The name of the class and module should be the same as the one
seen by Python. Check the name defined in the `PyModuleDef` or `PyTypeObject` as appropriate.

When you declare a class, you must also specify two aspects of its type in C: the type declaration you’d use for a pointer to an instance of this class, and a pointer to the `PyTypeObject` for this class.

Sample:

```c
/*[clinic input]
module _pickle
class _pickle.Pickler "PicklerObject *" "&Pickler
[clinic start generated code]*/

/*[clinic input]
_pickle.Pickler.dump

Write a pickled representation of obj to the open
[clinic start generated code]*/
```

8. Declare each of the parameters to the function. Each parameter should get its own line. All the parameter lines should be indented from the function name and the docstring.

The general form of these parameter lines is as follows:

```c
name_of_parameter: converter
```

If the parameter has a default value, add that after the converter:

```c
name_of_parameter: converter = default_value
```

Argument Clinic’s support for “default values” is quite
sophisticated; please see the section below on default values for more information.

Add a blank line below the parameters.

What's a “converter”? It establishes both the type of the variable used in C, and the method to convert the Python value into a C value at runtime. For now you’re going to use what's called a “legacy converter”—a convenience syntax intended to make porting old code into Argument Clinic easier.

For each parameter, copy the “format unit” for that parameter from the PyArg_Parse() format argument and specify that as its converter, as a quoted string. (“format unit” is the formal name for the one-to-three character substring of the format parameter that tells the argument parsing function what the type of the variable is and how to convert it. For more on format units please see Parsing arguments and building values.)

For multicharacter format units like z#, use the entire two-or-three character string.

Sample:

```c
/*[clinic input]
module _pickle
    class _pickle.Pickler "PicklerObject */ 
[clinic start generated code]*/

/ [clinic input]
    _pickle.Pickler.dump

        obj: 'O'
```
Write a pickled representation of obj to the open
9. If your function has | in the format string, meaning some parameters have default values, you can ignore it. Argument Clinic infers which parameters are optional based on whether or not they have default values.

   If your function has $ in the format string, meaning it takes keyword-only arguments, specify * on a line by itself before the first keyword-only argument, indented the same as the parameter lines.

   (_pickle.Pickler.dump has neither, so our sample is unchanged.)

10. If the existing C function calls PyArg_ParseTuple() (as opposed to PyArg_ParseTupleAndKeywords()), then all its arguments are positional-only.

   To mark all parameters as positional-only in Argument Clinic, add a / on a line by itself after the last parameter, indented the same as the parameter lines.

   Currently this is all-or-nothing; either all parameters are positional-only, or none of them are. (In the future Argument Clinic may relax this restriction.)

Sample:
It's helpful to write a per-parameter docstring for each parameter. But per-parameter docstrings are optional; you can skip this step if you prefer.

Here's how to add a per-parameter docstring. The first line of the per-parameter docstring must be indented further than the parameter definition. The left margin of this first line establishes the left margin for the whole per-parameter docstring; all the text you write will be outdented by this amount. You can write as much text as you like, across multiple lines if you wish.

Sample:

```c
/*[clinic input]
module _pickle
class _pickle.Pickler "PicklerObject *" 
[clinic start generated code]*/

/*[clinic input]
_pickle.Pickler.dump

    obj: 'O'

    The object to be pickled.

*/
```
Write a pickled representation of obj to the open file.

[clinic start generated code]*/

12. Save and close the file, then run Tools/clinic/clinic.py on it. With luck everything worked and your block now has output! Reopen the file in your text editor to see:

/*[clinic input]
module _pickle

class _pickle.Pickler "PicklerObject " 
&Pickler
[clinic start generated code]*/

/*[clinic end generated code: checksum=da39a3ee5e6b4b0d3255bfef95601890afd80709]*/

/*[clinic input]
_pickle.Pickler.dump

    obj: 'O'
    The object to be pickled.
    /

Write a pickled representation of obj to the open file.
[clinic start generated code]*/

PyDoc_STRVAR(_pickle_Pickler_dump__doc__,
"Write a pickled representation of obj to the open file.
"
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complaint.

13. Double-check that the argument-parsing code Argument Clinic generated looks basically the same as the existing code.

First, ensure both places use the same argument-parsing function. The existing code must call either `PyArg_ParseTuple()` or `PyArg_ParseTupleAndKeywords()`; ensure that the code generated by Argument Clinic calls the exact same function.

Second, the format string passed in to `PyArg_ParseTuple()` or `PyArg_ParseTupleAndKeywords()` should be exactly the same as the hand-written one in the existing function, up to the colon or semi-colon.

(Argument Clinic always generates its format strings with a : followed by the name of the function. If the existing code’s format string ends with ;, to provide usage help, this change is harmless–don’t worry about it.)

Third, for parameters whose format units require two arguments (like a length variable, or an encoding string, or a pointer to a conversion function), ensure that the second argument is exactly the same between the two invocations.

Fourth, inside the output portion of the block you’ll find a preprocessor macro defining the appropriate static `PyMethodDef` structure for this builtin:

```c
#define __PICKLE_PICKLER_DUMP_METHODDEF  \
{"dump", (PyCFunction)__pickle_Pickler_dump, METH_O}
```
This static structure should be exactly the same as the existing static `PyMethodDef` structure for this builtin.

If any of these items differ in any way, adjust your Argument Clinic function specification and rerun `Tools/clinic/clinic.py` until they are the same.

14. Notice that the last line of its output is the declaration of your “impl” function. This is where the builtin’s implementation goes. Delete the existing prototype of the function you’re modifying, but leave the opening curly brace. Now delete its argument parsing code and the declarations of all the variables it dumps the arguments into. Notice how the Python arguments are now arguments to this impl function; if the implementation used different names for these variables, fix it.

Let’s reiterate, just because it’s kind of weird. Your code should now look like this:

```c
static return_type
your_function_impl(...)
/*[clinic end generated code: checksum=...]*/
{
...
```

Argument Clinic generated the checksum line and the function prototype just above it. You should write the opening (and closing) curly braces for the function, and the implementation inside.

Sample:

```c
/*[clinic input]
module _pickle
class _pickle.Pickler "PicklerObject *" 
```
_pickle.Pickler.dump

    obj: 'O'
    The object to be pickled.
    /

Write a pickled representation of obj to the open

PyDoc_STRVAR(_pickle_Pickler_dump__doc__,
"Write a pickled representation of obj to the open
"
...  static PyObject *
_pickle_Pickler_dump_impl(PicklerObject *self, Py

/* Check whether the Pickler was initialized
Developers often forget to call __init__(
would trigger a segfault without this check
    if (self->write == NULL) {
        PyErr_Format(PicklingError,
            "Pickler.__init__() was not
            Py_TYPE(self)->tp_name);
        return NULL;
    }

    if (_Pickler_ClearBuffer(self) < 0)
        return NULL;

    ...
15. Remember the macro with the `PyMethodDef` structure for this function? Find the existing `PyMethodDef` structure for this function and replace it with a reference to the macro. (If the builtin is at module scope, this will probably be very near the end of the file; if the builtin is a class method, this will probably be below but relatively near to the implementation.)

Note that the body of the macro contains a trailing comma. So when you replace the existing static `PyMethodDef` structure with the macro, don't add a comma to the end.

Sample:

```c
static struct PyMethodDef Pickler_methods[] = {
    __PICKLE_PICKLER_DUMP_METHODDEF
    __PICKLE_PICKLER_CLEAR_MEMO_METHODDEF
    {NULL, NULL} /* sentinel */
};
```

16. Compile, then run the relevant portions of the regression-test suite. This change should not introduce any new compile-time warnings or errors, and there should be no externally-visible change to Python's behavior.

Well, except for one difference: `inspect.signature()` run on your function should now provide a valid signature!

Congratulations, you've ported your first function to work with Argument Clinic!
Advanced Topics

Now that you've had some experience working with Argument Clinic, it's time for some advanced topics.

Symbolic default values

The default value you provide for a parameter can't be any arbitrary expression. Currently the following are explicitly supported:

- Numeric constants (integer and float)
- String constants
- True, False, and None
- Simple symbolic constants like sys.maxsize, which must start with the name of the module

In case you're curious, this is implemented in from_builtin() in Lib/inspect.py.

(In the future, this may need to get even more elaborate, to allow full expressions like CONSTANT - 1.)

Renaming the C functions and variables generated by Argument Clinic

Argument Clinic automatically names the functions it generates for you. Occasionally this may cause a problem, if the generated name collides with the name of an existing C function. There's an easy solution: override the names used for the C functions. Just add the keyword "as" to your function declaration line, followed by the function name you wish to use. Argument Clinic will use that function
name for the base (generated) function, then add "_impl" to the end and use that for the name of the impl function.

For example, if we wanted to rename the C function names generated for pickle.Pickler.dump, it'd look like this:

```c
/*[clinic input]
pickle.Pickler.dump as pickler_dumper
...
```

The base function would now be named `pickler_dumper()`, and the impl function would now be named `pickler_dumper_impl()`.

Similarly, you may have a problem where you want to give a parameter a specific Python name, but that name may be inconvenient in C. Argument Clinic allows you to give a parameter different names in Python and in C, using the same "as" syntax:

```c
/*[clinic input]
pickle.Pickler.dump

    obj: object
    file as file_obj: object
    protocol: object = NULL
    *
    fix_imports: bool = True
```

Here, the name used in Python (in the signature and the keywords array) would be file, but the C variable would be named `file_obj`.

You can use this to rename the self parameter too!

**Converting functions using PyArg_UnpackTuple**
To convert a function parsing its arguments with `PyArg_UnpackTuple()`, simply write out all the arguments, specifying each as an object. You may specify the type argument to cast the type as appropriate. All arguments should be marked positional-only (add a / on a line by itself after the last argument).

Currently the generated code will use `PyArg_ParseTuple()`, but this will change soon.

**Optional Groups**

Some legacy functions have a tricky approach to parsing their arguments: they count the number of positional arguments, then use a switch statement to call one of several different `PyArg_ParseTuple()` calls depending on how many positional arguments there are. (These functions cannot accept keyword-only arguments.) This approach was used to simulate optional arguments back before `PyArg_ParseTupleAndKeywords()` was created.

While functions using this approach can often be converted to use `PyArg_ParseTupleAndKeywords()`, optional arguments, and default values, it's not always possible. Some of these legacy functions have behaviors `PyArg_ParseTupleAndKeywords()` doesn't directly support. The most obvious example is the built-in function `range()`, which has an optional argument on the *left* side of its required argument! Another example is `curses.window.addch()`, which has a group of two arguments that must always be specified together. (The arguments are called `x` and `y`; if you call the function passing in `x`, you must also pass in `y`–and if you don't pass in `x` you may not pass in `y` either.)
In any case, the goal of Argument Clinic is to support argument parsing for all existing CPython builtins without changing their semantics. Therefore Argument Clinic supports this alternate approach to parsing, using what are called `optional groups`. Optional groups are groups of arguments that must all be passed in together. They can be to the left or the right of the required arguments. They can only be used with positional-only parameters.

**Note:** Optional groups are only intended for use when converting functions that make multiple calls to `PyArg_ParseTuple()`! Functions that use any other approach for parsing arguments should almost never be converted to Argument Clinic using optional groups. Functions using optional groups currently cannot have accurate signatures in Python, because Python just doesn’t understand the concept. Please avoid using optional groups wherever possible.

To specify an optional group, add a `[` on a line by itself before the parameters you wish to group together, and a `]` on a line by itself after these parameters. As an example, here’s how `curses.window.addch` uses optional groups to make the first two parameters and the last parameter optional:

```c
/*[clinic input]
curses.window.addch

    [
    x: int
      X-coordinate.
    y: int
      Y-coordinate.
    ]
```
ch: object
  Character to add.

[  
  attr: long  
  Attributes for the character. 
]
/

Notes:

- For every optional group, one additional parameter will be passed into the impl function representing the group. The parameter will be an int named group_{direction}_{number}, where {direction} is either right or left depending on whether the group is before or after the required parameters, and {number} is a monotonically increasing number (starting at 1) indicating how far away the group is from the required parameters. When the impl is called, this parameter will be set to zero if this group was unused, and set to non-zero if this group was used. (By used or unused, I mean whether or not the parameters received arguments in this invocation.)
- If there are no required arguments, the optional groups will behave as if they’re to the right of the required arguments.
- In the case of ambiguity, the argument parsing code favors parameters on the left (before the required parameters).
- Optional groups can only contain positional-only parameters.
- Optional groups are only intended for legacy code. Please do not use optional groups for new code.

Using real Argument Clinic converters, instead of “legacy converters”
To save time, and to minimize how much you need to learn to achieve your first port to Argument Clinic, the walkthrough above tells you to use “legacy converters”. “Legacy converters” are a convenience, designed explicitly to make porting existing code to Argument Clinic easier. And to be clear, their use is acceptable when porting code for Python 3.4.

However, in the long term we probably want all our blocks to use Argument Clinic’s real syntax for converters. Why? A couple reasons:

- The proper converters are far easier to read and clearer in their intent.
- There are some format units that are unsupported as “legacy converters”, because they require arguments, and the legacy converter syntax doesn’t support specifying arguments.
- In the future we may have a new argument parsing library that isn’t restricted to what `PyArg_ParseTuple()` supports; this flexibility won’t be available to parameters using legacy converters.

Therefore, if you don’t mind a little extra effort, please use the normal converters instead of legacy converters.

In a nutshell, the syntax for Argument Clinic (non-legacy) converters looks like a Python function call. However, if there are no explicit arguments to the function (all functions take their default values), you may omit the parentheses. Thus `bool` and `bool()` are exactly the same converters.

All arguments to Argument Clinic converters are keyword-only. All Argument Clinic converters accept the following arguments:

- `c_default`
  
  The default value for this parameter when defined in C.
Specifically, this will be the initializer for the variable declared in the “parse function”. See the section on default values for how to use this. Specified as a string.

annotation
The annotation value for this parameter. Not currently supported, because PEP 8 mandates that the Python library may not use annotations.

In addition, some converters accept additional arguments. Here is a list of these arguments, along with their meanings:

accept
A set of Python types (and possibly pseudo-types); this restricts the allowable Python argument to values of these types. (This is not a general-purpose facility; as a rule it only supports specific lists of types as shown in the legacy converter table.)

To accept None, add NoneType to this set.

bitwise
Only supported for unsigned integers. The native integer value of this Python argument will be written to the parameter without any range checking, even for negative values.

converter
Only supported by the object converter. Specifies the name of a C "converter function" to use to convert this object to a native type.

encoding
Only supported for strings. Specifies the encoding to use when converting this string from a Python str (Unicode) value into a C char * value.

subclass_of
Only supported for the object converter. Requires that the Python value be a subclass of a Python type, as expressed in C.

type
Only supported for the object and self converters. Specifies the C type that will be used to declare the variable. Default value is "PyObject *".

zeroes
Only supported for strings. If true, embedded NUL bytes ("\0") are permitted inside the value. The length of the string will be passed in to the impl function, just after the string parameter, as a parameter named <parameter_name>_length.

Please note, not every possible combination of arguments will work. Usually these arguments are implemented by specific PyArg_ParseTuple format units, with specific behavior. For example, currently you cannot call unsigned_short without also specifying bitwise=True. Although it's perfectly reasonable to think this would work, these semantics don't map to any existing format unit. So Argument Clinic doesn't support it. (Or, at least, not yet.)

Below is a table showing the mapping of legacy converters into real Argument Clinic converters. On the left is the legacy converter, on the right is the text you’d replace it with.

<table>
<thead>
<tr>
<th>Legacy</th>
<th>Real</th>
</tr>
</thead>
<tbody>
<tr>
<td>'B'</td>
<td>unsigned_char(bitwise=True)</td>
</tr>
<tr>
<td>'b'</td>
<td>unsigned_char</td>
</tr>
<tr>
<td>'c'</td>
<td>char</td>
</tr>
<tr>
<td>'C'</td>
<td>int(accept={str})</td>
</tr>
<tr>
<td>'d'</td>
<td>double</td>
</tr>
<tr>
<td>Character</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td>'D'</td>
<td>Py_complex</td>
</tr>
<tr>
<td>'es'</td>
<td>str(encoding='name_of_encoding')</td>
</tr>
<tr>
<td>'es#'</td>
<td>str(encoding='name_of_encoding', zeroes=True)</td>
</tr>
<tr>
<td>'et'</td>
<td>str(encoding='name_of_encoding', accept={bytes, bytearray, str})</td>
</tr>
<tr>
<td>'et##'</td>
<td>str(encoding='name_of_encoding', accept={bytes, bytearray, str}, zeroes=True)</td>
</tr>
<tr>
<td>'f'</td>
<td>float</td>
</tr>
<tr>
<td>'h'</td>
<td>short</td>
</tr>
<tr>
<td>'H'</td>
<td>unsigned_short(bitwise=True)</td>
</tr>
<tr>
<td>'i'</td>
<td>int</td>
</tr>
<tr>
<td>'I'</td>
<td>unsigned_int(bitwise=True)</td>
</tr>
<tr>
<td>'k'</td>
<td>unsigned_long(bitwise=True)</td>
</tr>
<tr>
<td>'K'</td>
<td>unsigned_PY_LONG_LONG(bitwise=True)</td>
</tr>
<tr>
<td>'l'</td>
<td>long</td>
</tr>
<tr>
<td>'L'</td>
<td>PY_LONG_LONG</td>
</tr>
<tr>
<td>'n'</td>
<td>Py_ssize_t</td>
</tr>
<tr>
<td>'O'</td>
<td>object</td>
</tr>
<tr>
<td>'O!'</td>
<td>object(subclass_of='&amp;PySomething_Type')</td>
</tr>
<tr>
<td>'O&amp;'</td>
<td>object(converter='name_of_c_function')</td>
</tr>
<tr>
<td>'p'</td>
<td>bool</td>
</tr>
<tr>
<td>'S'</td>
<td>PyBytesObject</td>
</tr>
<tr>
<td>'s'</td>
<td>str</td>
</tr>
<tr>
<td>'s#'</td>
<td>str(zeroes=True)</td>
</tr>
<tr>
<td>'s*'</td>
<td>Py_buffer(accept={buffer, str})</td>
</tr>
<tr>
<td>'U'</td>
<td>unicode</td>
</tr>
<tr>
<td>'u'</td>
<td>Py_UNICODE</td>
</tr>
<tr>
<td>'u#'</td>
<td>Py_UNICODE(zeroes=True)</td>
</tr>
<tr>
<td>'w*'</td>
<td>Py_buffer(accept={rwbuffer})</td>
</tr>
<tr>
<td>'Y'</td>
<td>PyByteArrayObject</td>
</tr>
<tr>
<td>'y'</td>
<td>str(accept={bytes})</td>
</tr>
<tr>
<td>'y#'</td>
<td>str(accept={robuffer}, zeroes=True)</td>
</tr>
<tr>
<td>'y*'</td>
<td>Py_buffer</td>
</tr>
<tr>
<td>'Z'</td>
<td>Py_UNICODE(accept={str, NoneType})</td>
</tr>
<tr>
<td>'Z#'</td>
<td>Py_UNICODE(accept={str, NoneType}, zeroes=True)</td>
</tr>
<tr>
<td>'z'</td>
<td>str(accept={str, NoneType})</td>
</tr>
<tr>
<td>'z#'</td>
<td>str(accept={str, NoneType}, zeroes=True)</td>
</tr>
<tr>
<td>'z*'</td>
<td>Py_buffer(accept={buffer, str, NoneType})</td>
</tr>
</tbody>
</table>

As an example, here's our sample pickle.Pickler.dump using the proper converter:

```c
/*[clinic input]
pickle.Pickler.dump

    obj: object
        The object to be pickled.
    /

Write a pickled representation of obj to the open file
[clinic start generated code]*/
```

Argument Clinic will show you all the converters it has available. For
each converter it'll show you all the parameters it accepts, along with the default value for each parameter. Just run Tools/clinic/clinic.py --converters to see the full list.

**Py_buffer**

When using the Py_buffer converter (or the 's*', 'w*', '*y', or 'z*' legacy converters), you *must* not call `PyBuffer_Release()` on the provided buffer. Argument Clinic generates code that does it for you (in the parsing function).

**Advanced converters**

Remember those format units you skipped for your first time because they were advanced? Here's how to handle those too.

The trick is, all those format units take arguments—either conversion functions, or types, or strings specifying an encoding. (But “legacy converters” don't support arguments. That's why we skipped them for your first function.) The argument you specified to the format unit is now an argument to the converter; this argument is either converter (for 0&), subclass_of (for 0!), or encoding (for all the format units that start with e).

When using subclass_of, you may also want to use the other custom argument for object(): type, which lets you set the type actually used for the parameter. For example, if you want to ensure that the object is a subclass of PyUnicode_Type, you probably want to use the converter object(type='PyUnicodeObject *', subclass_of='&PyUnicode_Type').
One possible problem with using Argument Clinic: it takes away some possible flexibility for the format units starting with `e`. When writing a `PyArg_Parse` call by hand, you could theoretically decide at runtime what encoding string to pass in to `PyArg_ParseTuple()`. But now this string must be hard-coded at Argument-Clinic-preprocessing-time. This limitation is deliberate; it made supporting this format unit much easier, and may allow for future optimizations. This restriction doesn’t seem unreasonable; CPython itself always passes in static hard-coded encoding strings for parameters whose format units start with `e`.

Parameter default values

Default values for parameters can be any of a number of values. At their simplest, they can be string, int, or float literals:

```plaintext
foo: str = "abc"
bar: int = 123
bat: float = 45.6
```

They can also use any of Python’s built-in constants:

```plaintext
yep: bool = True
nope: bool = False
nada: object = None
```

There’s also special support for a default value of NULL, and for simple expressions, documented in the following sections.

The NULL default value

For string and object parameters, you can set them to `None` to indicate that there’s no default. However, that means the C variable will be
initialized to Py_None. For convenience’s sakes, there’s a special value called NULL for just this reason: from Python’s perspective it behaves like a default value of None, but the C variable is initialized with NULL.

Expressions specified as default values

The default value for a parameter can be more than just a literal value. It can be an entire expression, using math operators and looking up attributes on objects. However, this support isn’t exactly simple, because of some non-obvious semantics.

Consider the following example:

```python
goo: Py_ssize_t = sys.maxsize - 1
```

sys.maxsize can have different values on different platforms. Therefore Argument Clinic can’t simply evaluate that expression locally and hard-code it in C. So it stores the default in such a way that it will get evaluated at runtime, when the user asks for the function’s signature.

What namespace is available when the expression is evaluated? It’s evaluated in the context of the module the builtin came from. So, if your module has an attribute called “max_widgets”, you may simply use it:

```python
goo: Py_ssize_t = max_widgets
```

If the symbol isn’t found in the current module, it fails over to looking in sys.modules. That’s how it can find sys.maxsize for example. (Since you don’t know in advance what modules the user will load into
their interpreter, it’s best to restrict yourself to modules that are preloaded by Python itself.)

Evaluating default values only at runtime means Argument Clinic can’t compute the correct equivalent C default value. So you need to tell it explicitly. When you use an expression, you must also specify the equivalent expression in C, using the c_default parameter to the converter:

```python
foo: Py_ssize_t(c_default="PY_SSIZE_T_MAX - 1") = sys
```

Another complication: Argument Clinic can’t know in advance whether or not the expression you supply is valid. It parses it to make sure it looks legal, but it can’t actually know. You must be very careful when using expressions to specify values that are guaranteed to be valid at runtime!

Finally, because expressions must be representable as static C values, there are many restrictions on legal expressions. Here’s a list of Python features you’re not permitted to use:

- Function calls.
- Inline if statements (3 if foo else 5).
- Automatic sequence unpacking (*[1, 2, 3]).
- List/set/dict comprehensions and generator expressions.
- Tuple/list/set/dict literals.

### Using a return converter

By default the impl function Argument Clinic generates for you returns PyObject *. But your C function often computes some C type, then converts it into the PyObject * at the last moment. Argument Clinic
handles converting your inputs from Python types into native C types–why not have it convert your return value from a native C type into a Python type too?

That’s what a “return converter” does. It changes your impl function to return some C type, then adds code to the generated (non-impl) function to handle converting that value into the appropriate PyObject *.

The syntax for return converters is similar to that of parameter converters. You specify the return converter like it was a return annotation on the function itself. Return converters behave much the same as parameter converters; they take arguments, the arguments are all keyword-only, and if you’re not changing any of the default arguments you can omit the parentheses.

(If you use both "as" and a return converter for your function, the "as" should come before the return converter.)

There's one additional complication when using return converters: how do you indicate an error has occurred? Normally, a function returns a valid (non-NULL) pointer for success, and NULL for failure. But if you use an integer return converter, all integers are valid. How can Argument Clinic detect an error? Its solution: each return converter implicitly looks for a special value that indicates an error. If you return that value, and an error has been set (PyErr_Occurred() returns a true value), then the generated code will propagate the error. Otherwise it will encode the value you return like normal.

Currently Argument Clinic supports only a few return converters:

```
bool
int
```
None of these take parameters. For the first three, return -1 to indicate error. For DecodeFSDefault, the return type is `char *`; return a NULL pointer to indicate an error.

(There's also an experimental NoneType converter, which lets you return `Py_None` on success or NULL on failure, without having to increment the reference count on `Py_None`. I'm not sure it adds enough clarity to be worth using.)

To see all the return converters Argument Clinic supports, along with their parameters (if any), just run `Tools/clinic/clinic.py --converters` for the full list.

## Cloning existing functions

If you have a number of functions that look similar, you may be able to use Clinic's "clone" feature. When you clone an existing function, you reuse:

- its parameters, including
  - their names,
  - their converters, with all parameters,
  - their default values,
  - their per-parameter docstrings,
  - their `kind` (whether they're positional only, positional or
keyword, or keyword only), and
- its return converter.

The only thing not copied from the original function is its docstring; the syntax allows you to specify a new docstring.

Here's the syntax for cloning a function:

```plaintext
/***[clinic input]
module.class.new_function [as c_basename] = module.class.

Docstring for new_function goes here.
[clinic start generated code]*/

(The functions can be in different modules or classes. I wrote module.class in the sample just to illustrate that you must use the full path to both functions.)

Sorry, there's no syntax for partially-cloning a function, or cloning a function then modifying it. Cloning is an all-or nothing proposition.

Also, the function you are cloning from must have been previously defined in the current file.

Calling Python code

The rest of the advanced topics require you to write Python code which lives inside your C file and modifies Argument Clinic's runtime state. This is simple: you simply define a Python block.

A Python block uses different delimiter lines than an Argument Clinic function block. It looks like this:
All the code inside the Python block is executed at the time it's parsed. All text written to stdout inside the block is redirected into the “output” after the block.

As an example, here's a Python block that adds a static integer variable to the C code:

```python
print('static int __ignored_unused_variable__ = 0;')
```

Using a “self converter”

Argument Clinic automatically adds a “self” parameter for you using a default converter. It automatically sets the type of this parameter to the “pointer to an instance” you specified when you declared the type. However, you can override Argument Clinic’s converter and specify one yourself. Just add your own self parameter as the first parameter in a block, and ensure that its converter is an instance of self_converter or a subclass thereof.

What's the point? This lets you override the type of self, or give it a different default name.

How do you specify the custom type you want to cast self to? If you only have one or two functions with the same type for self, you can
directly use Argument Clinic's existing self converter, passing in the type you want to use as the type parameter:

```c
/*[clinic input]
_pickle.Pickler.dump
    self: self(type="PicklerObject *")
    obj: object
/
Write a pickled representation of the given object to
[clinic start generated code]*/
```

On the other hand, if you have a lot of functions that will use the same type for self, it's best to create your own converter, subclassing `self_converter` but overwriting the type member:

```python
/*[python input]
class PicklerObject_converter(self_converter):
    type = "PicklerObject *
[python start generated code]*/

/*[clinic input]
_pickle.Pickler.dump
    self: PicklerObject
    obj: object
/
Write a pickled representation of the given object to
[clinic start generated code]*/
```
Writing a custom converter

As we hinted at in the previous section... you can write your own converters! A converter is simply a Python class that inherits from CConverter. The main purpose of a custom converter is if you have a parameter using the 0& format unit–parsing this parameter means calling a `PyArg_ParseTuple()` “converter function”.

Your converter class should be named *something*_converter. If the name follows this convention, then your converter class will be automatically registered with Argument Clinic; its name will be the name of your class with the _converter suffix stripped off. (This is accomplished with a metaclass.)

You shouldn’t subclass CConverter.__init__. Instead, you should write a converter_init() function. converter_init() always accepts a self parameter; after that, all additional parameters must be keyword-only. Any arguments passed in to the converter in Argument Clinic will be passed along to your converter_init().

There are some additional members of CConverter you may wish to specify in your subclass. Here’s the current list:

- **type**
  The C type to use for this variable. type should be a Python string specifying the type, e.g. int. If this is a pointer type, the type string should end with '*'.

- **default**
  The Python default value for this parameter, as a Python value. Or the magic value unspecified if there is no default.

- **py_default**
default as it should appear in Python code, as a string. Or None if there is no default.

c_default
default as it should appear in C code, as a string. Or None if there is no default.

c_ignored_default
The default value used to initialize the C variable when there is no default, but not specifying a default may result in an “uninitialized variable” warning. This can easily happen when using option groups—although properly-written code will never actually use this value, the variable does get passed in to the impl, and the C compiler will complain about the “use” of the uninitialized value. This value should always be a non-empty string.

converter
The name of the C converter function, as a string.

impl_by_reference
A boolean value. If true, Argument Clinic will add a & in front of the name of the variable when passing it into the impl function.

parse_by_reference
A boolean value. If true, Argument Clinic will add a & in front of the name of the variable when passing it into PyArg_ParseTuple().

Here’s the simplest example of a custom converter, from Modules/zlibmodule.c:

/*[python input]

class capped_uint_converter(CConverter):
    type = 'unsigned int'
    converter = 'capped_uint_converter'

[python start generated code]*/
This block adds a converter to Argument Clinic named capped\_uint. Parameters declared as capped\_uint will be declared as type unsigned int, and will be parsed by the 'O&' format unit, which will call the capped\_uint\_converter converter function. capped\_uint variables automatically support default values.

More sophisticated custom converters can insert custom C code to handle initialization and cleanup. You can see more examples of custom converters in the CPython source tree; grep the C files for the string CConverter.

**Writing a custom return converter**

Writing a custom return converter is much like writing a custom converter. Except it's somewhat simpler, because return converters are themselves much simpler.

Return converters must subclass CReturnConverter. There are no examples yet of custom return converters, because they are not widely used yet. If you wish to write your own return converter, please read Tools/clinic/clinic.py, specifically the implementation of CReturnConverter and all its subclasses.

**METH\_O and METH\_NOARGS**

To convert a function using METH\_O, make sure the function’s single argument is using the object converter, and mark the arguments as positional-only:
To convert a function using METH_NOARGS, just don’t specify any arguments.

You can still use a self converter, a return converter, and specify a type argument to the object converter for METH_0.

**tp_new and tp_init functions**

You can convert `tp_new` and `tp_init` functions. Just name them `__new__` or `__init__` as appropriate. Notes:

- The function name generated for `__new__` doesn’t end in `__new__` like it would by default. It’s just the name of the class, converted into a valid C identifier.
- No PyMethodDef #define is generated for these functions.
- `__init__` functions return int, not PyObject *.
- Use the docstring as the class docstring.
- Although `__new__` and `__init__` functions must always accept both the args and kwargs objects, when converting you may specify any signature for these functions that you like. (If your function doesn’t support keywords, the parsing function generated will throw an exception if it receives any.)

**Changing and redirecting Clinic’s output**

It can be inconvenient to have Clinic’s output interspersed with your
conventional hand-edited C code. Luckily, Clinic is configurable: you can buffer up its output for printing later (or earlier!), or write its output to a separate file. You can also add a prefix or suffix to every line of Clinic’s generated output.

While changing Clinic’s output in this manner can be a boon to readability, it may result in Clinic code using types before they are defined, or your code attempting to use Clinic-generated code before it is defined. These problems can be easily solved by rearranging the declarations in your file, or moving where Clinic’s generated code goes. (This is why the default behavior of Clinic is to output everything into the current block; while many people consider this hampers readability, it will never require rearranging your code to fix definition-before-use problems.)

Let’s start with defining some terminology:

field

A field, in this context, is a subsection of Clinic’s output. For example, the #define for the PyObjectDef structure is a field, called methoddef_define. Clinic has seven different fields it can output per function definition:

```
docstring_prototype
docstring_definition
methoddef_define
impl_prototype
parser_prototype
parser_definition
impl_definition
```

All the names are of the form "<a>_<b>", where "<a>" is the semantic object represented (the parsing function, the impl
function, the docstring, or the methoddef structure) and "<b>" represents what kind of statement the field is. Field names that end in "_prototype" represent forward declarations of that thing, without the actual body/data of the thing; field names that end in "_definition" represent the actual definition of the thing, with the body/data of the thing. ("methoddef" is special, it's the only one that ends with "_define", representing that it's a preprocessor #define.)

**destination**

A destination is a place Clinic can write output to. There are five built-in destinations:

**block**

The default destination: printed in the output section of the current Clinic block.

**buffer**

A text buffer where you can save text for later. Text sent here is appended to the end of any existing text. It's an error to have any text left in the buffer when Clinic finishes processing a file.

**file**

A separate “clinic file” that will be created automatically by Clinic. The filename chosen for the file is {basename}.clinic{extension}, where basename and extension were assigned the output from os.path.splitext() run on the current file. (Example: the file destination for _pickle.c would be written to _pickle.clinic.c.)

**Important: When using a file destination, you must check in the generated file!**
two-pass
A buffer like buffer. However, a two-pass buffer can only be written once, and it prints out all text sent to it during all of processing, even from Clinic blocks after the

suppress
The text is suppressed–thrown away.

Clinic defines five new directives that let you reconfigure its output.

The first new directive is dump:

```bash
dump <destination>
```

This dumps the current contents of the named destination into the output of the current block, and empties it. This only works with buffer and two-pass destinations.

The second new directive is output. The most basic form of output is like this:

```bash
output <field> <destination>
```

This tells Clinic to output field to destination. output also supports a special meta-destination, called everything, which tells Clinic to output all fields to that destination.

output has a number of other functions:

```bash
output push
output pop
output preset <preset>
```

output push and output pop allow you to push and pop
configurations on an internal configuration stack, so that you can temporarily modify the output configuration, then easily restore the previous configuration. Simply push before your change to save the current configuration, then pop when you wish to restore the previous configuration.

output preset sets Clinic's output to one of several built-in preset configurations, as follows:

- **block**
  Clinic's original starting configuration. Writes everything immediately after the input block.

  Suppress the parser_prototype and docstring_prototype, write everything else to block.

- **file**
  Designed to write everything to the “clinic file” that it can. You then include this file near the top of your file. You may need to rearrange your file to make this work, though usually this just means creating forward declarations for various typedef and PyTypeObject definitions.

  Suppress the parser_prototype and docstring_prototype, write the impl_definition to block, and write everything else to file.

  The default filename is "{dirname}/clinic/{basename}.h".

- **buffer**
  Save up all most of the output from Clinic, to be written into your file near the end. For Python files implementing modules
or builtin types, it's recommended that you dump the buffer just above the static structures for your module or builtin type; these are normally very near the end. Using buffer may require even more editing than file, if your file has static PyMethodDef arrays defined in the middle of the file.

Suppress the parserPrototype, implPrototype, and docstringPrototype, write the implDefinition to block, and write everything else to file.

two-pass
Similar to the buffer preset, but writes forward declarations to the two-pass buffer, and definitions to the buffer. This is similar to the buffer preset, but may require less editing than buffer. Dump the two-pass buffer near the top of your file, and dump the buffer near the end just like you would when using the buffer preset.

Suppresses the implPrototype, write the implDefinition to block, write docstringPrototype, methoddefDefine, and parserPrototype to two-pass, write everything else to buffer.

partial-buffer
Similar to the buffer preset, but writes more things to block, only writing the really big chunks of generated code to buffer. This avoids the definition-before-use problem of buffer completely, at the small cost of having slightly more stuff in the block's output. Dump the buffer near the end, just like you would when using the buffer preset.
Suppresses the `impl_prototype`, write the `docstring_definition` and `parser_definition` to `buffer`, write everything else to `block`.

The third new directive is `destination`:

```
destination <name> <command> [...]
```

This performs an operation on the destination named `name`.

There are two defined subcommands: `new` and `clear`.

The new subcommand works like this:

```
destination <name> new <type>
```

This creates a new destination with name `<name>` and type `<type>`.

There are five destination types:

- `suppress`
  Thrown the text away.
- `block`
  Writes the text to the current block. This is what Clinic originally did.
- `buffer`
  A simple text buffer, like the “buffer” builtin destination above.
- `file`
  A text file. The file destination takes an extra argument, a template to use for building the filename, like so:

```
destination <name> new <type> <file_template>
```
The template can use three strings internally that will be replaced by bits of the filename:

{path}
    The full path to the file, including directory and full filename.

{dirname}
    The name of the directory the file is in.

{basename}
    Just the name of the file, not including the directory.

{basename_root}
    Basename with the extension clipped off (everything up to but not including the last '.').

{basename_extension}
    The last '.' and everything after it. If the basename does not contain a period, this will be the empty string.

If there are no periods in the filename, {basename} and {filename} are the same, and {extension} is empty. “{basename}{extension}” is always exactly the same as “{filename}”.

two-pass
    A two-pass buffer, like the “two-pass” builtin destination above.

The clear subcommand works like this:

destination <name> clear

It removes all the accumulated text up to this point in the destination. (I don’t know what you’d need this for, but I thought maybe it’d be useful while someone’s experimenting.)
The fourth new directive is set:

```plaintext
set line_prefix "string"
set line_suffix "string"
```

set lets you set two internal variables in Clinic. line_prefix is a string that will be prepended to every line of Clinic's output; line_suffix is a string that will be appended to every line of Clinic's output.

Both of these support two format strings:

```
{block comment start}
    Turns into the string /*, the start-comment text sequence for C files.
{block comment end}
    Turns into the string */, the end-comment text sequence for C files.
```

The final new directive is one you shouldn’t need to use directly, called preserve:

```plaintext
preserve
```

This tells Clinic that the current contents of the output should be kept, unmodified. This is used internally by Clinic when dumping output into file files; wrapping it in a Clinic block lets Clinic use its existing checksum functionality to ensure the file was not modified by hand before it gets overwritten.

**The #ifdef trick**

If you’re converting a function that isn’t available on all platforms,
there’s a trick you can use to make life a little easier. The existing code probably looks like this:

```c
#ifdef HAVE_FUNCTIONNAME
static module_functionname(...)
{
...
}
#endif /* HAVE_FUNCTIONNAME */
```

And then in the PyMethodDef structure at the bottom the existing code will have:

```c
#ifdef HAVE_FUNCTIONNAME
{'functionname', ... },
#endif /* HAVE_FUNCTIONNAME */
```

In this scenario, you should enclose the body of your impl function inside the `#ifdef`, like so:

```c
#ifdef HAVE_FUNCTIONNAME
/*[clinic input]*/
module.functionname
...
[clinic start generated code]*/
static module_functionname(...)
{
...
}
#endif /* HAVE_FUNCTIONNAME */
```

Then, remove those three lines from the PyMethodDef structure, replacing them with the macro Argument Clinic generated:

```
MODULE_FUNCTIONNAME_METHODDEF
```
(You can find the real name for this macro inside the generated code. Or you can calculate it yourself: it's the name of your function as defined on the first line of your block, but with periods changed to underscores, uppercased, and "_METHODDEF" added to the end.)

Perhaps you're wondering: what if HAVE_FUNCTIONNAME isn't defined? The MODULE_FUNCTIONNAME_METHODDEF macro won't be defined either!

Here's where Argument Clinic gets very clever. It actually detects that the Argument Clinic block might be deactivated by the #ifdef. When that happens, it generates a little extra code that looks like this:

```
#ifndef MODULE_FUNCTIONNAME_METHODDEF
#define MODULE_FUNCTIONNAME_METHODDEF
#endif /* !defined(MODULE_FUNCTIONNAME_METHODDEF) */
```

That means the macro always works. If the function is defined, this turns into the correct structure, including the trailing comma. If the function is undefined, this turns into nothing.

However, this causes one ticklish problem: where should Argument Clinic put this extra code when using the “block” output preset? It can’t go in the output block, because that could be deactivated by the #ifdef. (That's the whole point!)

In this situation, Argument Clinic writes the extra code to the “buffer” destination. This may mean that you get a complaint from Argument Clinic:

```
Warning in file "Modules/posixmodule.c" on line 1235
Destination buffer 'buffer' not empty at end of file
```
When this happens, just open your file, find the dump buffer block that Argument Clinic added to your file (it'll be at the very bottom), then move it above the PyMethodDef structure where that macro is used.

Using Argument Clinic in Python files

It's actually possible to use Argument Clinic to preprocess Python files. There's no point to using Argument Clinic blocks, of course, as the output wouldn't make any sense to the Python interpreter. But using Argument Clinic to run Python blocks lets you use Python as a Python preprocessor!

Since Python comments are different from C comments, Argument Clinic blocks embedded in Python files look slightly different. They look like this:

```python
#/*[python input]
#print("def foo(): pass")
#[python start generated code]*/
def foo(): pass
#/*[python checksum:...]*/
```
General Python FAQ

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General Information

What is Python?

Python is an interpreted, interactive, object-oriented programming language. It incorporates modules, exceptions, dynamic typing, very high level dynamic data types, and classes. Python combines remarkable power with very clear syntax. It has interfaces to many system calls and libraries, as well as to various window systems, and is extensible in C or C++. It is also usable as an extension language for applications that need a programmable interface. Finally, Python is portable: it runs on many Unix variants, on the Mac, and on Windows 2000 and later.

To find out more, start with The Python Tutorial. The Beginner’s Guide to Python links to other introductory tutorials and resources for learning Python.

What is the Python Software Foundation?

The Python Software Foundation is an independent non-profit organization that holds the copyright on Python versions 2.1 and newer. The PSF’s mission is to advance open source technology related to the Python programming language and to publicize the use of Python. The PSF’s home page is at https://www.python.org/psf/.

Donations to the PSF are tax-exempt in the US. If you use Python and find it helpful, please contribute via the PSF donation page.

Are there copyright restrictions on the use of Python?
You can do anything you want with the source, as long as you leave the copyrights in and display those copyrights in any documentation about Python that you produce. If you honor the copyright rules, it's OK to use Python for commercial use, to sell copies of Python in source or binary form (modified or unmodified), or to sell products that incorporate Python in some form. We would still like to know about all commercial use of Python, of course.

See the PSF license page to find further explanations and a link to the full text of the license.

The Python logo is trademarked, and in certain cases permission is required to use it. Consult the Trademark Usage Policy for more information.

**Why was Python created in the first place?**

Here's a very brief summary of what started it all, written by Guido van Rossum:

I had extensive experience with implementing an interpreted language in the ABC group at CWI, and from working with this group I had learned a lot about language design. This is the origin of many Python features, including the use of indentation for statement grouping and the inclusion of very-high-level data types (although the details are all different in Python).

I had a number of gripes about the ABC language, but also liked many of its features. It was impossible to extend the ABC language (or its implementation) to remedy my complaints – in fact its lack of extensibility was one of its biggest problems. I had some experience with using Modula-2+ and talked with the designers of Modula-3 and read the Modula-3 report. Modula-3 is
the origin of the syntax and semantics used for exceptions, and some other Python features.

I was working in the Amoeba distributed operating system group at CWI. We needed a better way to do system administration than by writing either C programs or Bourne shell scripts, since Amoeba had its own system call interface which wasn’t easily accessible from the Bourne shell. My experience with error handling in Amoeba made me acutely aware of the importance of exceptions as a programming language feature.

It occurred to me that a scripting language with a syntax like ABC but with access to the Amoeba system calls would fill the need. I realized that it would be foolish to write an Amoeba-specific language, so I decided that I needed a language that was generally extensible.

During the 1989 Christmas holidays, I had a lot of time on my hand, so I decided to give it a try. During the next year, while still mostly working on it in my own time, Python was used in the Amoeba project with increasing success, and the feedback from colleagues made me add many early improvements.

In February 1991, after just over a year of development, I decided to post to USENET. The rest is in the Misc/HISTORY file.

What is Python good for?

Python is a high-level general-purpose programming language that can be applied to many different classes of problems.

The language comes with a large standard library that covers areas such as string processing (regular expressions, Unicode, calculating
differences between files), Internet protocols (HTTP, FTP, SMTP, XML-RPC, POP, IMAP, CGI programming), software engineering (unit testing, logging, profiling, parsing Python code), and operating system interfaces (system calls, filesystems, TCP/IP sockets). Look at the table of contents for The Python Standard Library to get an idea of what’s available. A wide variety of third-party extensions are also available. Consult the Python Package Index to find packages of interest to you.

How does the Python version numbering scheme work?

Python versions are numbered A.B.C or A.B. A is the major version number – it is only incremented for really major changes in the language. B is the minor version number, incremented for less earth-shattering changes. C is the micro-level – it is incremented for each bugfix release. See PEP 6 for more information about bugfix releases.

Not all releases are bugfix releases. In the run-up to a new major release, a series of development releases are made, denoted as alpha, beta, or release candidate. Alphas are early releases in which interfaces aren’t yet finalized; it’s not unexpected to see an interface change between two alpha releases. Betas are more stable, preserving existing interfaces but possibly adding new modules, and release candidates are frozen, making no changes except as needed to fix critical bugs.

Alpha, beta and release candidate versions have an additional suffix. The suffix for an alpha version is “aN” for some small number N, the suffix for a beta version is “bN” for some small number N, and the suffix for a release candidate version is “cN” for some small number N. In other words, all versions labeled 2.0aN precede the versions
labeled 2.0bN, which precede versions labeled 2.0cN, and those precede 2.0.

You may also find version numbers with a “+” suffix, e.g. “2.2+”. These are unreleased versions, built directly from the Subversion trunk. In practice, after a final minor release is made, the Subversion trunk is incremented to the next minor version, which becomes the “a0” version, e.g. “2.4a0”.

See also the documentation for `sys.version`, `sys.hexversion`, and `sys.version_info`.

How do I obtain a copy of the Python source?

The latest Python source distribution is always available from python.org, at https://www.python.org/download/. The latest development sources can be obtained via anonymous Mercurial access at https://hg.python.org/cpython.

The source distribution is a gzipped tar file containing the complete C source, Sphinx-formatted documentation, Python library modules, example programs, and several useful pieces of freely distributable software. The source will compile and run out of the box on most UNIX platforms.

Consult the Getting Started section of the Python Developer’s Guide for more information on getting the source code and compiling it.

How do I get documentation on Python?

The standard documentation for the current stable version of Python is available at https://docs.python.org/3/. PDF, plain text, and
downloadable HTML versions are also available at https://docs.python.org/3/download.html.

The documentation is written in reStructuredText and processed by the Sphinx documentation tool. The reStructuredText source for the documentation is part of the Python source distribution.

I've never programmed before. Is there a Python tutorial?

There are numerous tutorials and books available. The standard documentation includes The Python Tutorial.

Consult the Beginner’s Guide to find information for beginning Python programmers, including lists of tutorials.

Is there a newsgroup or mailing list devoted to Python?

There is a newsgroup, comp.lang.python, and a mailing list, python-list. The newsgroup and mailing list are gatewayed into each other – if you can read news it’s unnecessary to subscribe to the mailing list. comp.lang.python is high-traffic, receiving hundreds of postings every day, and Usenet readers are often more able to cope with this volume.

Announcements of new software releases and events can be found in comp.lang.python.announce, a low-traffic moderated list that receives about five postings per day. It’s available as the python-announce mailing list.

More info about other mailing lists and newsgroups can be found at https://www.python.org/community/lists/.
How do I get a beta test version of Python?

Alpha and beta releases are available from https://www.python.org/download/. All releases are announced on the comp.lang.python and comp.lang.python.announce newsgroups and on the Python home page at https://www.python.org/; an RSS feed of news is available.

You can also access the development version of Python through Mercurial. See https://docs.python.org/devguide/faq.html for details.

How do I submit bug reports and patches for Python?

To report a bug or submit a patch, please use the Roundup installation at https://bugs.python.org/.

You must have a Roundup account to report bugs; this makes it possible for us to contact you if we have follow-up questions. It will also enable Roundup to send you updates as we act on your bug. If you had previously used SourceForge to report bugs to Python, you can obtain your Roundup password through Roundup’s password reset procedure.

For more information on how Python is developed, consult the Python Developer’s Guide.

Are there any published articles about Python that I can reference?

It’s probably best to cite your favorite book about Python.
The very first article about Python was written in 1991 and is now quite outdated.


**Are there any books on Python?**

Yes, there are many, and more are being published. See the python.org wiki at [https://wiki.python.org/moin/PythonBooks](https://wiki.python.org/moin/PythonBooks) for a list.

You can also search online bookstores for “Python” and filter out the Monty Python references; or perhaps search for “Python” and “language”.

**Where in the world is www.python.org located?**

The Python project’s infrastructure is located all over the world. [www.python.org](http://www.python.org) is graciously hosted by [Rackspace](http://www.rackspace.com), with CDN caching provided by [Fastly](http://www.fastly.com). [Upfront Systems](http://www.upfrontsystems.com) hosts [bugs.python.org](http://bugs.python.org). Many other Python services like [the Wiki](http://wiki.python.org) are hosted by [Oregon State University Open Source Lab](http://www.osuosl.org).

**Why is it called Python?**

When he began implementing Python, Guido van Rossum was also reading the published scripts from “*Monty Python's Flying Circus*”, a BBC comedy series from the 1970s. Van Rossum thought he needed a name that was short, unique, and slightly mysterious, so he decided to call the language Python.
Do I have to like “Monty Python’s Flying Circus”?

No, but it helps. :)

Python in the real world

How stable is Python?

Very stable. New, stable releases have been coming out roughly every 6 to 18 months since 1991, and this seems likely to continue. Currently there are usually around 18 months between major releases.

The developers issue “bugfix” releases of older versions, so the stability of existing releases gradually improves. Bugfix releases, indicated by a third component of the version number (e.g. 2.5.3, 2.6.2), are managed for stability; only fixes for known problems are included in a bugfix release, and it's guaranteed that interfaces will remain the same throughout a series of bugfix releases.

The latest stable releases can always be found on the Python download page. There are two recommended production-ready versions at this point in time, because at the moment there are two branches of stable releases: 2.x and 3.x. Python 3.x may be less useful than 2.x, since currently there is more third party software available for Python 2 than for Python 3. Python 2 code will generally not run unchanged in Python 3.

How many people are using Python?

There are probably tens of thousands of users, though it's difficult to obtain an exact count.

Python is available for free download, so there are no sales figures, and it's available from many different sites and packaged with many Linux distributions, so download statistics don't tell the whole story either.
The comp.lang.python newsgroup is very active, but not all Python users post to the group or even read it.

**Have any significant projects been done in Python?**

See [https://www.python.org/about/success](https://www.python.org/about/success) for a list of projects that use Python. Consulting the proceedings for past Python conferences will reveal contributions from many different companies and organizations.

High-profile Python projects include the Mailman mailing list manager and the Zope application server. Several Linux distributions, most notably Red Hat, have written part or all of their installer and system administration software in Python. Companies that use Python internally include Google, Yahoo, and Lucasfilm Ltd.

**What new developments are expected for Python in the future?**

See [https://www.python.org/dev/peps/](https://www.python.org/dev/peps/) for the Python Enhancement Proposals (PEPs). PEPs are design documents describing a suggested new feature for Python, providing a concise technical specification and a rationale. Look for a PEP titled “Python X.Y Release Schedule”, where X.Y is a version that hasn’t been publicly released yet.

New development is discussed on the python-dev mailing list.

**Is it reasonable to propose incompatible changes to Python?**
In general, no. There are already millions of lines of Python code around the world, so any change in the language that invalidates more than a very small fraction of existing programs has to be frowned upon. Even if you can provide a conversion program, there’s still the problem of updating all documentation; many books have been written about Python, and we don’t want to invalidate them all at a single stroke.

Providing a gradual upgrade path is necessary if a feature has to be changed. PEP 5 describes the procedure followed for introducing backward-incompatible changes while minimizing disruption for users.

**Is Python a good language for beginning programmers?**

Yes.

It is still common to start students with a procedural and statically typed language such as Pascal, C, or a subset of C++ or Java. Students may be better served by learning Python as their first language. Python has a very simple and consistent syntax and a large standard library and, most importantly, using Python in a beginning programming course lets students concentrate on important programming skills such as problem decomposition and data type design. With Python, students can be quickly introduced to basic concepts such as loops and procedures. They can probably even work with user-defined objects in their very first course.

For a student who has never programmed before, using a statically typed language seems unnatural. It presents additional complexity that the student must master and slows the pace of the course. The students are trying to learn to think like a computer, decompose
problems, design consistent interfaces, and encapsulate data. While learning to use a statically typed language is important in the long term, it is not necessarily the best topic to address in the students’ first programming course.

Many other aspects of Python make it a good first language. Like Java, Python has a large standard library so that students can be assigned programming projects very early in the course that do something. Assignments aren’t restricted to the standard four-function calculator and check balancing programs. By using the standard library, students can gain the satisfaction of working on realistic applications as they learn the fundamentals of programming. Using the standard library also teaches students about code reuse. Third-party modules such as PyGame are also helpful in extending the students’ reach.

Python’s interactive interpreter enables students to test language features while they’re programming. They can keep a window with the interpreter running while they enter their program’s source in another window. If they can’t remember the methods for a list, they can do something like this:

```python
>>> L = []
>>> dir(L)
['__add__', '__class__', '__contains__', '__delattr__', '__dir__', '__doc__', '__eq__', '__format__', '__ge__', '__getattribute__', '__getitem__', '__gt__', '__hash__', '__imul__', '__init__', '__iter__', '__len__', '__le__', '__mod__', '__mul__', '__ne__', '__new__', '__reduce__', '__reduce_ex__', '__repr__', '__reversed__', '__rmul__', '__setattr__', '__sizeof__', '__str__', '__subclasshook__', 'append', 'clear', 'copy', 'count', 'extend', 'insert', 'pop', 'reverse', 'sort']
>>> [d for d in dir(L) if '__' not in d]
```
[`append`, `clear`, `copy`, `count`, `extend`, `index`, `insert`, `pop`, `remove`, `reverse`, `sort`]

```python
>>> help(L.append)
Help on built-in function append:

append(...)  
    L.append(object) -> None -- append object to end

>>> L.append(1)
>>> L
[1]
```

With the interpreter, documentation is never far from the student as he’s programming.

There are also good IDEs for Python. IDLE is a cross-platform IDE for Python that is written in Python using Tkinter. PythonWin is a Windows-specific IDE. Emacs users will be happy to know that there is a very good Python mode for Emacs. All of these programming environments provide syntax highlighting, auto-indenting, and access to the interactive interpreter while coding. Consult the Python wiki for a full list of Python editing environments.

If you want to discuss Python’s use in education, you may be interested in joining the edu-sig mailing list.
Programming FAQ

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General Questions

Is there a source code level debugger with breakpoints, single-stepping, etc.?

Yes.

The pdb module is a simple but adequate console-mode debugger for Python. It is part of the standard Python library, and is documented in the Library Reference Manual. You can also write your own debugger by using the code for pdb as an example.

The IDLE interactive development environment, which is part of the standard Python distribution (normally available as Tools/scripts/idle), includes a graphical debugger.

PythonWin is a Python IDE that includes a GUI debugger based on pdb. The Pythonwin debugger colors breakpoints and has quite a few cool features such as debugging non-Pythonwin programs. Pythonwin is available as part of the Python for Windows Extensions project and as a part of the ActivePython distribution (see http://www.activestate.com/activepython).

Boa Constructor is an IDE and GUI builder that uses wxWidgets. It offers visual frame creation and manipulation, an object inspector, many views on the source like object browsers, inheritance hierarchies, doc string generated html documentation, an advanced debugger, integrated help, and Zope support.

Eric is an IDE built on PyQt and the Scintilla editing component.

Pydb is a version of the standard Python debugger pdb, modified for
use with DDD (Data Display Debugger), a popular graphical debugger front end. Pydb can be found at http://bashdb.sourceforge.net/pydb/ and DDD can be found at http://www.gnu.org/software/ddd.

There are a number of commercial Python IDEs that include graphical debuggers. They include:

- Wing IDE (http://wingware.com/)
- Komodo IDE (http://komodoide.com/)
- PyCharm (https://www.jetbrains.com/pycharm/)

Is there a tool to help find bugs or perform static analysis?

Yes.

PyChecker is a static analysis tool that finds bugs in Python source code and warns about code complexity and style. You can get PyChecker from http://pychecker.sourceforge.net/.

Pylint is another tool that checks if a module satisfies a coding standard, and also makes it possible to write plug-ins to add a custom feature. In addition to the bug checking that PyChecker performs, Pylint offers some additional features such as checking line length, whether variable names are well-formed according to your coding standard, whether declared interfaces are fully implemented, and more. http://docs.pylint.org/ provides a full list of Pylint’s features.

How can I create a stand-alone binary from a Python script?

You don’t need the ability to compile Python to C code if all you want is
a stand-alone program that users can download and run without having to install the Python distribution first. There are a number of tools that determine the set of modules required by a program and bind these modules together with a Python binary to produce a single executable.

One is to use the freeze tool, which is included in the Python source tree as `Tools/freeze`. It converts Python byte code to C arrays; a C compiler you can embed all your modules into a new program, which is then linked with the standard Python modules.

It works by scanning your source recursively for import statements (in both forms) and looking for the modules in the standard Python path as well as in the source directory (for built-in modules). It then turns the bytecode for modules written in Python into C code (array initializers that can be turned into code objects using the marshal module) and creates a custom-made config file that only contains those built-in modules which are actually used in the program. It then compiles the generated C code and links it with the rest of the Python interpreter to form a self-contained binary which acts exactly like your script.

Obviously, freeze requires a C compiler. There are several other utilities which don’t. One is Thomas Heller’s py2exe (Windows only) at http://www.py2exe.org/

Another tool is Anthony Tuininga’s `cx_Freeze`.

Are there coding standards or a style guide for Python programs?

Yes. The coding style required for standard library modules is
documented as **PEP 8**.
Core Language

Why am I getting an UnboundLocalError when the variable has a value?

It can be a surprise to get the UnboundLocalError in previously working code when it is modified by adding an assignment statement somewhere in the body of a function.

This code:

```python
>>> x = 10
>>> def bar():
...     print(x)
>>> bar()
10
```

works, but this code:

```python
>>> x = 10
>>> def foo():
...     print(x)
...     x += 1
```

results in an UnboundLocalError:

```python
>>> foo()
Traceback (most recent call last):
  ... 
UnboundLocalError: local variable 'x' referenced before assignment
```

This is because when you make an assignment to a variable in a scope, that variable becomes local to that scope and shadows any
similarly named variable in the outer scope. Since the last statement in foo assigns a new value to x, the compiler recognizes it as a local variable. Consequently when the earlier print(x) attempts to print the uninitialized local variable and an error results.

In the example above you can access the outer scope variable by declaring it global:

```python
>>> x = 10
>>> def foobar():
...     global x
...     print(x)
...     x += 1
>>> foobar()
10
```

This explicit declaration is required in order to remind you that (unlike the superficially analogous situation with class and instance variables) you are actually modifying the value of the variable in the outer scope:

```python
>>> print(x)
11
```

You can do a similar thing in a nested scope using the `nonlocal` keyword:

```python
>>> def foo():
...     x = 10
...     def bar():
...         nonlocal x
...         print(x)
...         x += 1
...         bar()
...     print(x)
>>> foo()
```
What are the rules for local and global variables in Python?

In Python, variables that are only referenced inside a function are implicitly global. If a variable is assigned a value anywhere within the function’s body, it’s assumed to be a local unless explicitly declared as global.

Though a bit surprising at first, a moment’s consideration explains this. On one hand, requiring `global` for assigned variables provides a bar against unintended side-effects. On the other hand, if `global` was required for all global references, you’d be using `global` all the time. You’d have to declare as global every reference to a built-in function or to a component of an imported module. This clutter would defeat the usefulness of the `global` declaration for identifying side-effects.

Why do lambdas defined in a loop with different values all return the same result?

Assume you use a for loop to define a few different lambdas (or even plain functions), e.g.:

```python
>>> squares = []
>>> for x in range(5):
...     squares.append(lambda: x**2)
```

This gives you a list that contains 5 lambdas that calculate `x**2`. You might expect that, when called, they would return, respectively, 0, 1, 4,
9, and 16. However, when you actually try you will see that they all return 16:

```python
>>> squares[2]()
16
>>> squares[4]()
16
```

This happens because x is not local to the lambdas, but is defined in the outer scope, and it is accessed when the lambda is called — not when it is defined. At the end of the loop, the value of x is 4, so all the functions now return 4**2, i.e. 16. You can also verify this by changing the value of x and see how the results of the lambdas change:

```python
>>> x = 8
>>> squares[2]()
64
```

In order to avoid this, you need to save the values in variables local to the lambdas, so that they don’t rely on the value of the global x:

```python
>>> squares = []
>>> for x in range(5):
...     squares.append(lambda n=x: n**2)
```

Here, n=x creates a new variable n local to the lambda and computed when the lambda is defined so that it has the same value that x had at that point in the loop. This means that the value of n will be 0 in the first lambda, 1 in the second, 2 in the third, and so on. Therefore each lambda will now return the correct result:

```python
>>> squares[2]()
```
Note that this behaviour is not peculiar to lambdas, but applies to regular functions too.

**How do I share global variables across modules?**

The canonical way to share information across modules within a single program is to create a special module (often called config or cfg). Just import the config module in all modules of your application; the module then becomes available as a global name. Because there is only one instance of each module, any changes made to the module object get reflected everywhere. For example:

**config.py:**

```python
x = 0  # Default value of the 'x' configuration setting
```

**mod.py:**

```python
import config
config.x = 1
```

**main.py:**

```python
import config
import mod
print(config.x)
```

Note that using a module is also the basis for implementing the Singleton design pattern, for the same reason.
What are the “best practices” for using import in a module?

In general, don’t use `from modulename import *`. Doing so clutters the importer’s namespace, and makes it much harder for linters to detect undefined names.

Import modules at the top of a file. Doing so makes it clear what other modules your code requires and avoids questions of whether the module name is in scope. Using one import per line makes it easy to add and delete module imports, but using multiple imports per line uses less screen space.

It’s good practice if you import modules in the following order:

1. standard library modules – e.g. `sys`, `os`, `getopt`, `re`
2. third-party library modules (anything installed in Python’s `site-packages` directory) – e.g. `mx.DateTime`, `ZODB`, `PIL.Image`, etc.
3. locally-developed modules

It is sometimes necessary to move imports to a function or class to avoid problems with circular imports. Gordon McMillan says:

Circular imports are fine where both modules use the “import `<module>`” form of import. They fail when the 2nd module wants to grab a name out of the first (“from module import name”) and the import is at the top level. That’s because names in the 1st are not yet available, because the first module is busy importing the 2nd.

In this case, if the second module is only used in one function, then the import can easily be moved into that function. By the time the import is called, the first module will have finished initializing, and the second module can do its import.
It may also be necessary to move imports out of the top level of code if some of the modules are platform-specific. In that case, it may not even be possible to import all of the modules at the top of the file. In this case, importing the correct modules in the corresponding platform-specific code is a good option.

Only move imports into a local scope, such as inside a function definition, if it's necessary to solve a problem such as avoiding a circular import or are trying to reduce the initialization time of a module. This technique is especially helpful if many of the imports are unnecessary depending on how the program executes. You may also want to move imports into a function if the modules are only ever used in that function. Note that loading a module the first time may be expensive because of the one time initialization of the module, but loading a module multiple times is virtually free, costing only a couple of dictionary lookups. Even if the module name has gone out of scope, the module is probably available in `sys.modules`.

**Why are default values shared between objects?**

This type of bug commonly bites neophyte programmers. Consider this function:

```python
def foo(mydict={}):  # Danger: shared reference to one dict for all calls...
    ... compute something ...
    mydict[key] = value
    return mydict
```

The first time you call this function, `mydict` contains a single item. The second time, `mydict` contains two items because when `foo()` begins executing, `mydict` starts out with an item already in it.
It is often expected that a function call creates new objects for default values. This is not what happens. Default values are created exactly once, when the function is defined. If that object is changed, like the dictionary in this example, subsequent calls to the function will refer to this changed object.

By definition, immutable objects such as numbers, strings, tuples, and None, are safe from change. Changes to mutable objects such as dictionaries, lists, and class instances can lead to confusion.

Because of this feature, it is good programming practice to not use mutable objects as default values. Instead, use None as the default value and inside the function, check if the parameter is None and create a new list/dictionary/whatever if it is. For example, don't write:

```python
def foo(mydict={}):
    ...
```

but:

```python
def foo(mydict=None):
    if mydict is None:
        mydict = {}  # create a new dict for local namespace
```

This feature can be useful. When you have a function that's time-consuming to compute, a common technique is to cache the parameters and the resulting value of each call to the function, and return the cached value if the same value is requested again. This is called “memoizing”, and can be implemented like this:

```python
# Callers will never provide a third parameter for this function.
def expensive(arg1, arg2, _cache={}):
    if (arg1, arg2) in _cache:
```
You could use a global variable containing a dictionary instead of the default value; it's a matter of taste.

How can I pass optional or keyword parameters from one function to another?

Collect the arguments using the * and ** specifiers in the function's parameter list; this gives you the positional arguments as a tuple and the keyword arguments as a dictionary. You can then pass these arguments when calling another function by using * and **:

```python
def f(x, *args, **kwargs):
    ...
    kwargs['width'] = '14.3c'
    ...
    g(x, *args, **kwargs)
```

What is the difference between arguments and parameters?

Parameters are defined by the names that appear in a function definition, whereas arguments are the values actually passed to a function when calling it. Parameters define what types of arguments a function can accept. For example, given the function definition:
def func(foo, bar=None, **kwargs):
    pass

foo, bar and kwargs are parameters of func. However, when calling
func, for example:

func(42, bar=314, extra=somevar)

the values 42, 314, and somevar are arguments.

Why did changing list ‘y’ also change list ‘x’?

If you wrote code like:

```python
>>> x = []
>>> y = x
>>> y.append(10)
>>> y
[10]
>>> x
[10]
```

you might be wondering why appending an element to y changed x too.

There are two factors that produce this result:

1. Variables are simply names that refer to objects. Doing y = x
doesn't create a copy of the list – it creates a new variable y that
refers to the same object x refers to. This means that there is only
one object (the list), and both x and y refer to it.
2. Lists are mutable, which means that you can change their
content.
After the call to `append()`, the content of the mutable object has changed from `[]` to `[10]`. Since both the variables refer to the same object, using either name accesses the modified value `[10]`.

If we instead assign an immutable object to `x`:

```python
>>> x = 5  # ints are immutable
>>> y = x
>>> x = x + 1  # 5 can't be mutated, we are creating a new object
>>> x
6
>>> y
5
```

we can see that in this case `x` and `y` are not equal anymore. This is because integers are immutable, and when we do `x = x + 1` we are not mutating the int 5 by incrementing its value; instead, we are creating a new object (the int 6) and assigning it to `x` (that is, changing which object `x` refers to). After this assignment we have two objects (the ints 6 and 5) and two variables that refer to them (`x` now refers to 6 but `y` still refers to 5).

Some operations (for example `y.append(10)` and `y.sort()`) mutate the object, whereas superficially similar operations (for example `y = y + [10]` and `sorted(y)`) create a new object. In general in Python (and in all cases in the standard library) a method that mutates an object will return `None` to help avoid getting the two types of operations confused. So if you mistakenly write `y.sort()` thinking it will give you a sorted copy of `y`, you'll instead end up with `None`, which will likely cause your program to generate an easily diagnosed error.
However, there is one class of operations where the same operation sometimes has different behaviors with different types: the augmented assignment operators. For example, `+=` mutates lists but not tuples or ints (`a_list += [1, 2, 3]` is equivalent to `a_list.extend([1, 2, 3])` and mutates `a_list`, whereas `some_tuple += (1, 2, 3)` and `some_int += 1` create new objects).

In other words:

- If we have a mutable object (`list`, `dict`, `set`, etc.), we can use some specific operations to mutate it and all the variables that refer to it will see the change.
- If we have an immutable object (`str`, `int`, `tuple`, etc.), all the variables that refer to it will always see the same value, but operations that transform that value into a new value always return a new object.

If you want to know if two variables refer to the same object or not, you can use the `is` operator, or the built-in function `id()`.

**How do I write a function with output parameters (call by reference)?**

Remember that arguments are passed by assignment in Python. Since assignment just creates references to objects, there's no alias between an argument name in the caller and callee, and so no call-by-reference per se. You can achieve the desired effect in a number of ways.

1. By returning a tuple of the results:

```python
def func2(a, b):
a = 'new-value'
    # a and b are local names
```
\[ b = b + 1 \]  # assigned to new object
\[ \text{return } a, b \]  # return new values

\[ x, y = 'old-value', 99 \]
\[ x, y = \text{func2}(x, y) \]
\[ \text{print}(x, y) \]  # output: new-value 100

This is almost always the clearest solution.

2. By using global variables. This isn’t thread-safe, and is not recommended.

3. By passing a mutable (changeable in-place) object:

```python
def func1(a):
    a[0] = 'new-value'  # 'a' references a mutable list
    a[1] = a[1] + 1     # changes a shared object

args = ['old-value', 99]
func1(args)
print(args[0], args[1])  # output: new-value 100
```

4. By passing in a dictionary that gets mutated:

```python
def func3(args):
    args['a'] = 'new-value'  # args is a mutable dictionary
    args['b'] = args['b'] + 1 # change it in-place

args = {'a': 'old-value', 'b': 99}
func3(args)
print(args['a'], args['b'])
```

5. Or bundle up values in a class instance:
class callByRef:
    def __init__(self, **args):
        for (key, value) in args.items():
            setattr(self, key, value)

def func4(args):
    args.a = 'new-value'          # args is a mutable
    args.b = args.b + 1           # change object:

args = callByRef(a='old-value', b=99)
func4(args)
print(args.a, args.b)

There’s almost never a good reason to get this complicated.

Your best choice is to return a tuple containing the multiple results.

**How do you make a higher order function in Python?**

You have two choices: you can use nested scopes or you can use callable objects. For example, suppose you wanted to define \( f(x) = a \cdot x + b \). Using nested scopes:

```
def linear(a, b):
    def result(x):
        return a * x + b
    return result
```

Or using a callable object:

```
class linear:
```
def __init__(self, a, b):
    self.a, self.b = a, b

def __call__(self, x):
    return self.a * x + self.b

In both cases,

taxes = linear(0.3, 2)

gives a callable object where taxes(10e6) == 0.3 * 10e6 + 2.

The callable object approach has the disadvantage that it is a bit slower and results in slightly longer code. However, note that a collection of callables can share their signature via inheritance:

class exponential(linear):
    # __init__ inherited
    def __call__(self, x):
        return self.a * (x ** self.b)

Object can encapsulate state for several methods:

class counter:

    value = 0

    def set(self, x):
        self.value = x

    def up(self):
        self.value = self.value + 1

    def down(self):
        self.value = self.value - 1
count = counter()
inc, dec, reset = count.up, count.down, count.set

Here inc(), dec() and reset() act like functions which share the same counting variable.

**How do I copy an object in Python?**

In general, try `copy.copy()` or `copy.deepcopy()` for the general case. Not all objects can be copied, but most can.

Some objects can be copied more easily. Dictionaries have a `copy()` method:

    newdict = olddict.copy()

Sequences can be copied by slicing:

    new_l = l[:]

**How can I find the methods or attributes of an object?**

For an instance `x` of a user-defined class, `dir(x)` returns an alphabetized list of the names containing the instance attributes and methods and attributes defined by its class.

**How can my code discover the name of an object?**
Generally speaking, it can’t, because objects don’t really have names. Essentially, assignment always binds a name to a value; The same is true of def and class statements, but in that case the value is a callable. Consider the following code:

```python
class A:
    pass
B = A
a = B()
b = a
print(b)
<__main__.A object at 0x16D07CC>
print(a)
<__main__.A object at 0x16D07CC>
```

Arguably the class has a name: even though it is bound to two names and invoked through the name B the created instance is still reported as an instance of class A. However, it is impossible to say whether the instance’s name is a or b, since both names are bound to the same value.

Generally speaking it should not be necessary for your code to “know the names” of particular values. Unless you are deliberately writing introspective programs, this is usually an indication that a change of approach might be beneficial.

In comp.lang.python, Fredrik Lundh once gave an excellent analogy in answer to this question:

The same way as you get the name of that cat you found on your porch: the cat (object) itself cannot tell you its name, and it doesn’t really care – so the only way to find out what it’s called is to ask all
your neighbours (namespaces) if it’s their cat (object)...

....and don’t be surprised if you’ll find that it’s known by many names, or no name at all!

What’s up with the comma operator’s precedence?

Comma is not an operator in Python. Consider this session:

```python
>>> "a" in "b", "a"
(False, 'a')
```

Since the comma is not an operator, but a separator between expressions the above is evaluated as if you had entered:

```python
("a" in "b"), "a"
```

not:

```python
"a" in ("b", "a")
```

The same is true of the various assignment operators (=, += etc). They are not truly operators but syntactic delimiters in assignment statements.

Is there an equivalent of C’s "?:" ternary operator?

Yes, there is. The syntax is as follows:

```python
[on_true] if [expression] else [on_false]
```

```python
x, y = 50, 25
```
small = x if x < y else y

Before this syntax was introduced in Python 2.5, a common idiom was to use logical operators:

[expression] and [on_true] or [on_false]

However, this idiom is unsafe, as it can give wrong results when on_true has a false boolean value. Therefore, it is always better to use the ... if ... else ... form.

Is it possible to write obfuscated one-liners in Python?

Yes. Usually this is done by nesting lambda within lambda. See the following three examples, due to Ulf Bartelt:

```python
from functools import reduce

# Primes < 1000
print(list(filter(None, map(lambda y:y*reduce(lambda x,y=y%x,range(2,int(pow(y,0.5)+1))),1),
map(lambda x,y=y:y%x,range(2,int(pow(y,0.5)+1))),1)),

# First 10 Fibonacci numbers
print(list(map(lambda x,f=lambda x,y:x+y,map(lambda x,y=x+y,range(10))))

# Mandelbrot set
print((lambda Ru,Ro,Iu,Io,IM,Sx,Sy:reduce(lambda x,y=x+y,map(lambda x,y=x+y,range(1000)))):L(Iu+y*(
```
Don’t try this at home, kids!
Numbers and strings

How do I specify hexadecimal and octal integers?

To specify an octal digit, precede the octal value with a zero, and then a lower or uppercase “o”. For example, to set the variable “a” to the octal value “10” (8 in decimal), type:

```python
>>> a = 0o10
>>> a
8
```

Hexadecimal is just as easy. Simply precede the hexadecimal number with a zero, and then a lower or uppercase “x”. Hexadecimal digits can be specified in lower or uppercase. For example, in the Python interpreter:

```python
>>> a = 0xa5
>>> a
165
>>> b = 0XB2
>>> b
178
```

Why does -22 // 10 return -3?

It's primarily driven by the desire that i % j have the same sign as j. If you want that, and also want:

```python
i == (i // j) * j + (i % j)
```

then integer division has to return the floor. C also requires that identity
to hold, and then compilers that truncate \( i \div j \) need to make \( i \mod j \) have the same sign as \( i \).

There are few real use cases for \( i \mod j \) when \( j \) is negative. When \( j \) is positive, there are many, and in virtually all of them it’s more useful for \( i \mod j \) to be \( \geq 0 \). If the clock says 10 now, what did it say 200 hours ago? \(-190 \mod 12 == 2 \) is useful; \(-190 \mod 12 == -10 \) is a bug waiting to bite.

**How do I convert a string to a number?**

For integers, use the built-in `int()` type constructor, e.g. `int('144') == 144`. Similarly, `float()` converts to floating-point, e.g. `float('144') == 144.0`.

By default, these interpret the number as decimal, so that `int('0144') == 144` and `int('0x144')` raises `ValueError`. `int(string, base)` takes the base to convert from as a second optional argument, so `int('0x144', 16) == 324`. If the base is specified as 0, the number is interpreted using Python’s rules: a leading '0o' indicates octal, and '0x' indicates a hex number.

Do not use the built-in function `eval()` if all you need is to convert strings to numbers. `eval()` will be significantly slower and it presents a security risk: someone could pass you a Python expression that might have unwanted side effects. For example, someone could pass `__import__('os').system("rm -rf $HOME")` which would erase your home directory.

`eval()` also has the effect of interpreting numbers as Python expressions, so that e.g. `eval('09')` gives a syntax error because...
Python does not allow leading ‘0’ in a decimal number (except ‘0’).

How do I convert a number to a string?

To convert, e.g., the number 144 to the string ‘144’, use the built-in type constructor `str()`. If you want a hexadecimal or octal representation, use the built-in functions `hex()` or `oct()`. For fancy formatting, see the String Formatting section, e.g. "{:04d}".format(144) yields '0144' and "{:3f}".format(1.0/3.0) yields '0.333'.

How do I modify a string in place?

You can’t, because strings are immutable. In most situations, you should simply construct a new string from the various parts you want to assemble it from. However, if you need an object with the ability to modify in-place unicode data, try using an `io.StringIO` object or the `array` module:

```python
>>> import io
>>> s = "Hello, world"
>>> sio = io.StringIO(s)
>>> sio.getvalue()
'Hello, world'
>>> sio.seek(7)
7
>>> sio.write("there!"
6
>>> sio.getvalue()
'Hello, there!'

>>> import array
>>> a = array.array('u', s)
```
How do I use strings to call functions/methods?

There are various techniques.

- The best is to use a dictionary that maps strings to functions. The primary advantage of this technique is that the strings do not need to match the names of the functions. This is also the primary technique used to emulate a case construct:

```python
def a():
    pass

def b():
    pass

dispatch = {'go': a, 'stop': b}  # Note lack of parens for func names

dispatch[get_input()]()  # Note trailing parens to call function
```

- Use the built-in function `getattr()`:

```python
import foo
getattr(foo, 'bar')()
```

Note that `getattr()` works on any object, including classes, class instances, modules, and so on.
This is used in several places in the standard library, like this:

```python
class Foo:
    def do_foo(self):
        ...

    def do_bar(self):
        ...

f = getattr(foo_instance, 'do_' + opname)
f()
```

- Use `locals()` or `eval()` to resolve the function name:

```python
def myFunc():
    print("hello")

fname = "myFunc"

f = locals()[fname]
f()

f = eval(fname)
f()
```

Note: Using `eval()` is slow and dangerous. If you don’t have absolute control over the contents of the string, someone could pass a string that resulted in an arbitrary function being executed.

Is there an equivalent to Perl’s chomp() for removing trailing newlines from strings?

You can use `S.rstrip("\r\n")` to remove all occurrences of any line terminator from the end of the string `S` without removing other
trailing whitespace. If the string S represents more than one line, with several empty lines at the end, the line terminators for all the blank lines will be removed:

```python
>>> lines = ("line 1 \r\n"...
            "\r\n"
            "\r\n")
>>> lines.rstrip("\n\r")
'line 1 '  
```

Since this is typically only desired when reading text one line at a time, using S.rstrip() this way works well.

**Is there a scanf() or sscanf() equivalent?**

Not as such.

For simple input parsing, the easiest approach is usually to split the line into whitespace-delimited words using the `split()` method of string objects and then convert decimal strings to numeric values using `int()` or `float()`. `split()` supports an optional “sep” parameter which is useful if the line uses something other than whitespace as a separator.

For more complicated input parsing, regular expressions are more powerful than C’s `sscanf()` and better suited for the task.

**What does ‘UnicodeDecodeError’ or ‘UnicodeEncodeError’ error mean?**

See the [Unicode HOWTO](https://docs.python.org/3/library/unicode.html).
Performance

My program is too slow. How do I speed it up?

That’s a tough one, in general. First, here are a list of things to remember before diving further:

- Performance characteristics vary across Python implementations. This FAQ focusses on CPython.
- Behaviour can vary across operating systems, especially when talking about I/O or multi-threading.
- You should always find the hot spots in your program before attempting to optimize any code (see the profile module).
- Writing benchmark scripts will allow you to iterate quickly when searching for improvements (see the timeit module).
- It is highly recommended to have good code coverage (through unit testing or any other technique) before potentially introducing regressions hidden in sophisticated optimizations.

That being said, there are many tricks to speed up Python code. Here are some general principles which go a long way towards reaching acceptable performance levels:

- Making your algorithms faster (or changing to faster ones) can yield much larger benefits than trying to sprinkle micro-optimization tricks all over your code.
- Use the right data structures. Study documentation for the Built-in Types and the collections module.
- When the standard library provides a primitive for doing something, it is likely (although not guaranteed) to be faster than any alternative you may come up with. This is doubly true for primitives written in C, such as builtins and some extension types. For example, be sure to use either the list.sort() built-in
method or the related `sorted()` function to do sorting (and see the sorting mini-HOWTO for examples of moderately advanced usage).

- Abstractions tend to create indirections and force the interpreter to work more. If the levels of indirection outweigh the amount of useful work done, your program will be slower. You should avoid excessive abstraction, especially under the form of tiny functions or methods (which are also often detrimental to readability).

If you have reached the limit of what pure Python can allow, there are tools to take you further away. For example, Cython can compile a slightly modified version of Python code into a C extension, and can be used on many different platforms. Cython can take advantage of compilation (and optional type annotations) to make your code significantly faster than when interpreted. If you are confident in your C programming skills, you can also write a C extension module yourself.

**See also:** The wiki page devoted to performance tips.

**What is the most efficient way to concatenate many strings together?**

`str` and `bytes` objects are immutable, therefore concatenating many strings together is inefficient as each concatenation creates a new object. In the general case, the total runtime cost is quadratic in the total string length.

To accumulate many `str` objects, the recommended idiom is to place them into a list and call `str.join()` at the end:

```python
chunks = []
for s in my_strings:
    chunks.append(s)
```
result = ''.join(chunks)

(another reasonably efficient idiom is to use `io.StringIO`)

To accumulate many `bytes` objects, the recommended idiom is to extend a `bytearray` object using in-place concatenation (the `+=` operator):

```python
result = bytearray()
for b in my_bytes_objects:
    result += b
```
Sequences (Tuples/Lists)

How do I convert between tuples and lists?

The type constructor `tuple(seq)` converts any sequence (actually, any iterable) into a tuple with the same items in the same order.

For example, `tuple([1, 2, 3])` yields `(1, 2, 3)` and `tuple('abc')` yields ('a', 'b', 'c'). If the argument is a tuple, it does not make a copy but returns the same object, so it is cheap to call `tuple()` when you aren't sure that an object is already a tuple.

The type constructor `list(seq)` converts any sequence or iterable into a list with the same items in the same order. For example, `list((1, 2, 3))` yields `[1, 2, 3]` and `list('abc')` yields ['a', 'b', 'c']. If the argument is a list, it makes a copy just like `seq[:]` would.

What’s a negative index?

Python sequences are indexed with positive numbers and negative numbers. For positive numbers 0 is the first index, 1 is the second index and so forth. For negative indices -1 is the last index and -2 is the penultimate (next to last) index and so forth. Think of `seq[-n]` as the same as `seq[len(seq)-n]`.

Using negative indices can be very convenient. For example `S[: :-1]` is all of the string except for its last character, which is useful for removing the trailing newline from a string.

How do I iterate over a sequence in reverse
order?

Use the reversed() built-in function, which is new in Python 2.4:

```python
for x in reversed(sequence):
    ... # do something with x...
```

This won't touch your original sequence, but build a new copy with reversed order to iterate over.

With Python 2.3, you can use an extended slice syntax:

```python
for x in sequence[::-1]:
    ... # do something with x...
```

How do you remove duplicates from a list?

See the Python Cookbook for a long discussion of many ways to do this:

http://code.activestate.com/recipes/52560/

If you don’t mind reordering the list, sort it and then scan from the end of the list, deleting duplicates as you go:

```python
if mylist:
    mylist.sort()
    last = mylist[-1]
    for i in range(len(mylist)-2, -1, -1):
        if last == mylist[i]:
            del mylist[i]
        else:
            last = mylist[i]
```
If all elements of the list may be used as set keys (i.e. they are all \texttt{hashable}) this is often faster

\begin{verbatim}
mylist = list(set(mylist))
\end{verbatim}

This converts the list into a set, thereby removing duplicates, and then back into a list.

**How do you make an array in Python?**

Use a list:

\begin{verbatim}
["this", 1, "is", "an", "array"]
\end{verbatim}

Lists are equivalent to C or Pascal arrays in their time complexity; the primary difference is that a Python list can contain objects of many different types.

The \texttt{array} module also provides methods for creating arrays of fixed types with compact representations, but they are slower to index than lists. Also note that the Numeric extensions and others define array-like structures with various characteristics as well.

To get Lisp-style linked lists, you can emulate cons cells using tuples:

\begin{verbatim}
lisp_list = ("like", ("this", ("example", None))
\end{verbatim}

If mutability is desired, you could use lists instead of tuples. Here the analogue of lisp car is \texttt{lisp\_list[0]} and the analogue of cdr is \texttt{lisp\_list[1]}. Only do this if you're sure you really need to, because it's usually a lot slower than using Python lists.
How do I create a multidimensional list?

You probably tried to make a multidimensional array like this:

```
>>> A = [[None] * 2] * 3
```

This looks correct if you print it:

```
>>> A
[[None, None], [None, None], [None, None]]
```

But when you assign a value, it shows up in multiple places:

```
>>> A[0][0] = 5
>>> A
[[5, None], [5, None], [5, None]]
```

The reason is that replicating a list with * doesn’t create copies, it only creates references to the existing objects. The *3 creates a list containing 3 references to the same list of length two. Changes to one row will show in all rows, which is almost certainly not what you want.

The suggested approach is to create a list of the desired length first and then fill in each element with a newly created list:

```
A = [None] * 3
for i in range(3):
    A[i] = [None] * 2
```

This generates a list containing 3 different lists of length two. You can also use a list comprehension:

```
w, h = 2, 3
A = [[None] * w for i in range(h)]
```
Or, you can use an extension that provides a matrix datatype; **Numeric Python** is the best known.

**How do I apply a method to a sequence of objects?**

Use a list comprehension:

```
result = [obj.method() for obj in mylist]
```

**Why does a_tuple[i] += ['item'] raise an exception when the addition works?**

This is because of a combination of the fact that augmented assignment operators are *assignment* operators, and the difference between mutable and immutable objects in Python.

This discussion applies in general when augmented assignment operators are applied to elements of a tuple that point to mutable objects, but we'll use a list and `+=` as our exemplar.

If you wrote:

```
>>> a_tuple = (1, 2)
>>> a_tuple[0] += 1
Traceback (most recent call last):
...
TypeError: 'tuple' object does not support item assignment
```

The reason for the exception should be immediately clear: 1 is added to the object `a_tuple[0]` points to (1), producing the result object, 2,
but when we attempt to assign the result of the computation, 2, to element 0 of the tuple, we get an error because we can’t change what an element of a tuple points to.

Under the covers, what this augmented assignment statement is doing is approximately this:

```python
>>> result = a_tuple[0] + 1
>>> a_tuple[0] = result
```

```
Traceback (most recent call last):
  ...
TypeError: 'tuple' object does not support item assignment
```

It is the assignment part of the operation that produces the error, since a tuple is immutable.

When you write something like:

```python
>>> a_tuple = (['foo'], 'bar')
>>> a_tuple[0] += ['item']
```

```
Traceback (most recent call last):
  ...
TypeError: 'tuple' object does not support item assignment
```

The exception is a bit more surprising, and even more surprising is the fact that even though there was an error, the append worked:

```python
>>> a_tuple[0]
['foo', 'item']
```

To see why this happens, you need to know that (a) if an object implements an `_iadd_` magic method, it gets called when the `+=` augmented assignment is executed, and its return value is what gets
used in the assignment statement; and (b) for lists, __iadd__ is equivalent to calling extend on the list and returning the list. That's why we say that for lists, += is a “shorthand” for list.extend:

```python
>>> a_list = []
>>> a_list += [1]
>>> a_list
[1]
```

This is equivalent to:

```python
>>> result = a_list.__iadd__([1])
>>> a_list = result
```

The object pointed to by a_list has been mutated, and the pointer to the mutated object is assigned back to a_list. The end result of the assignment is a no-op, since it is a pointer to the same object that a_list was previously pointing to, but the assignment still happens.

Thus, in our tuple example what is happening is equivalent to:

```python
>>> result = a_tuple[0].__iadd__(['item'])
>>> a_tuple[0] = result
Traceback (most recent call last):
  ...TypeError: 'tuple' object does not support item assignment
```

The __iadd__ succeeds, and thus the list is extended, but even though result points to the same object that a_tuple[0] already points to, that final assignment still results in an error, because tuples are immutable.
Dictionaries

How can I get a dictionary to store and display its keys in a consistent order?

Use `collections.OrderedDict`.

I want to do a complicated sort: can you do a Schwartzian Transform in Python?

The technique, attributed to Randal Schwartz of the Perl community, sorts the elements of a list by a metric which maps each element to its “sort value”. In Python, just use the key argument for the `sort()` method:

```python
Isorted = L[:]
Isorted.sort(key=lambda s: int(s[10:15]))
```

The key argument is new in Python 2.4, for older versions this kind of sorting is quite simple to do with list comprehensions. To sort a list of strings by their uppercase values:

```python
tmp1 = [(x.upper(), x) for x in L]  # Schwartzian transform
tmp1.sort()
Usorted = [x[1] for x in tmp1]
```

To sort by the integer value of a subfield extending from positions 10-15 in each string:

```python
tmp2 = [(int(s[10:15]), s) for s in L]  # Schwartzian transform
tmp2.sort()
```
Isorted = [x[1] for x in tmp2]

For versions prior to 3.0, Isorted may also be computed by

```python
def intfield(s):
    return int(s[10:15])

def Icmp(s1, s2):
    return cmp(intfield(s1), intfield(s2))

Isorted = L[:]
Isorted.sort(Icmp)
```

but since this method calls intfield() many times for each element of L, it is slower than the Schwartzian Transform.

**How can I sort one list by values from another list?**

Merge them into an iterator of tuples, sort the resulting list, and then pick out the element you want.

```python
>>> list1 = ['what', 'I'm', 'sorting', 'by']
>>> list2 = ['something', 'else', 'to', 'sort']
>>> pairs = zip(list1, list2)
>>> pairs = sorted(pairs)
>>> pairs
[('I'm', 'else'), ('by', 'sort'), ('sorting', 'to'), ('what', 'something')]
>>> result = [x[1] for x in pairs]
>>> result
['else', 'sort', 'to', 'something']
```

An alternative for the last step is:
>>> result = []
>>> for p in pairs: result.append(p[1])

If you find this more legible, you might prefer to use this instead of the final list comprehension. However, it is almost twice as slow for long lists. Why? First, the `append()` operation has to reallocate memory, and while it uses some tricks to avoid doing that each time, it still has to do it occasionally, and that costs quite a bit. Second, the expression “result.append” requires an extra attribute lookup, and third, there’s a speed reduction from having to make all those function calls.
Objects

What is a class?

A class is the particular object type created by executing a class statement. Class objects are used as templates to create instance objects, which embody both the data (attributes) and code (methods) specific to a datatype.

A class can be based on one or more other classes, called its base class(es). It then inherits the attributes and methods of its base classes. This allows an object model to be successively refined by inheritance. You might have a generic Mailbox class that provides basic accessor methods for a mailbox, and subclasses such as MboxMailbox, MaildirMailbox, OutlookMailbox that handle various specific mailbox formats.

What is a method?

A method is a function on some object x that you normally call as x.name(arguments...). Methods are defined as functions inside the class definition:

```python
class C:
    def meth(self, arg):
        return arg * 2 + self.attribute
```

What is self?

Self is merely a conventional name for the first argument of a method. A method defined as meth(self, a, b, c) should be called as
x.meth(a, b, c) for some instance x of the class in which the definition occurs; the called method will think it is called as meth(x, a, b, c).

See also Why must ‘self’ be used explicitly in method definitions and calls?

**How do I check if an object is an instance of a given class or of a subclass of it?**

Use the built-in function `isinstance(obj, cls)`. You can check if an object is an instance of any of a number of classes by providing a tuple instead of a single class, e.g. `isinstance(obj, (class1, class2, ...))`, and can also check whether an object is one of Python's built-in types, e.g. `isinstance(obj, str)` or `isinstance(obj, (int, float, complex))`.

Note that most programs do not use `isinstance()` on user-defined classes very often. If you are developing the classes yourself, a more proper object-oriented style is to define methods on the classes that encapsulate a particular behaviour, instead of checking the object's class and doing a different thing based on what class it is. For example, if you have a function that does something:

```python
def search(obj):
    if isinstance(obj, Mailbox):
        # ... code to search a mailbox
    elif isinstance(obj, Document):
        # ... code to search a document
    elif ...
```

A better approach is to define a `search()` method on all the classes
and just call it:

```python
class Mailbox:
    def search(self):
        # ... code to search a mailbox

class Document:
    def search(self):
        # ... code to search a document

obj.search()
```

**What is delegation?**

Delegation is an object oriented technique (also called a design pattern). Let's say you have an object `x` and want to change the behaviour of just one of its methods. You can create a new class that provides a new implementation of the method you’re interested in changing and delegates all other methods to the corresponding method of `x`.

Python programmers can easily implement delegation. For example, the following class implements a class that behaves like a file but converts all written data to uppercase:

```python
class UpperOut:
    def __init__(self, outfile):
        self._outfile = outfile

    def write(self, s):
        self._outfile.write(s.upper())

    def __getattr__(self, name):
```
Here the UpperOut class redefines the write() method to convert the argument string to uppercase before calling the underlying self.__outfile.write() method. All other methods are delegated to the underlying self.__outfile object. The delegation is accomplished via the __getattr__ method; consult the language reference for more information about controlling attribute access.

Note that for more general cases delegation can get trickier. When attributes must be set as well as retrieved, the class must define a __setattr__() method too, and it must do so carefully. The basic implementation of __setattr__() is roughly equivalent to the following:

```python
class X:
    ...
    def __setattr__(self, name, value):
        self.__dict__[name] = value
    ...
```

Most __setattr__() implementations must modify self.__dict__ to store local state for self without causing an infinite recursion.

**How do I call a method defined in a base class from a derived class that overrides it?**

Use the built-in super() function:

```python
class Derived(Base):
    def meth (self):
```
For version prior to 3.0, you may be using classic classes: For a class definition such as `class Derived(Base): ...` you can call method `meth()` defined in Base (or one of Base's base classes) as `Base.meth(self, arguments...)`. Here, `Base.meth` is an unbound method, so you need to provide the `self` argument.

**How can I organize my code to make it easier to change the base class?**

You could define an alias for the base class, assign the real base class to it before your class definition, and use the alias throughout your class. Then all you have to change is the value assigned to the alias. Incidentally, this trick is also handy if you want to decide dynamically (e.g. depending on availability of resources) which base class to use. Example:

```python
BaseAlias = <real base class>

class Derived(BaseAlias):
    def meth(self):
        BaseAlias.meth(self)
...  
```

**How do I create static class data and static class methods?**

Both static data and static methods (in the sense of C++ or Java) are supported in Python.

For static data, simply define a class attribute. To assign a new value...
to the attribute, you have to explicitly use the class name in the assignment:

class C:
    count = 0  # number of times C.__init__ called

def __init__(self):
    C.count = C.count + 1

def getcount(self):
    return C.count  # or return self.count

c.count also refers to C.count for any c such that isinstance(c, C) holds, unless overridden by c itself or by some class on the base-class search path from c.__class__ back to C.

Caution: within a method of C, an assignment like self.count = 42 creates a new and unrelated instance named “count” in self’s own dict. Rebinding of a class-static data name must always specify the class whether inside a method or not:

C.count = 314

Static methods are possible:

class C:
    @staticmethod
def static(arg1, arg2, arg3):
        # No 'self' parameter!
        ...

However, a far more straightforward way to get the effect of a static method is via a simple module-level function:
def getcount():
    return C.count

If your code is structured so as to define one class (or tightly related class hierarchy) per module, this supplies the desired encapsulation.

**How can I overload constructors (or methods) in Python?**

This answer actually applies to all methods, but the question usually comes up first in the context of constructors.

In C++ you’d write

```cpp
class C {
    C() { cout << "No arguments\n"; }
    C(int i) { cout << "Argument is " << i << "\n";
}
```

In Python you have to write a single constructor that catches all cases using default arguments. For example:

```python
class C:
    def __init__(self, i=None):
        if i is None:
            print("No arguments")
        else:
            print("Argument is", i)
```

This is not entirely equivalent, but close enough in practice.

You could also try a variable-length argument list, e.g.
The same approach works for all method definitions.

I try to use \_\_spam\_ and I get an error about \_SomeClassName\_\_spam.

Variable names with double leading underscores are “mangled” to provide a simple but effective way to define class private variables. Any identifier of the form \_\_spam\_ (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam\_, where classname is the current class name with any leading underscores stripped.

This doesn’t guarantee privacy: an outside user can still deliberately access the “\_classname\_\_spam\_” attribute, and private values are visible in the object’s \_\_dict\_. Many Python programmers never bother to use private variable names at all.

My class defines \_\_del\_\_ but it is not called when I delete the object.

There are several possible reasons for this.

The del statement does not necessarily call \_\_del\_(\_) – it simply decrements the object’s reference count, and if this reaches zero \_\_del\_(\_) is called.

If your data structures contain circular links (e.g. a tree where each child has a parent reference and each parent has a list of children) the reference counts will never go back to zero. Once in a while Python
runs an algorithm to detect such cycles, but the garbage collector might run some time after the last reference to your data structure vanishes, so your `__del__()` method may be called at an inconvenient and random time. This is inconvenient if you're trying to reproduce a problem. Worse, the order in which object's `__del__()` methods are executed is arbitrary. You can run `gc.collect()` to force a collection, but there are pathological cases where objects will never be collected.

Despite the cycle collector, it's still a good idea to define an explicit `close()` method on objects to be called whenever you're done with them. The `close()` method can then remove attributes that refer to subobjects. Don't call `__del__()` directly – `__del__()` should call `close()` and `close()` should make sure that it can be called more than once for the same object.

Another way to avoid cyclical references is to use the `weakref` module, which allows you to point to objects without incrementing their reference count. Tree data structures, for instance, should use weak references for their parent and sibling references (if they need them!).

Finally, if your `__del__()` method raises an exception, a warning message is printed to `sys.stderr`.

**How do I get a list of all instances of a given class?**

Python does not keep track of all instances of a class (or of a built-in type). You can program the class's constructor to keep track of all instances by keeping a list of weak references to each instance.
Why does the result of `id()` appear to be not unique?

The `id()` builtin returns an integer that is guaranteed to be unique during the lifetime of the object. Since in CPython, this is the object’s memory address, it happens frequently that after an object is deleted from memory, the next freshly created object is allocated at the same position in memory. This is illustrated by this example:

```python
>>> id(1000)
13901272
>>> id(2000)
13901272
```

The two ids belong to different integer objects that are created before, and deleted immediately after execution of the `id()` call. To be sure that objects whose id you want to examine are still alive, create another reference to the object:

```python
>>> a = 1000; b = 2000
>>> id(a)
13901272
>>> id(b)
13891296
```
Modules

How do I create a .pyc file?

When a module is imported for the first time (or when the source file has changed since the current compiled file was created) a .pyc file containing the compiled code should be created in a __pycache__ subdirectory of the directory containing the .py file. The .pyc file will have a filename that starts with the same name as the .py file, and ends with .pyc, with a middle component that depends on the particular python binary that created it. (See PEP 3147 for details.)

One reason that a .pyc file may not be created is a permissions problem with the directory containing the source file, meaning that the __pycache__ subdirectory cannot be created. This can happen, for example, if you develop as one user but run as another, such as if you are testing with a web server.

Unless the PYTHONDONTWRITEBYTECODE environment variable is set, creation of a .pyc file is automatic if you’re importing a module and Python has the ability (permissions, free space, etc...) to create a __pycache__ subdirectory and write the compiled module to that subdirectory.

Running Python on a top level script is not considered an import and no .pyc will be created. For example, if you have a top-level module foo.py that imports another module xyz.py, when you run foo (by typing python foo.py as a shell command), a .pyc will be created for xyz because xyz is imported, but no .pyc file will be created for foo since foo.py isn’t being imported.
If you need to create a .pyc file for foo – that is, to create a .pyc file for a module that is not imported – you can, using the `py_compile` and `compileall` modules.

The `py_compile` module can manually compile any module. One way is to use the `compile()` function in that module interactively:

```python
>>> import py_compile
>>> py_compile.compile('foo.py')
```

This will write the .pyc to a __pycache__ subdirectory in the same location as foo.py (or you can override that with the optional parameter cfile).

You can also automatically compile all files in a directory or directories using the `compileall` module. You can do it from the shell prompt by running `compileall.py` and providing the path of a directory containing Python files to compile:

```bash
dirname/compileall.py
```

How do I find the current module name?

A module can find out its own module name by looking at the predefined global variable __name__. If this has the value '__main__', the program is running as a script. Many modules that are usually used by importing them also provide a command-line interface or a self-test, and only execute this code after checking __name__:

```python
def main():
    print('Running test...')
```
if __name__ == '__main__':
    main()

How can I have modules that mutually import each other?

Suppose you have the following modules:

foo.py:

```python
from bar import bar_var
foo_var = 1
```

bar.py:

```python
from foo import foo_var
bar_var = 2
```

The problem is that the interpreter will perform the following steps:

- main imports foo
- Empty globals for foo are created
- foo is compiled and starts executing
- foo imports bar
- Empty globals for bar are created
- bar is compiled and starts executing
- bar imports foo (which is a no-op since there already is a module named foo)
- bar.foo_var = foo.foo_var

The last step fails, because Python isn’t done with interpreting foo yet and the global symbol dictionary for foo is still empty.
The same thing happens when you use `import foo`, and then try to access `foo.foo_var` in global code.

There are (at least) three possible workarounds for this problem.

Guido van Rossum recommends avoiding all uses of `from <module> import ...`, and placing all code inside functions. Initializations of global variables and class variables should use constants or built-in functions only. This means everything from an imported module is referenced as `<module>..<name>`.

Jim Roskind suggests performing steps in the following order in each module:

- exports (globals, functions, and classes that don’t need imported base classes)
- import statements
- active code (including globals that are initialized from imported values).

van Rossum doesn’t like this approach much because the imports appear in a strange place, but it does work.

Matthias Urlich recommends restructuring your code so that the recursive import is not necessary in the first place.

These solutions are not mutually exclusive.

`__import__('x.y.z')` returns `<module 'x'>`; how do I get `z`?

Consider using the convenience function `import_module()` from `importlib` instead:
When I edit an imported module and reimport it, the changes don't show up. Why does this happen?

For reasons of efficiency as well as consistency, Python only reads the module file on the first time a module is imported. If it didn't, in a program consisting of many modules where each one imports the same basic module, the basic module would be parsed and re-parsed many times. To force re-reading of a changed module, do this:

```python
import importlib
import modname
importlib.reload(modname)
```

Warning: this technique is not 100% fool-proof. In particular, modules containing statements like

```python
from modname import some_objects
```

will continue to work with the old version of the imported objects. If the module contains class definitions, existing class instances will not be updated to use the new class definition. This can result in the following paradoxical behaviour:

```python
>>> import importlib
>>> import cls
>>> c = cls.C()  # Create an instance
>>> importlib.reload(cls)
<module 'cls' from 'cls.py'>
>>> isinstance(c, cls.C)  # isinstance is false
False
```
The nature of the problem is made clear if you print out the “identity” of the class objects:

```python
>>> hex(id(c.__class__))
'0x7352a0'
>>> hex(id(cls.C))
'0x4198d0'
```
Design and History FAQ
Why does Python use indentation for grouping of statements?

Guido van Rossum believes that using indentation for grouping is extremely elegant and contributes a lot to the clarity of the average Python program. Most people learn to love this feature after a while.

Since there are no begin/end brackets there cannot be a disagreement between grouping perceived by the parser and the human reader. Occasionally C programmers will encounter a fragment of code like this:

```python
if (x <= y)
    x++;  
    y--; 
z++; 
```

Only the `x++` statement is executed if the condition is true, but the indentation leads you to believe otherwise. Even experienced C programmers will sometimes stare at it a long time wondering why `y` is being decremented even for `x > y`.

Because there are no begin/end brackets, Python is much less prone to coding-style conflicts. In C there are many different ways to place the braces. If you’re used to reading and writing code that uses one style, you will feel at least slightly uneasy when reading (or being required to write) another style.

Many coding styles place begin/end brackets on a line by themselves. This makes programs considerably longer and wastes valuable screen space, making it harder to get a good overview of a program. Ideally, a function should fit on one screen (say, 20-30 lines). 20 lines of Python
can do a lot more work than 20 lines of C. This is not solely due to the lack of begin/end brackets – the lack of declarations and the high-level data types are also responsible – but the indentation-based syntax certainly helps.
Why am I getting strange results with simple arithmetic operations?

See the next question.
Why are floating-point calculations so inaccurate?

Users are often surprised by results like this:

```
>>> 1.2 - 1.0
0.19999999999999996
```

and think it is a bug in Python. It's not. This has little to do with Python, and much more to do with how the underlying platform handles floating-point numbers.

The `float` type in CPython uses a C double for storage. A `float` object's value is stored in binary floating-point with a fixed precision (typically 53 bits) and Python uses C operations, which in turn rely on the hardware implementation in the processor, to perform floating-point operations. This means that as far as floating-point operations are concerned, Python behaves like many popular languages including C and Java.

Many numbers that can be written easily in decimal notation cannot be expressed exactly in binary floating-point. For example, after:

```
>>> x = 1.2
```

the value stored for x is a (very good) approximation to the decimal value 1.2, but is not exactly equal to it. On a typical machine, the actual stored value is:

```
1.0011001100110011001100110011001100110011001100110011
```
which is exactly:

```
1.19999999999999995559107901499373838305473327636718
```

The typical precision of 53 bits provides Python floats with 15-16 decimal digits of accuracy.

For a fuller explanation, please see the floating point arithmetic chapter in the Python tutorial.
Why are Python strings immutable?

There are several advantages.

One is performance: knowing that a string is immutable means we can allocate space for it at creation time, and the storage requirements are fixed and unchanging. This is also one of the reasons for the distinction between tuples and lists.

Another advantage is that strings in Python are considered as “elemental” as numbers. No amount of activity will change the value 8 to anything else, and in Python, no amount of activity will change the string “eight” to anything else.
Why must ‘self’ be used explicitly in method definitions and calls?

The idea was borrowed from Modula-3. It turns out to be very useful, for a variety of reasons.

First, it’s more obvious that you are using a method or instance attribute instead of a local variable. Reading `self.x` or `self.meth()` makes it absolutely clear that an instance variable or method is used even if you don’t know the class definition by heart. In C++, you can sort of tell by the lack of a local variable declaration (assuming globals are rare or easily recognizable) – but in Python, there are no local variable declarations, so you’d have to look up the class definition to be sure. Some C++ and Java coding standards call for instance attributes to have an `m_` prefix, so this explicitness is still useful in those languages, too.

Second, it means that no special syntax is necessary if you want to explicitly reference or call the method from a particular class. In C++, if you want to use a method from a base class which is overridden in a derived class, you have to use the `::` operator – in Python you can write `baseclass.methodname(self, <argument list>)`. This is particularly useful for `__init__()` methods, and in general in cases where a derived class method wants to extend the base class method of the same name and thus has to call the base class method somehow.

Finally, for instance variables it solves a syntactic problem with assignment: since local variables in Python are (by definition!) those variables to which a value is assigned in a function body (and that aren’t explicitly declared global), there has to be some way to tell the
interpreter that an assignment was meant to assign to an instance variable instead of to a local variable, and it should preferably be syntactic (for efficiency reasons). C++ does this through declarations, but Python doesn't have declarations and it would be a pity having to introduce them just for this purpose. Using the explicit `self.var` solves this nicely. Similarly, for using instance variables, having to write `self.var` means that references to unqualified names inside a method don’t have to search the instance's directories. To put it another way, local variables and instance variables live in two different namespaces, and you need to tell Python which namespace to use.
Why can’t I use an assignment in an expression?

Many people used to C or Perl complain that they want to use this C idiom:

```c
while (line = readline(f)) {
    // do something with line
}
```

where in Python you’re forced to write this:

```python
while True:
    line = f.readline()
    if not line:
        break
    ... # do something with line
```

The reason for not allowing assignment in Python expressions is a common, hard-to-find bug in those other languages, caused by this construct:

```python
if (x = 0) {
    // error handling
}
else {
    // code that only works for nonzero x
}
```

The error is a simple typo: `x = 0`, which assigns 0 to the variable `x`, was written while the comparison `x == 0` is certainly what was intended.
Many alternatives have been proposed. Most are hacks that save some typing but use arbitrary or cryptic syntax or keywords, and fail the simple criterion for language change proposals: it should intuitively suggest the proper meaning to a human reader who has not yet been introduced to the construct.

An interesting phenomenon is that most experienced Python programmers recognize the `while True` idiom and don’t seem to be missing the assignment in expression construct much; it’s only newcomers who express a strong desire to add this to the language.

There’s an alternative way of spelling this that seems attractive but is generally less robust than the “while True” solution:

```python
line = f.readline()
while line:
    ... # do something with line...
    line = f.readline()
```

The problem with this is that if you change your mind about exactly how you get the next line (e.g. you want to change it into `sys.stdin.readline()`) you have to remember to change two places in your program – the second occurrence is hidden at the bottom of the loop.

The best approach is to use iterators, making it possible to loop through objects using the `for` statement. For example, `file` objects support the iterator protocol, so you can write simply:

```python
for line in f:
    ... # do something with line...
```
Why does Python use methods for some functionality (e.g. list.index()) but functions for other (e.g. len(list))?

The major reason is history. Functions were used for those operations that were generic for a group of types and which were intended to work even for objects that didn’t have methods at all (e.g. tuples). It is also convenient to have a function that can readily be applied to an amorphous collection of objects when you use the functional features of Python (map(), zip() et al).

In fact, implementing len(), max(), min() as a built-in function is actually less code than implementing them as methods for each type. One can quibble about individual cases but it’s a part of Python, and it’s too late to make such fundamental changes now. The functions have to remain to avoid massive code breakage.

**Note:** For string operations, Python has moved from external functions (the string module) to methods. However, len() is still a function.
Why is join() a string method instead of a list or tuple method?

Strings became much more like other standard types starting in Python 1.6, when methods were added which give the same functionality that has always been available using the functions of the string module. Most of these new methods have been widely accepted, but the one which appears to make some programmers feel uncomfortable is:

```
"", ".join(['1', '2', '4', '8', '16'])
```

which gives the result:

```
"1, 2, 4, 8, 16"
```

There are two common arguments against this usage.

The first runs along the lines of: “It looks really ugly using a method of a string literal (string constant)”, to which the answer is that it might, but a string literal is just a fixed value. If the methods are to be allowed on names bound to strings there is no logical reason to make them unavailable on literals.

The second objection is typically cast as: “I am really telling a sequence to join its members together with a string constant”. Sadly, you aren’t. For some reason there seems to be much less difficulty with having `split()` as a string method, since in that case it is easy to see that

```
"1, 2, 4, 8, 16".split("", ")
```
is an instruction to a string literal to return the substrings delimited by the given separator (or, by default, arbitrary runs of white space).

**join()** is a string method because in using it you are telling the separator string to iterate over a sequence of strings and insert itself between adjacent elements. This method can be used with any argument which obeys the rules for sequence objects, including any new classes you might define yourself. Similar methods exist for bytes and bytearray objects.
How fast are exceptions?

A try/except block is extremely efficient if no exceptions are raised. Actually catching an exception is expensive. In versions of Python prior to 2.0 it was common to use this idiom:

```python
try:
    value = mydict[key]
except KeyError:
    mydict[key] = getvalue(key)
    value = mydict[key]
```

This only made sense when you expected the dict to have the key almost all the time. If that wasn’t the case, you coded it like this:

```python
if key in mydict:
    value = mydict[key]
else:
    value = mydict[key] = getvalue(key)
```

For this specific case, you could also use `value = dict.setdefault(key, getvalue(key))`, but only if the `getvalue()` call is cheap enough because it is evaluated in all cases.
Why isn’t there a switch or case statement in Python?

You can do this easily enough with a sequence of if... elif... else. There have been some proposals for switch statement syntax, but there is no consensus (yet) on whether and how to do range tests. See PEP 275 for complete details and the current status.

For cases where you need to choose from a very large number of possibilities, you can create a dictionary mapping case values to functions to call. For example:

```python
def function_1(...):
    ...

functions = {'a': function_1,
             'b': function_2,
             'c': self.method_1,
             ...
}

func = functions[value]
func()
```

For calling methods on objects, you can simplify yet further by using the `getattr()` built-in to retrieve methods with a particular name:

```python
def visit_a(self, ...):
    ...
    ...

def dispatch(self, value):
    method_name = 'visit_' + str(value)
    method = getattr(self, method_name)
```
It's suggested that you use a prefix for the method names, such as `visit_` in this example. Without such a prefix, if values are coming from an untrusted source, an attacker would be able to call any method on your object.
Can’t you emulate threads in the interpreter instead of relying on an OS-specific thread implementation?

Answer 1: Unfortunately, the interpreter pushes at least one C stack frame for each Python stack frame. Also, extensions can call back into Python at almost random moments. Therefore, a complete threads implementation requires thread support for C.

Answer 2: Fortunately, there is Stackless Python, which has a completely redesigned interpreter loop that avoids the C stack.
Why can’t lambda expressions contain statements?

Python lambda expressions cannot contain statements because Python's syntactic framework can’t handle statements nested inside expressions. However, in Python, this is not a serious problem. Unlike lambda forms in other languages, where they add functionality, Python lambdas are only a shorthand notation if you’re too lazy to define a function.

Functions are already first class objects in Python, and can be declared in a local scope. Therefore the only advantage of using a lambda instead of a locally-defined function is that you don’t need to invent a name for the function – but that’s just a local variable to which the function object (which is exactly the same type of object that a lambda expression yields) is assigned!
Can Python be compiled to machine code, C or some other language?

Practical answer:

Cython and Pyrex compile a modified version of Python with optional annotations into C extensions. Weave makes it easy to intermingle Python and C code in various ways to increase performance. Nuitka is an up-and-coming compiler of Python into C++ code, aiming to support the full Python language.

Theoretical answer:

Not trivially. Python’s high level data types, dynamic typing of objects and run-time invocation of the interpreter (using eval() or exec()) together mean that a naïvely “compiled” Python program would probably consist mostly of calls into the Python run-time system, even for seemingly simple operations like $x+1$.

Several projects described in the Python newsgroup or at past Python conferences have shown that this approach is feasible, although the speedups reached so far are only modest (e.g. 2x). Jython uses the same strategy for compiling to Java bytecode. (Jim Hugunin has demonstrated that in combination with whole-program analysis, speedups of 1000x are feasible for small demo programs. See the proceedings from the 1997 Python conference for more information.)
How does Python manage memory?

The details of Python memory management depend on the implementation. The standard implementation of Python, CPython, uses reference counting to detect inaccessible objects, and another mechanism to collect reference cycles, periodically executing a cycle detection algorithm which looks for inaccessible cycles and deletes the objects involved. The gc module provides functions to perform a garbage collection, obtain debugging statistics, and tune the collector's parameters.

Other implementations (such as Jython or PyPy), however, can rely on a different mechanism such as a full-blown garbage collector. This difference can cause some subtle porting problems if your Python code depends on the behavior of the reference counting implementation.

In some Python implementations, the following code (which is fine in CPython) will probably run out of file descriptors:

```python
for file in very_long_list_of_files:
    f = open(file)
    c = f.read(1)
```

Indeed, using CPython's reference counting and destructor scheme, each new assignment to `f` closes the previous file. With a traditional GC, however, those file objects will only get collected (and closed) at varying and possibly long intervals.

If you want to write code that will work with any Python implementation, you should explicitly close the file or use the `with` statement; this will work regardless of memory management scheme:
for file in very_long_list_of_files:
    with open(file) as f:
        c = f.read(1)
Why doesn’t CPython use a more traditional garbage collection scheme?

For one thing, this is not a C standard feature and hence it’s not portable. (Yes, we know about the Boehm GC library. It has bits of assembler code for most common platforms, not for all of them, and although it is mostly transparent, it isn’t completely transparent; patches are required to get Python to work with it.)

Traditional GC also becomes a problem when Python is embedded into other applications. While in a standalone Python it’s fine to replace the standard malloc() and free() with versions provided by the GC library, an application embedding Python may want to have its own substitute for malloc() and free(), and may not want Python’s. Right now, CPython works with anything that implements malloc() and free() properly.
Why isn’t all memory freed when CPython exits?

Objects referenced from the global namespaces of Python modules are not always deallocated when Python exits. This may happen if there are circular references. There are also certain bits of memory that are allocated by the C library that are impossible to free (e.g. a tool like Purify will complain about these). Python is, however, aggressive about cleaning up memory on exit and does try to destroy every single object.

If you want to force Python to delete certain things on deallocation use the `atexit` module to run a function that will force those deletions.
Why are there separate tuple and list data types?

Lists and tuples, while similar in many respects, are generally used in fundamentally different ways. Tuples can be thought of as being similar to Pascal records or C structs; they're small collections of related data which may be of different types which are operated on as a group. For example, a Cartesian coordinate is appropriately represented as a tuple of two or three numbers.

Lists, on the other hand, are more like arrays in other languages. They tend to hold a varying number of objects all of which have the same type and which are operated on one-by-one. For example, `os.listdir('.')` returns a list of strings representing the files in the current directory. Functions which operate on this output would generally not break if you added another file or two to the directory.

Tuples are immutable, meaning that once a tuple has been created, you can’t replace any of its elements with a new value. Lists are mutable, meaning that you can always change a list's elements. Only immutable elements can be used as dictionary keys, and hence only tuples and not lists can be used as keys.
How are lists implemented?

Python’s lists are really variable-length arrays, not Lisp-style linked lists. The implementation uses a contiguous array of references to other objects, and keeps a pointer to this array and the array’s length in a list head structure.

This makes indexing a list a[i] an operation whose cost is independent of the size of the list or the value of the index.

When items are appended or inserted, the array of references is resized. Some cleverness is applied to improve the performance of appending items repeatedly; when the array must be grown, some extra space is allocated so the next few times don’t require an actual resize.
How are dictionaries implemented?

Python’s dictionaries are implemented as resizable hash tables. Compared to B-trees, this gives better performance for lookup (the most common operation by far) under most circumstances, and the implementation is simpler.

Dictionaries work by computing a hash code for each key stored in the dictionary using the `hash()` built-in function. The hash code varies widely depending on the key and a per-process seed; for example, “Python” could hash to -539294296 while “python”, a string that differs by a single bit, could hash to 1142331976. The hash code is then used to calculate a location in an internal array where the value will be stored. Assuming that you’re storing keys that all have different hash values, this means that dictionaries take constant time – O(1), in computer science notation – to retrieve a key. It also means that no sorted order of the keys is maintained, and traversing the array as the `.keys()` and `.items()` do will output the dictionary’s content in some arbitrary jumbled order that can change with every invocation of a program.
Why must dictionary keys be immutable?

The hash table implementation of dictionaries uses a hash value calculated from the key value to find the key. If the key were a mutable object, its value could change, and thus its hash could also change. But since whoever changes the key object can’t tell that it was being used as a dictionary key, it can’t move the entry around in the dictionary. Then, when you try to look up the same object in the dictionary it won’t be found because its hash value is different. If you tried to look up the old value it wouldn’t be found either, because the value of the object found in that hash bin would be different.

If you want a dictionary indexed with a list, simply convert the list to a tuple first; the function \texttt{tuple(L)} creates a tuple with the same entries as the list \texttt{L}. Tuples are immutable and can therefore be used as dictionary keys.

Some unacceptable solutions that have been proposed:

- Hash lists by their address (object ID). This doesn’t work because if you construct a new list with the same value it won’t be found; e.g.:

  ```python
  mydict = {[1, 2]: '12'}
  print(mydict[[1, 2]])
  ```

  would raise a KeyError exception because the id of the \([1, 2]\) used in the second line differs from that in the first line. In other words, dictionary keys should be compared using ==, not using \texttt{is}.

- Make a copy when using a list as a key. This doesn’t work
because the list, being a mutable object, could contain a reference to itself, and then the copying code would run into an infinite loop.

- Allow lists as keys but tell the user not to modify them. This would allow a class of hard-to-track bugs in programs when you forgot or modified a list by accident. It also invalidates an important invariant of dictionaries: every value in d.keys() is usable as a key of the dictionary.

- Mark lists as read-only once they are used as a dictionary key. The problem is that it's not just the top-level object that could change its value; you could use a tuple containing a list as a key. Entering anything as a key into a dictionary would require marking all objects reachable from there as read-only – and again, self-referential objects could cause an infinite loop.

There is a trick to get around this if you need to, but use it at your own risk: You can wrap a mutable structure inside a class instance which has both a `__eq__()` and a `__hash__()` method. You must then make sure that the hash value for all such wrapper objects that reside in a dictionary (or other hash based structure), remain fixed while the object is in the dictionary (or other structure).

```python
class ListWrapper:
    def __init__(self, the_list):
        self.the_list = the_list
    def __eq__(self, other):
        return self.the_list == other.the_list
    def __hash__(self):
        l = self.the_list
        result = 98767 - len(l)*555
        for i, el in enumerate(l):
            try:
```
result = result + (hash(el) % 9999999)

except Exception:
    result = (result % 7777777) + i * 33

return result

Note that the hash computation is complicated by the possibility that some members of the list may be unhashable and also by the possibility of arithmetic overflow.

Furthermore it must always be the case that if o1 == o2 (i.e. o1.__eq__(o2) is True) then hash(o1) == hash(o2) (i.e. o1.__hash__() == o2.__hash__()), regardless of whether the object is in a dictionary or not. If you fail to meet these restrictions dictionaries and other hash based structures will misbehave.

In the case of ListWrapper, whenever the wrapper object is in a dictionary the wrapped list must not change to avoid anomalies. Don't do this unless you are prepared to think hard about the requirements and the consequences of not meeting them correctly. Consider yourself warned.
Why doesn’t list.sort() return the sorted list?

In situations where performance matters, making a copy of the list just to sort it would be wasteful. Therefore, `list.sort()` sorts the list in place. In order to remind you of that fact, it does not return the sorted list. This way, you won’t be fooled into accidentally overwriting a list when you need a sorted copy but also need to keep the unsorted version around.

If you want to return a new list, use the built-in `sorted()` function instead. This function creates a new list from a provided iterable, sorts it and returns it. For example, here’s how to iterate over the keys of a dictionary in sorted order:

```python
for key in sorted(mydict):
    ... # do whatever with mydict[key]...
```
How do you specify and enforce an interface spec in Python?

An interface specification for a module as provided by languages such as C++ and Java describes the prototypes for the methods and functions of the module. Many feel that compile-time enforcement of interface specifications helps in the construction of large programs.

Python 2.6 adds an `abc` module that lets you define Abstract Base Classes (ABCs). You can then use `isinstance()` and `issubclass()` to check whether an instance or a class implements a particular ABC. The `collections.abc` module defines a set of useful ABCs such as `Iterable`, `Container`, and `MutableMapping`.

For Python, many of the advantages of interface specifications can be obtained by an appropriate test discipline for components. There is also a tool, PyChecker, which can be used to find problems due to subclassing.

A good test suite for a module can both provide a regression test and serve as a module interface specification and a set of examples. Many Python modules can be run as a script to provide a simple “self test.” Even modules which use complex external interfaces can often be tested in isolation using trivial “stub” emulations of the external interface. The `doctest` and `unittest` modules or third-party test frameworks can be used to construct exhaustive test suites that exercise every line of code in a module.

An appropriate testing discipline can help build large complex applications in Python as well as having interface specifications would.
In fact, it can be better because an interface specification cannot test certain properties of a program. For example, the append() method is expected to add new elements to the end of some internal list; an interface specification cannot test that your append() implementation will actually do this correctly, but it’s trivial to check this property in a test suite.

Writing test suites is very helpful, and you might want to design your code with an eye to making it easily tested. One increasingly popular technique, test-directed development, calls for writing parts of the test suite first, before you write any of the actual code. Of course Python allows you to be sloppy and not write test cases at all.
Why is there no goto?

You can use exceptions to provide a “structured goto” that even works across function calls. Many feel that exceptions can conveniently emulate all reasonable uses of the “go” or “goto” constructs of C, Fortran, and other languages. For example:

```python
class label(Exception): pass  # declare a label

try:
    ...
    if condition: raise label()  # goto label
    ...
except label:  # where to goto
    pass
    ...
```

This doesn't allow you to jump into the middle of a loop, but that's usually considered an abuse of goto anyway. Use sparingly.
Why can’t raw strings (r-strings) end with a backslash?

More precisely, they can’t end with an odd number of backslashes: the unpaired backslash at the end escapes the closing quote character, leaving an unterminated string.

Raw strings were designed to ease creating input for processors (chiefly regular expression engines) that want to do their own backslash escape processing. Such processors consider an unmatched trailing backslash to be an error anyway, so raw strings disallow that. In return, they allow you to pass on the string quote character by escaping it with a backslash. These rules work well when r-strings are used for their intended purpose.

If you’re trying to build Windows pathnames, note that all Windows system calls accept forward slashes too:

```
f = open("/mydir/file.txt")  # works fine!
```

If you’re trying to build a pathname for a DOS command, try e.g. one of

```
dir = r"\this\is\my\dos\dir" "\\"
dir = r"\this\is\my\dos\dir\ "[\:-1]
dir = "\\this\\is\\my\\dos\\dir\\"
```
Why doesn’t Python have a “with” statement for attribute assignments?

Python has a ‘with’ statement that wraps the execution of a block, calling code on the entrance and exit from the block. Some language have a construct that looks like this:

```
with obj:
    a = 1  # equivalent to obj.a = 1
    total = total + 1  # obj.total = obj.total + 1
```

In Python, such a construct would be ambiguous.

Other languages, such as Object Pascal, Delphi, and C++, use static types, so it’s possible to know, in an unambiguous way, what member is being assigned to. This is the main point of static typing – the compiler always knows the scope of every variable at compile time.

Python uses dynamic types. It is impossible to know in advance which attribute will be referenced at runtime. Member attributes may be added or removed from objects on the fly. This makes it impossible to know, from a simple reading, what attribute is being referenced: a local one, a global one, or a member attribute?

For instance, take the following incomplete snippet:

```
def foo(a):
    with a:
        print(x)
```

The snippet assumes that “a” must have a member attribute called “x”. However, there is nothing in Python that tells the interpreter this. What
should happen if “a” is, let us say, an integer? If there is a global variable named “x”, will it be used inside the with block? As you see, the dynamic nature of Python makes such choices much harder.

The primary benefit of “with” and similar language features (reduction of code volume) can, however, easily be achieved in Python by assignment. Instead of:

```python
function(args).mydict[index][index].a = 21
function(args).mydict[index][index].b = 42
function(args).mydict[index][index].c = 63
```

write this:

```python
ref = function(args).mydict[index][index]
ref.a = 21
ref.b = 42
ref.c = 63
```

This also has the side-effect of increasing execution speed because name bindings are resolved at run-time in Python, and the second version only needs to perform the resolution once.
Why are colons required for the if/while/def/class statements?

The colon is required primarily to enhance readability (one of the results of the experimental ABC language). Consider this:

```python
if a == b
    print(a)
```

versus

```python
if a == b:
    print(a)
```

Notice how the second one is slightly easier to read. Notice further how a colon sets off the example in this FAQ answer; it's a standard usage in English.

Another minor reason is that the colon makes it easier for editors with syntax highlighting; they can look for colons to decide when indentation needs to be increased instead of having to do a more elaborate parsing of the program text.
Why does Python allow commas at the end of lists and tuples?

Python lets you add a trailing comma at the end of lists, tuples, and dictionaries:

```python
[1, 2, 3,]
('a', 'b', 'c',)
d = {
    "A": [1, 5],
    "B": [6, 7],  # last trailing comma is optional
}
```

There are several reasons to allow this.

When you have a literal value for a list, tuple, or dictionary spread across multiple lines, it's easier to add more elements because you don't have to remember to add a comma to the previous line. The lines can also be reordered without creating a syntax error.

Accidentally omitting the comma can lead to errors that are hard to diagnose. For example:

```python
x = [
    "fee",
    "fie",
    "foo",
    "fum"
]
```

This list looks like it has four elements, but it actually contains three: “fee”, “fiefoo” and “fum”. Always adding the comma avoids this source
of error.

Allowing the trailing comma may also make programmatic code generation easier.
Library and Extension FAQ

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General Library Questions

How do I find a module or application to perform task X?

Check the Library Reference to see if there's a relevant standard library module. (Eventually you'll learn what's in the standard library and will be able to skip this step.)

For third-party packages, search the Python Package Index or try Google or another Web search engine. Searching for “Python” plus a keyword or two for your topic of interest will usually find something helpful.

Where is the math.py (socket.py, regex.py, etc.) source file?

If you can’t find a source file for a module it may be a built-in or dynamically loaded module implemented in C, C++ or other compiled language. In this case you may not have the source file or it may be something like mathmodule.c, somewhere in a C source directory (not on the Python Path).

There are (at least) three kinds of modules in Python:

1. modules written in Python (.py);

2. modules written in C and dynamically loaded (.dll, .pyd, .so, .sl, etc);

3. modules written in C and linked with the interpreter; to get a list of these, type:
import sys
print(sys.builtin_module_names)

How do I make a Python script executable on Unix?

You need to do two things: the script file’s mode must be executable and the first line must begin with `#!` followed by the path of the Python interpreter.

The first is done by executing `chmod +x scriptfile` or perhaps `chmod 755 scriptfile`.

The second can be done in a number of ways. The most straightforward way is to write

```bash
#!/usr/local/bin/python
```

as the very first line of your file, using the pathname for where the Python interpreter is installed on your platform.

If you would like the script to be independent of where the Python interpreter lives, you can use the `env` program. Almost all Unix variants support the following, assuming the Python interpreter is in a directory on the user's PATH:

```bash
#!/usr/bin/env python
```

Don’t do this for CGI scripts. The PATH variable for CGI scripts is often very minimal, so you need to use the actual absolute pathname of the interpreter.
Occasionally, a user’s environment is so full that the /usr/bin/env program fails; or there’s no env program at all. In that case, you can try the following hack (due to Alex Rezinsky):

```
#!/bin/sh
"
exec python $0 ${1+"$@"}
"
```

The minor disadvantage is that this defines the script’s __doc__ string. However, you can fix that by adding

```
__doc__ = """...Whatever..."""
```

**Is there a curses/termcap package for Python?**

For Unix variants: The standard Python source distribution comes with a curses module in the Modules subdirectory, though it’s not compiled by default. (Note that this is not available in the Windows distribution – there is no curses module for Windows.)

The curses module supports basic curses features as well as many additional functions from nczurses and SYSV curses such as colour, alternative character set support, pads, and mouse support. This means the module isn't compatible with operating systems that only have BSD curses, but there don't seem to be any currently maintained OSes that fall into this category.

For Windows: use the consolelib module.

**Is there an equivalent to C’s onexit() in Python?**
The `atexit` module provides a register function that is similar to C's `onexit()`.

**Why don’t my signal handlers work?**

The most common problem is that the signal handler is declared with the wrong argument list. It is called as

```python
handler(signum, frame)
```

so it should be declared with two arguments:

```python
def handler(signum, frame):
    ...
```
Common tasks

How do I test a Python program or component?

Python comes with two testing frameworks. The doctest module finds examples in the docstrings for a module and runs them, comparing the output with the expected output given in the docstring.

The unittest module is a fancier testing framework modelled on Java and Smalltalk testing frameworks.

To make testing easier, you should use good modular design in your program. Your program should have almost all functionality encapsulated in either functions or class methods – and this sometimes has the surprising and delightful effect of making the program run faster (because local variable accesses are faster than global accesses). Furthermore the program should avoid depending on mutating global variables, since this makes testing much more difficult to do.

The “global main logic” of your program may be as simple as

```python
if __name__ == '__main__':
    main_logic()
```

at the bottom of the main module of your program.

Once your program is organized as a tractable collection of functions and class behaviours you should write test functions that exercise the behaviours. A test suite that automates a sequence of tests can be associated with each module. This sounds like a lot of work, but since Python is so terse and flexible it’s surprisingly easy. You can make
coding much more pleasant and fun by writing your test functions in parallel with the “production code”, since this makes it easy to find bugs and even design flaws earlier.

“Support modules” that are not intended to be the main module of a program may include a self-test of the module.

```python
if __name__ == "__main__":
    self_test()
```

Even programs that interact with complex external interfaces may be tested when the external interfaces are unavailable by using “fake” interfaces implemented in Python.

**How do I create documentation from doc strings?**

The `pydoc` module can create HTML from the doc strings in your Python source code. An alternative for creating API documentation purely from docstrings is `epydoc`. `Sphinx` can also include docstring content.

**How do I get a single keypress at a time?**

For Unix variants there are several solutions. It’s straightforward to do this using `curses`, but `curses` is a fairly large module to learn.
Threads

How do I program using threads?

Be sure to use the `threading` module and not the `_thread` module. The `threading` module builds convenient abstractions on top of the low-level primitives provided by the `_thread` module.

Aahz has a set of slides from his threading tutorial that are helpful; see [http://www.pythoncraft.com/OSCON2001/](http://www.pythoncraft.com/OSCON2001/).

None of my threads seem to run: why?

As soon as the main thread exits, all threads are killed. Your main thread is running too quickly, giving the threads no time to do any work.

A simple fix is to add a sleep to the end of the program that’s long enough for all the threads to finish:

```python
import threading, time

def thread_task(name, n):
    for i in range(n):
        print(name, i)

for i in range(10):
    T = threading.Thread(target=thread_task, args=(str(T.start(),

time.sleep(10)  # <---------------------------!

But now (on many platforms) the threads don’t run in parallel, but
appear to run sequentially, one at a time! The reason is that the OS thread scheduler doesn’t start a new thread until the previous thread is blocked.

A simple fix is to add a tiny sleep to the start of the run function:

```python
def thread_task(name, n):
    time.sleep(0.001)  # <---------------------!
    for i in range(n):
        print(name, i)

for i in range(10):
    T = threading.Thread(target=thread_task, args=(str(T.start(),

time.sleep(10)
```

Instead of trying to guess a good delay value for `time.sleep()`, it’s better to use some kind of semaphore mechanism. One idea is to use the `queue` module to create a queue object, let each thread append a token to the queue when it finishes, and let the main thread read as many tokens from the queue as there are threads.

**How do I parcel out work among a bunch of worker threads?**

The easiest way is to use the new `concurrent.futures` module, especially the `ThreadPoolExecutor` class.

Or, if you want fine control over the dispatching algorithm, you can write your own logic manually. Use the `queue` module to create a queue containing a list of jobs. The `Queue` class maintains a list of objects and has a `.put(obj)` method that adds items to the queue
and a `.get()` method to return them. The class will take care of the locking necessary to ensure that each job is handed out exactly once.

Here's a trivial example:

```python
import threading, queue, time

# The worker thread gets jobs off the queue. When the queue
# assumes there will be no more work and exits.
# (Realistically workers will run until terminated.)
def worker():
    print('Running worker')
    time.sleep(0.1)
    while True:
        try:
            arg = q.get(block=False)
        except queue.Empty:
            print('Worker', threading.currentThread(), 'queue empty')
            break
        else:
            print('Worker', threading.currentThread(), 'running with argument', arg)
            time.sleep(0.5)

# Create queue
q = queue.Queue()

# Start a pool of 5 workers
for i in range(5):
    t = threading.Thread(target=worker, name='worker
    t.start()

# Begin adding work to the queue
for i in range(50):
    q.put(i)
```
# Give threads time to run

```python
def main():
    print('Main thread sleeping')
    time.sleep(5)
```

When run, this will produce the following output:

```
Running worker
Running worker
Running worker
Running worker
Running worker
Main thread sleeping
Worker <Thread(worker 1, started 130283832797456)> running with argument 0
Worker <Thread(worker 2, started 130283824404752)> running with argument 1
Worker <Thread(worker 3, started 130283816012048)> running with argument 2
Worker <Thread(worker 4, started 130283807619344)> running with argument 3
Worker <Thread(worker 5, started 130283799226640)> running with argument 4
Worker <Thread(worker 1, started 130283832797456)> running with argument 5
...```

Consult the module's documentation for more details; the `Queue` class provides a featureful interface.

**What kinds of global value mutation are thread-safe?**

A **global interpreter lock** (GIL) is used internally to ensure that only one thread runs in the Python VM at a time. In general, Python offers to switch among threads only between bytecode instructions; how frequently it switches can be set via `sys.setswitchinterval()`. Each bytecode instruction and therefore all the C implementation code reached from each instruction is therefore atomic from the point of
view of a Python program.

In theory, this means an exact accounting requires an exact understanding of the PVM bytecode implementation. In practice, it means that operations on shared variables of built-in data types (ints, lists, dicts, etc) that “look atomic” really are.

For example, the following operations are all atomic (L, L1, L2 are lists, D, D1, D2 are dicts, x, y are objects, i, j are ints):

```python
L.append(x)
L1.extend(L2)
x = L[i]
x = L.pop()
L1[i:j] = L2
L.sort()
x = y
x.field = y
D[x] = y
D1.update(D2)
D.keys()
```

These aren't:

```python
i = i+1
L.append(L[-1])
L[i] = L[j]
D[x] = D[x] + 1
```

Operations that replace other objects may invoke those other objects’ `__del__()` method when their reference count reaches zero, and that can affect things. This is especially true for the mass updates to dictionaries and lists. When in doubt, use a mutex!
Can’t we get rid of the Global Interpreter Lock?

The global interpreter lock (GIL) is often seen as a hindrance to Python’s deployment on high-end multiprocessor server machines, because a multi-threaded Python program effectively only uses one CPU, due to the insistence that (almost) all Python code can only run while the GIL is held.

Back in the days of Python 1.5, Greg Stein actually implemented a comprehensive patch set (the “free threading” patches) that removed the GIL and replaced it with fine-grained locking. Adam Olsen recently did a similar experiment in his python-safethread project. Unfortunately, both experiments exhibited a sharp drop in single-thread performance (at least 30% slower), due to the amount of fine-grained locking necessary to compensate for the removal of the GIL.

This doesn’t mean that you can’t make good use of Python on multi-CPU machines! You just have to be creative with dividing the work up between multiple processes rather than multiple threads. The ProcessPoolExecutor class in the new concurrent.futures module provides an easy way of doing so; the multiprocessing module provides a lower-level API in case you want more control over dispatching of tasks.

Judicious use of C extensions will also help; if you use a C extension to perform a time-consuming task, the extension can release the GIL while the thread of execution is in the C code and allow other threads to get some work done. Some standard library modules such as zlib and hashlib already do this.

It has been suggested that the GIL should be a per-interpreter-state lock rather than truly global; interpreters then wouldn’t be able to share
objects. Unfortunately, this isn’t likely to happen either. It would be a tremendous amount of work, because many object implementations currently have global state. For example, small integers and short strings are cached; these caches would have to be moved to the interpreter state. Other object types have their own free list; these free lists would have to be moved to the interpreter state. And so on.

And I doubt that it can even be done in finite time, because the same problem exists for 3rd party extensions. It is likely that 3rd party extensions are being written at a faster rate than you can convert them to store all their global state in the interpreter state.

And finally, once you have multiple interpreters not sharing any state, what have you gained over running each interpreter in a separate process?
Input and Output

How do I delete a file? (And other file questions...)

Use `os.remove(filename)` or `os.unlink(filename)`; for documentation, see the `os` module. The two functions are identical; `unlink()` is simply the name of the Unix system call for this function.

To remove a directory, use `os.rmdir()`; use `os.mkdir()` to create one. `os.makedirs(path)` will create any intermediate directories in `path` that don't exist. `os.removedirs(path)` will remove intermediate directories as long as they're empty; if you want to delete an entire directory tree and its contents, use `shutil.rmtree()`.

To rename a file, use `os.rename(old_path, new_path)`.

To truncate a file, open it using `f = open(filename, "rb+"), and use `f.truncate(offset)`; offset defaults to the current seek position. There's also `os.ftruncate(fd, offset)` for files opened with `os.open()`, where `fd` is the file descriptor (a small integer).

The `shutil` module also contains a number of functions to work on files including `copyfile()`, `copytree()`, and `rmtree()`.

How do I copy a file?

The `shutil` module contains a `copyfile()` function. Note that on MacOS 9 it doesn't copy the resource fork and Finder info.

How do I read (or write) binary data?
To read or write complex binary data formats, it’s best to use the `struct` module. It allows you to take a string containing binary data (usually numbers) and convert it to Python objects; and vice versa.

For example, the following code reads two 2-byte integers and one 4-byte integer in big-endian format from a file:

```python
import struct

with open(filename, "rb") as f:
    s = f.read(8)
    x, y, z = struct.unpack(">hhl", s)
```

The ‘>’ in the format string forces big-endian data; the letter ‘h’ reads one “short integer” (2 bytes), and ‘l’ reads one “long integer” (4 bytes) from the string.

For data that is more regular (e.g. a homogeneous list of ints or floats), you can also use the `array` module.

**Note:** To read and write binary data, it is mandatory to open the file in binary mode (here, passing "rb" to `open()`). If you use "r" instead (the default), the file will be open in text mode and `f.read()` will return `str` objects rather than `bytes` objects.

I can’t seem to use `os.read()` on a pipe created with `os.popen();` why?

`os.read()` is a low-level function which takes a file descriptor, a small integer representing the opened file. `os.popen()` creates a high-level file object, the same type returned by the built-in `open()` function. Thus, to read $n$ bytes from a pipe $p$ created with
os.popen(), you need to use p.read(n).

How do I access the serial (RS232) port?

For Win32, POSIX (Linux, BSD, etc.), Jython:

   http://pyserial.sourceforge.net

For Unix, see a Usenet post by Mitch Chapman:

   http://groups.google.com/groups?
selm=34A04430.CF9@ohioee.com

Why doesn’t closing sys.stdout (stdin, stderr) really close it?

Python file objects are a high-level layer of abstraction on low-level C file descriptors.

For most file objects you create in Python via the built-in open() function, f.close() marks the Python file object as being closed from Python’s point of view, and also arranges to close the underlying C file descriptor. This also happens automatically in f’s destructor, when f becomes garbage.

But stdin, stdout and stderr are treated specially by Python, because of the special status also given to them by C. Running sys.stdout.close() marks the Python-level file object as being closed, but does not close the associated C file descriptor.

To close the underlying C file descriptor for one of these three, you should first be sure that’s what you really want to do (e.g., you may confuse extension modules trying to do I/O). If it is, use os.close():
```python
os.close(stdin.fileno())
os.close(stdout.fileno())
os.close(stderr.fileno())
```

Or you can use the numeric constants 0, 1 and 2, respectively.
What WWW tools are there for Python?

See the chapters titled Internet Protocols and Support and Internet Data Handling in the Library Reference Manual. Python has many modules that will help you build server-side and client-side web systems.

A summary of available frameworks is maintained by Paul Boddie at https://wiki.python.org/moin/WebProgramming.


How can I mimic CGI form submission (METHOD=POST)?

I would like to retrieve web pages that are the result of POSTing a form. Is there existing code that would let me do this easily?

Yes. Here's a simple example that uses urllib.request:

```python
#!/usr/local/bin/python

import urllib.request

### build the query string
qs = "First=Josephine&MI=Q&Last=Public"

### connect and send the server a path
req = urllib.request.urlopen('http://www.some-server.out-there/cgi-bin/some-cgi-script')
```
```python
with req:
    msg, hdrs = req.read(), req.info()
```

Note that in general for percent-encoded POST operations, query strings must be quoted using `urllib.parse.urlencode()`. For example, to send `name=Guy Steele, Jr.:

```python
>>> import urllib.parse
>>> urllib.parseurlencode({'name': 'Guy Steele, Jr.
'name=Guy+Steele%2C+Jr.'
```

See also: [HOWTO Fetch Internet Resources Using The urllib Package](#) for extensive examples.

**What module should I use to help with generating HTML?**

You can find a collection of useful links on the [Web Programming wiki page](#).

**How do I send mail from a Python script?**

Use the standard library module `smtplib`.

Here’s a very simple interactive mail sender that uses it. This method will work on any host that supports an SMTP listener.

```python
import sys, smtplib
fromaddr = input("From: ")
toaddrs = input("To: ").split(',,')
```
print("Enter message, end with ^D:")
msg = ''
while True:
    line = sys.stdin.readline()
    if not line:
        break
    msg += line

# The actual mail send
server = smtplib.SMTP('localhost')
server.sendmail(fromaddr, toaddr, msg)
server.quit()

A Unix-only alternative uses sendmail. The location of the sendmail program varies between systems; sometimes it is /usr/lib/sendmail, sometimes /usr/sbin/sendmail. The sendmail manual page will help you out. Here's some sample code:

SENDMAIL = "/usr/sbin/sendmail"  # sendmail location
import os
p = os.popen("%s -t -i" % SENDMAIL, "w")
p.write("To: receiver@example.com\n")
p.write("Subject: test\n")
p.write("\n")  # blank line separating headers from
p.write("Some text\n")
p.write("some more text\n")
sts = p.close()
if sts != 0:
    print("Sendmail exit status", sts)

How do I avoid blocking in the connect() method of a socket?

The select module is commonly used to help with asynchronous I/O
on sockets.

To prevent the TCP connect from blocking, you can set the socket to non-blocking mode. Then when you do the connect(), you will either connect immediately (unlikely) or get an exception that contains the error number as .errno. errno.EINPROGRESS indicates that the connection is in progress, but hasn't finished yet. Different OSes will return different values, so you're going to have to check what's returned on your system.

You can use the connect_ex() method to avoid creating an exception. It will just return the errno value. To poll, you can call connect_ex() again later – 0 or errno.EISCONN indicate that you're connected – or you can pass this socket to select to check if it's writable.

**Note:** The asyncore module presents a framework-like approach to the problem of writing non-blocking networking code. The third-party Twisted library is a popular and feature-rich alternative.
Databases

Are there any interfaces to database packages in Python?

Yes.

Interfaces to disk-based hashes such as DBM and GDBM are also included with standard Python. There is also the sqlite3 module, which provides a lightweight disk-based relational database.

Support for most relational databases is available. See the DatabaseProgramming wiki page for details.

How do you implement persistent objects in Python?

The pickle library module solves this in a very general way (though you still can’t store things like open files, sockets or windows), and the shelve library module uses pickle and (g)dbm to create persistent mappings containing arbitrary Python objects.
Mathematics and Numerics

How do I generate random numbers in Python?

The standard module `random` implements a random number generator. Usage is simple:

```python
import random
random.random()
```

This returns a random floating point number in the range [0, 1).

There are also many other specialized generators in this module, such as:

- `randrange(a, b)` chooses an integer in the range [a, b).
- `uniform(a, b)` chooses a floating point number in the range [a, b).
- `normalvariate(mean, sdev)` samples the normal (Gaussian) distribution.

Some higher-level functions operate on sequences directly, such as:

- `choice(S)` chooses random element from a given sequence
- `shuffle(L)` shuffles a list in-place, i.e. permutes it randomly

There's also a Random class you can instantiate to create independent multiple random number generators.
Extending/Embedding FAQ

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Can I create my own functions in C?

Yes, you can create built-in modules containing functions, variables, exceptions and even new types in C. This is explained in the document *Extending and Embedding the Python Interpreter*.

Most intermediate or advanced Python books will also cover this topic.
Can I create my own functions in C++?

Yes, using the C compatibility features found in C++. Place `extern "C" { ... }` around the Python include files and put `extern "C"` before each function that is going to be called by the Python interpreter. Global or static C++ objects with constructors are probably not a good idea.
Writing C is hard; are there any alternatives?

There are a number of alternatives to writing your own C extensions, depending on what you're trying to do.

Cython and its relative Pyrex are compilers that accept a slightly modified form of Python and generate the corresponding C code. Cython and Pyrex make it possible to write an extension without having to learn Python's C API.

If you need to interface to some C or C++ library for which no Python extension currently exists, you can try wrapping the library's data types and functions with a tool such as SWIG. SIP, CXX Boost, or Weave are also alternatives for wrapping C++ libraries.
How can I execute arbitrary Python statements from C?

The highest-level function to do this is `PyRun_SimpleString()` which takes a single string argument to be executed in the context of the module `__main__` and returns 0 for success and -1 when an exception occurred (including `SyntaxError`). If you want more control, use `PyRun_String()`; see the source for `PyRun_SimpleString()` in Python/pythonrun.c.
How can I evaluate an arbitrary Python expression from C?

Call the function `PyRun_String()` from the previous question with the start symbol `Py_eval_input`; it parses an expression, evaluates it and returns its value.
How do I extract C values from a Python object?

That depends on the object’s type. If it’s a tuple, `PyTuple_Size()` returns its length and `PyTuple_GetItem()` returns the item at a specified index. Lists have similar functions, `PyListSize()` and `PyList_GetItem()`.

For bytes, `PyBytes_Size()` returns its length and `PyBytes_AsStringAndSize()` provides a pointer to its value and its length. Note that Python bytes objects may contain null bytes so C’s `strlen()` should not be used.

To test the type of an object, first make sure it isn’t `NULL`, and then use `PyBytes_Check()`, `PyTuple_Check()`, `PyList_Check()`, etc.

There is also a high-level API to Python objects which is provided by the so-called ‘abstract’ interface – read Include/abstract.h for further details. It allows interfacing with any kind of Python sequence using calls like `PySequence_Length()`, `PySequence_GetItem()`, etc. as well as many other useful protocols such as numbers (`PyNumber_Index()` et al.) and mappings in the PyMapping APIs.
How do I use `Py_BuildValue()` to create a tuple of arbitrary length?

You can't. Use `PyTuple_Pack()` instead.
How do I call an object’s method from C?

The **PyObject_CallMethod()** function can be used to call an arbitrary method of an object. The parameters are the object, the name of the method to call, a format string like that used with **Py_BuildValue()**, and the argument values:

```c
PyObject *
PyObject_CallMethod(PyObject *object, const char *method_name,
                    const char *arg_format, ...);
```

This works for any object that has methods – whether built-in or user-defined. You are responsible for eventually **Py_DECREF()**‘ing the return value.

To call, e.g., a file object’s “seek” method with arguments 10, 0 (assuming the file object pointer is “f”):

```c
res = PyObject_CallMethod(f, "seek", "(ii)", 10, 0);
if (res == NULL) {
    ... an exception occurred ...
} else {
    Py_DECREF(res);
}
```

Note that since **PyObject_CallObject()** *always* wants a tuple for the argument list, to call a function without arguments, pass “()” for the format, and to call a function with one argument, surround the argument in parentheses, e.g. “(i)“. 
How do I catch the output from `PyErr_Print()` (or anything that prints to stdout/stderr)?

In Python code, define an object that supports the `write()` method. Assign this object to `sys.stdout` and `sys.stderr`. Call `print_error`, or just allow the standard traceback mechanism to work. Then, the output will go wherever your `write()` method sends it.

The easiest way to do this is to use the `io.StringIO` class:

```python
>>> import io, sys
>>> sys.stdout = io.StringIO()
>>> print('foo')
>>> print('hello world!')
>>> sys.stderr.write(sys.stdout.getvalue())
foo
hello world!
```

A custom object to do the same would look like this:

```python
>>> import io, sys
>>> class StdoutCatcher(io.TextIOBase):
...     def __init__(self):
...         self.data = []
...     def write(self, stuff):
...         self.data.append(stuff)
...
>>> import sys
>>> sys.stdout = StdoutCatcher()
>>> print('foo')
>>> print('hello world!')
>>> sys.stderr.write(''.join(sys.stdout.data))
```
foo
hello world!
How do I access a module written in Python from C?

You can get a pointer to the module object as follows:

```c
module = PyImport_ImportModule("<modulename>");
```

If the module hasn't been imported yet (i.e. it is not yet present in `sys.modules`), this initializes the module; otherwise it simply returns the value of `sys.modules["<modulename>"]`. Note that it doesn't enter the module into any namespace – it only ensures it has been initialized and is stored in `sys.modules`.

You can then access the module's attributes (i.e. any name defined in the module) as follows:

```c
attr = PyObject_GetAttrString(module, "<attrname>");
```

Calling `PyObject_SetAttrString()` to assign to variables in the module also works.
How do I interface to C++ objects from Python?

Depending on your requirements, there are many approaches. To do this manually, begin by reading the “Extending and Embedding” document. Realize that for the Python run-time system, there isn’t a whole lot of difference between C and C++ – so the strategy of building a new Python type around a C structure (pointer) type will also work for C++ objects.

For C++ libraries, see Writing C is hard; are there any alternatives?.
I added a module using the Setup file and the make fails; why?

Setup must end in a newline, if there is no newline there, the build process fails. (Fixing this requires some ugly shell script hackery, and this bug is so minor that it doesn't seem worth the effort.)
How do I debug an extension?

When using GDB with dynamically loaded extensions, you can’t set a breakpoint in your extension until your extension is loaded.

In your .gdbinit file (or interactively), add the command:

```
br _PyImport_LoadDynamicModule
```

Then, when you run GDB:

```
$ gdb /local/bin/python
(gdb) run myscript.py
(gdb) continue # repeat until your extension is loaded
(gdb) finish # so that your extension is loaded
(gdb) br myfunction.c:50
(gdb) continue
```
I want to compile a Python module on my Linux system, but some files are missing. Why?

Most packaged versions of Python don’t include the /usr/lib/python2.x/config/ directory, which contains various files required for compiling Python extensions.

For Red Hat, install the python-devel RPM to get the necessary files.

For Debian, run apt-get install python-dev.
What does “SystemError: _PyImport_FixupExtension: module yourmodule not loaded” mean?

This means that you have created an extension module named “yourmodule”, but your module init function does not initialize with that name.

Every module init function will have a line similar to:

```python
module = Py_InitModule("yourmodule", yourmodule_functions)
```

If the string passed to this function is not the same name as your extension module, the `SystemError` exception will be raised.
How do I tell “incomplete input” from “invalid input”?  

Sometimes you want to emulate the Python interactive interpreter’s behavior, where it gives you a continuation prompt when the input is incomplete (e.g. you typed the start of an “if” statement or you didn’t close your parentheses or triple string quotes), but it gives you a syntax error message immediately when the input is invalid.

In Python you can use the codeop module, which approximates the parser’s behavior sufficiently. IDLE uses this, for example.

The easiest way to do it in C is to call PyRun_InteractiveLoop() (perhaps in a separate thread) and let the Python interpreter handle the input for you. You can also set the PyOS_ReadlineFunctionPointer() to point at your custom input function. See Modules/readline.c and Parser/myreadline.c for more hints.

However sometimes you have to run the embedded Python interpreter in the same thread as your rest application and you can’t allow the PyRun_InteractiveLoop() to stop while waiting for user input. The one solution then is to call PyParser_ParseString() and test for e.error equal to E_EOF, which means the input is incomplete). Here’s a sample code fragment, untested, inspired by code from Alex Farber:

```c
#include <Python.h>
#include <node.h>
#include <errcode.h>
#include <grammar.h>
#include <parsetok.h>
```
Another solution is trying to compile the received string with `Py_CompileString()`. If it compiles without errors, try to execute the returned code object by calling `PyEval_EvalCode()`. Otherwise save the input for later. If the compilation fails, find out if it's an error or just more input is required - by extracting the message string from the exception tuple and comparing it to the string “unexpected EOF while parsing”. Here is a complete example using the GNU readline library (you may want to ignore `SIGINT` while calling `readline()`):

```c
#include <stdio.h>
#include <readline.h>

#include <Python.h>
#include <object.h>
```
#include <compile.h>
#include <eval.h>

int main (int argc, char* argv[]) {
    int i, j, done = 0; /* length of line, code */
    char ps1[] = ">>> ";
    char ps2[] = "... ";
    char *prompt = ps1;
    char *msg, *line, *code = NULL;
    PyObject *src, *glb, *loc;

    Py_Initialize ();
    loc = PyDict_New ();
    glb = PyDict_New ();
    PyDict_SetItemString (glb, "__builtins__", PyEval_GetBuiltins ());

    while (!done) {
        line = readline (prompt);

        if (NULL == line) /* Ctrl-D pressed */
            done = 1;
        else {
            i = strlen (line);

            if (i > 0)
                add_history (line); /* save non-empty lines */

            if (NULL == code) /* no code yet */
                j = 0;
            else
                j = strlen (code);
        }
    }
}
code = realloc (code, i + j + 2);
if (NULL == code)       /* out */
    exit (1);

if (0 == j)             /* code */
    code[0] = '\0';    /* keep */

strncat (code, line, i); /* append */
code[i + j] = '\n';    /* append */
code[i + j + 1] = '\0';

src = Py_CompileString (code, "<stdin>", Py_single_input

if (NULL != src)        /* compile */
{
    if (ps1 == prompt ||
        '\n' == code[i + j - 1]) /* "..." and double 'n' */
    {
        dum = PyEval_EvalCode (src, glb, loc);
        Py_XDECREF (dum);
        Py_XDECREF (src);
        free (code);
        code = NULL;
        if (PyErr_Occurred ())
            PyErr_Print ();
        prompt = ps1;
    }
}       /* syntax */
else if (PyErr_ExceptionMatches (PyExc_SyntaxError))
{
    PyErr_Fetch (&exc, &val, &trb);    /* clear error */

    if (PyArg_ParseTuple (val, "sO", &msg, &obj)
        !strcmp (msg, "unexpected EOF while parsing"))
    {
        Py_XDECREF (exc);
    }
}
Py_XDECREF (val);
Py_XDECREF (trb);
prompt = ps2;
}
else /* some other syntax error */
{
    PyErr_Restore (exc, val, trb);
    PyErr_Print ();
    free (code);
    code = NULL;
    prompt = ps1;
}
}
else /* some non-syntax error */
{
    PyErr_Print ();
    free (code);
    code = NULL;
    prompt = ps1;
}
free (line);
}
}
Py_XDECREF (glb);
Py_XDECREF (loc);
Py_Finalize();
exit(0);
How do I find undefined g++ symbols __builtin_new or __pure_virtual?

To dynamically load g++ extension modules, you must recompile Python, relink it using g++ (change LINKCC in the Python Modules Makefile), and link your extension module using g++ (e.g., g++ -shared -o mymodule.so mymodule.o).
Can I create an object class with some methods implemented in C and others in Python (e.g. through inheritance)?

Yes, you can inherit from built-in classes such as `int`, `list`, `dict`, etc.

The Boost Python Library (BPL, http://www.boost.org/libs/python/doc/index.html) provides a way of doing this from C++ (i.e. you can inherit from an extension class written in C++ using the BPL).
# Python on Windows FAQ

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How do I run a Python program under Windows?

This is not necessarily a straightforward question. If you are already familiar with running programs from the Windows command line then everything will seem obvious; otherwise, you might need a little more guidance.

Unless you use some sort of integrated development environment, you will end up typing Windows commands into what is variously referred to as a “DOS window” or “Command prompt window”. Usually you can create such a window from your Start menu; under Windows 7 the menu selection is Start ▶ Programs ▶ Accessories ▶ Command Prompt. You should be able to recognize when you have started such a window because you will see a Windows “command prompt”, which usually looks like this:

C:\>

The letter may be different, and there might be other things after it, so you might just as easily see something like:

D:\YourName\Projects\Python>
depending on how your computer has been set up and what else you have recently done with it. Once you have started such a window, you are well on the way to running Python programs.

You need to realize that your Python scripts have to be processed by another program called the Python interpreter. The interpreter reads your script, compiles it into bytecodes, and then executes the bytecodes to run your program. So, how do you arrange for the interpreter to handle your Python?

First, you need to make sure that your command window recognises the word “python” as an instruction to start the interpreter. If you have opened a command window, you should try entering the command python and hitting return.:

C:\Users\YourName> python

You should then see something like:

Python 3.3.0 (v3.3.0:bd8af90ebf2, Sep 29 2012, 10:5
Type "help", "copyright", "credits" or "license" for
>>> print("Hello")
Hello
>>> "Hello" * 3
'HelloHelloHello'
Many people use the interactive mode as a convenient yet highly programmable calculator. When you want to end your interactive Python session, hold the Ctrl key down while you enter a Z, then hit the “Enter” key to get back to your Windows command prompt.

You may also find that you have a Start-menu entry such as Start ▶ Programs ▶ Python 3.3 ▶ Python (command line) that results in you seeing the >>> prompt in a new window. If so, the window will disappear after you enter the Ctrl-Z character; Windows is running a single “python” command in the window, and closes it when you terminate the interpreter.

If the python command, instead of displaying the interpreter prompt >>>, gives you a message like:

```
'python' is not recognized as an internal or external command,
```

or:

```
Bad command or filename
```

then you need to make sure that your computer knows where to find the Python interpreter. To do this you will have to modify a setting called PATH, which is a list of directories where Windows will look for programs.

You should arrange for Python’s installation directory to be added to the PATH of every command window as it starts. If you installed Python
fairly recently then the command

```
dir C:\py*
```

will probably tell you where it is installed; the usual location is something like C:\Python33. Otherwise you will be reduced to a search of your whole disk ... use Tools ▶ Find or hit the Search button and look for “python.exe”. Supposing you discover that Python is installed in the C:\Python33 directory (the default at the time of writing), you should make sure that entering the command

```
c:\Python33\python
```

starts up the interpreter as above (and don’t forget you’ll need a “Ctrl-Z” and an “Enter” to get out of it). Once you have verified the directory, you can add it to the system path to make it easier to start Python by just running the python command. This is currently an option in the installer as of CPython 3.3.

More information about environment variables can be found on the Using Python on Windows page.
How do I make Python scripts executable?

On Windows, the standard Python installer already associates the .py extension with a file type (Python.File) and gives that file type an open command that runs the interpreter (D:\Program Files\Python\python.exe "%1" %*). This is enough to make scripts executable from the command prompt as ‘foo.py’. If you’d rather be able to execute the script by simple typing ‘foo’ with no extension you need to add .py to the PATHEXT environment variable.
Why does Python sometimes take so long to start?

Usually Python starts very quickly on Windows, but occasionally there are bug reports that Python suddenly begins to take a long time to start up. This is made even more puzzling because Python will work fine on other Windows systems which appear to be configured identically.

The problem may be caused by a misconfiguration of virus checking software on the problem machine. Some virus scanners have been known to introduce startup overhead of two orders of magnitude when the scanner is configured to monitor all reads from the filesystem. Try checking the configuration of virus scanning software on your systems to ensure that they are indeed configured identically. McAfee, when configured to scan all file system read activity, is a particular offender.
How do I make an executable from a Python script?

See [http://cx-freeze.sourceforge.net/](http://cx-freeze.sourceforge.net/) for a distutils extension that allows you to create console and GUI executables from Python code. *py2exe*, the most popular extension for building Python 2.x-based executables, does not yet support Python 3 but a version that does is in development.
Is a *.pyd file the same as a DLL?

Yes, .pyd files are dll's, but there are a few differences. If you have a DLL named foo.pyd, then it must have a function PyInit_foo(). You can then write Python “import foo”, and Python will search for foo.pyd (as well as foo.py, foo.pyc) and if it finds it, will attempt to call PyInit_foo() to initialize it. You do not link your .exe with foo.lib, as that would cause Windows to require the DLL to be present.

Note that the search path for foo.pyd is PYTHONPATH, not the same as the path that Windows uses to search for foo.dll. Also, foo.pyd need not be present to run your program, whereas if you linked your program with a dll, the dll is required. Of course, foo.pyd is required if you want to say import foo. In a DLL, linkage is declared in the source code with __declspec(dllexport). In a .pyd, linkage is defined in a list of available functions.
How can I embed Python into a Windows application?

Embedding the Python interpreter in a Windows app can be summarized as follows:

1. Do _not_ build Python into your .exe file directly. On Windows, Python must be a DLL to handle importing modules that are themselves DLL’s. (This is the first key undocumented fact.) Instead, link to pythonNN.dll; it is typically installed in C:\Windows\System. NN is the Python version, a number such as “33” for Python 3.3.

You can link to Python in two different ways. Load-time linking means linking against pythonNN.lib, while run-time linking means linking against pythonNN.dll. (General note: pythonNN.lib is the so-called “import lib” corresponding to pythonNN.dll. It merely defines symbols for the linker.)

Run-time linking greatly simplifies link options; everything happens at run time. Your code must load pythonNN.dll using the Windows LoadLibraryEx() routine. The code must also use access routines and data in pythonNN.dll (that is, Python's C API's) using pointers obtained by the Windows GetProcAddress() routine. Macros can make using these pointers transparent to any C code that calls routines in Python's C API.

Borland note: convert pythonNN.lib to OMF format using Coff2Omf.exe first.
2. If you use SWIG, it is easy to create a Python “extension module” that will make the app’s data and methods available to Python. SWIG will handle just about all the grungy details for you. The result is C code that you link into your .exe file (!) You do _not_ have to create a DLL file, and this also simplifies linking.

3. SWIG will create an init function (a C function) whose name depends on the name of the extension module. For example, if the name of the module is leo, the init function will be called initleo(). If you use SWIG shadow classes, as you should, the init function will be called initleoc(). This initializes a mostly hidden helper class used by the shadow class.

The reason you can link the C code in step 2 into your .exe file is that calling the initialization function is equivalent to importing the module into Python! (This is the second key undocumented fact.)

4. In short, you can use the following code to initialize the Python interpreter with your extension module.

```
#include "python.h"
...
Py_Initialize(); // Initialize Python.
initmyAppc(); // Initialize (import) the helper
PyRun_SimpleString("import myApp"); // Import the
```

5. There are two problems with Python’s C API which will become apparent if you use a compiler other than MSVC, the compiler used to build pythonNN.dll.

Problem 1: The so-called “Very High Level” functions that take FILE * arguments will not work in a multi-compiler environment because each compiler’s notion of a struct FILE will be different.
From an implementation standpoint these are very _low_ level functions.

Problem 2: SWIG generates the following code when generating wrappers to void functions:

```c
Py_INCREF(Py_None);
_resultobj = Py_None;
return _resultobj;
```

Alas, Py_None is a macro that expands to a reference to a complex data structure called _Py_NoneStruct inside pythonNN.dll. Again, this code will fail in a mult-compiler environment. Replace such code by:

```c
return Py_BuildValue(""");
```

It may be possible to use SWIG’s %typemap command to make the change automatically, though I have not been able to get this to work (I’m a complete SWIG newbie).

6. Using a Python shell script to put up a Python interpreter window from inside your Windows app is not a good idea; the resulting window will be independent of your app’s windowing system. Rather, you (or the wxPythonWindow class) should create a “native” interpreter window. It is easy to connect that window to the Python interpreter. You can redirect Python’s i/o to _any_ object that supports read and write, so all you need is a Python object (defined in your extension module) that contains read() and write() methods.
How do I keep editors from inserting tabs into my Python source?

The FAQ does not recommend using tabs, and the Python style guide, **PEP 8**, recommends 4 spaces for distributed Python code; this is also the Emacs python-mode default.

Under any editor, mixing tabs and spaces is a bad idea. MSVC is no different in this respect, and is easily configured to use spaces: Take Tools ▶ Options ▶ Tabs, and for file type “Default” set “Tab size” and “Indent size” to 4, and select the “Insert spaces” radio button.

If you suspect mixed tabs and spaces are causing problems in leading whitespace, run Python with the `-t` switch or run `Tools/Scripts/tabnanny.py` to check a directory tree in batch mode.
How do I check for a keypress without blocking?

Use the msvcrt module. This is a standard Windows-specific extension module. It defines a function `kbhit()` which checks whether a keyboard hit is present, and `getch()` which gets one character without echoing it.
How do I emulate os.kill() in Windows?

Prior to Python 2.7 and 3.2, to terminate a process, you can use ctypes:

```python
import ctypes
def kill(pid):
    """kill function for Win32""
    kernel32 = ctypes.windll.kernel32
    handle = kernel32.OpenProcess(1, 0, pid)
    return (0 != kernel32.TerminateProcess(handle, 0))
```

In 2.7 and 3.2, os.kill() is implemented similar to the above function, with the additional feature of being able to send Ctrl+C and Ctrl+Break to console subprocesses which are designed to handle those signals. See os.kill() for further details.
How do I extract the downloaded documentation on Windows?

Sometimes, when you download the documentation package to a Windows machine using a web browser, the file extension of the saved file ends up being .EXE. This is a mistake; the extension should be .TGZ.

Simply rename the downloaded file to have the .TGZ extension, and WinZip will be able to handle it. (If your copy of WinZip doesn’t, get a newer one from http://www.winzip.com.)
Graphic User Interface FAQ

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General GUI Questions
What platform-independent GUI toolkits exist for Python?

Depending on what platform(s) you are aiming at, there are several. Some of them haven’t been ported to Python 3 yet. At least Tkinter and Qt are known to be Python 3-compatible.

Tkinter

Standard builds of Python include an object-oriented interface to the Tcl/Tk widget set, called tkinter. This is probably the easiest to install (since it comes included with most binary distributions of Python) and use. For more info about Tk, including pointers to the source, see the Tcl/Tk home page. Tcl/Tk is fully portable to the Mac OS X, Windows, and Unix platforms.

wxWidgets

wxWidgets (http://www.wxwidgets.org) is a free, portable GUI class library written in C++ that provides a native look and feel on a number of platforms, with Windows, Mac OS X, GTK, X11, all listed as current stable targets. Language bindings are available for a number of languages including Python, Perl, Ruby, etc.

wxPython (http://www.wxpython.org) is the Python binding for wxwidgets. While it often lags slightly behind the official wxWidgets releases, it also offers a number of features via pure Python extensions that are not available in other language bindings. There is an active wxPython user and developer community.

Both wxWidgets and wxPython are free, open source, software with
permissive licences that allow their use in commercial products as well as in freeware or shareware.

**Qt**

There are bindings available for the Qt toolkit (using either PyQt or PySide) and for KDE (PyKDE). PyQt is currently more mature than PySide, but you must buy a PyQt license from Riverbank Computing if you want to write proprietary applications. PySide is free for all applications.

Qt 4.5 upwards is licensed under the LGPL license; also, commercial licenses are available from The Qt Company.

**Gtk+**

The GObject introspection bindings for Python allow you to write GTK+ 3 applications. There is also a Python GTK+ 3 Tutorial.

The older PyGtk bindings for the Gtk+ 2 toolkit have been implemented by James Henstridge; see <http://www.pygtk.org>.

**FLTK**

Python bindings for the FLTK toolkit, a simple yet powerful and mature cross-platform windowing system, are available from the PyFLTK project.

**FOX**

A wrapper for the FOX toolkit called FXpy is available. FOX supports
both Unix variants and Windows.

**OpenGL**

For OpenGL bindings, see PyOpenGL.
What platform-specific GUI toolkits exist for Python?

By installing the PyObjc Objective-C bridge, Python programs can use Mac OS X's Cocoa libraries.

Pythonwin by Mark Hammond includes an interface to the Microsoft Foundation Classes and a Python programming environment that's written mostly in Python using the MFC classes.
Tkinter questions

How do I freeze Tkinter applications?

Freeze is a tool to create stand-alone applications. When freezing Tkinter applications, the applications will not be truly stand-alone, as the application will still need the Tcl and Tk libraries.

One solution is to ship the application with the Tcl and Tk libraries, and point to them at run-time using the TCL_LIBRARY and TK_LIBRARY environment variables.

To get truly stand-alone applications, the Tcl scripts that form the library have to be integrated into the application as well. One tool supporting that is SAM (stand-alone modules), which is part of the Tix distribution (http://tix.sourceforge.net/).

Build Tix with SAM enabled, perform the appropriate call to Tclsam_init(), etc. inside Python's Modules/tkappinit.c, and link with libtclsam and libtksam (you might include the Tix libraries as well).

Can I have Tk events handled while waiting for I/O?

On platforms other than Windows, yes, and you don't even need threads! But you'll have to restructure your I/O code a bit. Tk has the equivalent of Xt's XtAddInput() call, which allows you to register a callback function which will be called from the Tk mainloop when I/O is possible on a file descriptor. See File Handlers.
I can’t get key bindings to work in Tkinter: why?

An often-heard complaint is that event handlers bound to events with the `bind()` method don’t get handled even when the appropriate key is pressed.

The most common cause is that the widget to which the binding applies doesn’t have “keyboard focus”. Check out the Tk documentation for the focus command. Usually a widget is given the keyboard focus by clicking in it (but not for labels; see the `takefocus` option).
“Why is Python Installed on my Computer?” FAQ
What is Python?

Python is a programming language. It’s used for many different applications. It’s used in some high schools and colleges as an introductory programming language because Python is easy to learn, but it’s also used by professional software developers at places such as Google, NASA, and Lucasfilm Ltd.

If you wish to learn more about Python, start with the Beginner’s Guide to Python.
Why is Python installed on my machine?

If you find Python installed on your system but don’t remember installing it, there are several possible ways it could have gotten there.

- Perhaps another user on the computer wanted to learn programming and installed it; you'll have to figure out who's been using the machine and might have installed it.
- A third-party application installed on the machine might have been written in Python and included a Python installation. There are many such applications, from GUI programs to network servers and administrative scripts.
- Some Windows machines also have Python installed. At this writing we’re aware of computers from Hewlett-Packard and Compaq that include Python. Apparently some of HP/Compaq's administrative tools are written in Python.
- Many Unix-compatible operating systems, such as Mac OS X and some Linux distributions, have Python installed by default; it's included in the base installation.
Can I delete Python?

That depends on where Python came from.

If someone installed it deliberately, you can remove it without hurting anything. On Windows, use the Add/Remove Programs icon in the Control Panel.

If Python was installed by a third-party application, you can also remove it, but that application will no longer work. You should use that application's uninstaller rather than removing Python directly.

If Python came with your operating system, removing it is not recommended. If you remove it, whatever tools were written in Python will no longer run, and some of them might be important to you. Reinstalling the whole system would then be required to fix things again.
Glossary

>>> The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

... The default Python prompt of the interactive shell when entering code for an indented code block or within a pair of matching left and right delimiters (parentheses, square brackets or curly braces).

2to3 A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See 2to3 - Automated Python 2 to 3 code translation.

abstract base class

Abstract base classes complement duck-typing by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with magic methods). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections.abc` module), numbers (in the `numbers` module), streams (in the `io` module), import finders and loaders (in the `importlib.abc` module). You can create your own ABCs with the `abc` module.
**argument**
A value passed to a function (or method) when calling the function. There are two kinds of argument:

- *keyword argument*: an argument preceded by an identifier (e.g. `name=`) in a function call or passed as a value in a dictionary preceded by **`.** For example, 3 and 5 are both keyword arguments in the following calls to `complex()`:

```python
complex(real=3, imag=5)
complex(**{'real': 3, 'imag': 5})
```

- *positional argument*: an argument that is not a keyword argument. Positional arguments can appear at the beginning of an argument list and/or be passed as elements of an iterable preceded by *`. For example, 3 and 5 are both positional arguments in the following calls:

```python
complex(3, 5)
complex(*(3, 5))
```

Arguments are assigned to the named local variables in a function body. See the Calls section for the rules governing this assignment. Syntactically, any expression can be used to represent an argument; the evaluated value is assigned to the local variable.

See also the parameter glossary entry, the FAQ question on the difference between arguments and parameters, and PEP 362.

**asynchronous context manager**
An object which controls the environment seen in an async with statement by defining `__aenter__()` and `__aexit__()` methods. Introduced by PEP 492.
asynchronous iterable
An object, that can be used in an async for statement. Must return an awaitable from its __aiter__() method, which should in turn be resolved in an asynchronous iterator object. Introduced by PEP 492.

asynchronous iterator
An object that implements __aiter__() and __anext__() methods, that must return awaitable objects. async for resolves awaitable returned from asynchronous iterator’s __anext__() method until it raises StopAsyncIteration exception. Introduced by PEP 492.

attribute
A value associated with an object which is referenced by name using dotted expressions. For example, if an object o has an attribute a it would be referenced as o.a.

awaitable
An object that can be used in an await expression. Can be a coroutine or an object with an __await__() method. See also PEP 492.

BDFL
Benevolent Dictator For Life, a.k.a. Guido van Rossum, Python’s creator.

binary file
A file object able to read and write bytes-like objects.

See also: A text file reads and writes str objects.

bytes-like object
An object that supports the Buffer Protocol and can export a C-contiguous buffer. This includes all bytes, bytearray, and
array.array objects, as well as many common memoryview objects. Bytes-like objects can be used for various operations that work with binary data; these include compression, saving to a binary file, and sending over a socket.

Some operations need the binary data to be mutable. The documentation often refers to these as “read-write bytes-like objects”. Example mutable buffer objects include bytearray and a memoryview of a bytearray. Other operations require the binary data to be stored in immutable objects (“read-only bytes-like objects”); examples of these include bytes and a memoryview of a bytes object.

bytecode
Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in .pyc and .pyo files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This “intermediate language” is said to run on a virtual machine that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for the dis module.

class
A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

coección
The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer 3, but in `3+4.5`, each argument is of a different type (one `int`, one `float`), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

**complex number**

An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of -1), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

**context manager**

An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See [PEP 343](https://www.python.org/dev/peps/pep-0343/).

**contiguous**

A buffer is considered contiguous exactly if it is either *C-contiguous* or *Fortran contiguous*. Zero-dimensional buffers are C and Fortran contiguous. In one-dimensional arrays, the items must be layed out in memory next to each other, in order of increasing indexes starting from zero. In multidimensional C-contiguous arrays, the
last index varies the fastest when visiting items in order of memory address. However, in Fortran contiguous arrays, the first index varies the fastest.

**coroutine**

Coroutines is a more generalized form of subroutines. Subroutines are entered at one point and exited at another point. Coroutines can be entered, exited, and resumed at many different points. They can be implemented with the `async def` statement. See also PEP 492.

**coroutine function**

A function which returns a coroutine object. A coroutine function may be defined with the `async def` statement, and may contain `await`, `async for`, and `async with` keywords. These were introduced by PEP 492.

**CPython**

The canonical implementation of the Python programming language, as distributed on python.org. The term “CPython” is used when necessary to distinguish this implementation from others such as Jython or IronPython.

**decorator**

A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```python
def f(...):
    ...
f = staticmethod(f)
```
The same concept exists for classes, but is less commonly used there. See the documentation for function definitions and class definitions for more about decorators.

descriptor
Any object which defines the methods \_\_get\_\_(\_), \_\_set\_\_(\_), or \_\_delete\_\_(\_). When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using \texttt{a.b} to get, set or delete an attribute looks up the object named \texttt{b} in the class dictionary for \texttt{a}, but if \texttt{b} is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors’ methods, see Implementing Descriptors.

dictionary
An associative array, where arbitrary keys are mapped to values. The keys can be any object with \_\_hash\_\_(\_) and \_\_eq\_\_(\_) methods. Called a hash in Perl.

dictionary view
The objects returned from \texttt{dict.keys()}, \texttt{dict.values()}, and \texttt{dict.items()} are called dictionary views. They provide a dynamic view on the dictionary’s entries, which means that when the dictionary changes, the view reflects these changes. To force the dictionary view to become a full list use \texttt{list(dictview)}. 

```python
@staticmethod
def f(...):
    ...
```
See Dictionary view objects.

**docstring**

A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

**duck-typing**

A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used (“If it looks like a duck and quacks like a duck, it must be a duck.”) By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note, however, that duck-typing can be complemented with abstract base classes.) Instead, it typically employs `hasattr()` tests or EAFP programming.

**EAFP**

Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the LBYL style common to many other languages such as C.

**expression**

A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also statements which cannot be used as expressions, such as `if`. Assignments
are also statements, not expressions.

**extension module**
A module written in C or C++, using Python’s C API to interact with the core and with user code.

**file object**
An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw *binary files*, buffered *binary files* and *text files*. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the `open()` function.

**file-like object**
A synonym for *file object*.

**finder**
An object that tries to find the *loader* for a module. It must implement either a method named `find_loader()` or a method named `find_module()`. See PEP 302 and PEP 420 for details and `importlib.abc.Finder` for an abstract base class.

**floor division**
Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to 2 in contrast to the 2.75 returned by float true division. Note that `(-11) // 4` is -3 because that is -2.75 rounded *downward*. See PEP 238.
**function**

A series of statements which returns some value to a caller. It can also be passed zero or more arguments which may be used in the execution of the body. See also parameter, method, and the Function definitions section.

**function annotation**

An arbitrary metadata value associated with a function parameter or return value. Its syntax is explained in section Function definitions. Annotations may be accessed via the __annotations__ special attribute of a function object.

Python itself does not assign any particular meaning to function annotations. They are intended to be interpreted by third-party libraries or tools. See PEP 3107, which describes some of their potential uses.

**__future__**

A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter.

By importing the __future__ module and evaluating its variables, you can see when a new feature was first added to the language and when it becomes the default:

```python
>>> import __future__
>>> __future__.division
-feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

**garbage collection**

The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a
cyclic garbage collector that is able to detect and break reference cycles.

**generator**
A function which returns a generator iterator. It looks like a normal function except that it contains `yield` expressions for producing a series of values usable in a for-loop or that can be retrieved one at a time with the `next()` function.

Usually refers to a generator function, but may refer to a generator iterator in some contexts. In cases where the intended meaning isn’t clear, using the full terms avoids ambiguity.

**generator iterator**
An object created by a generator function.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the generator iterator resumes, it picks-up where it left-off (in contrast to functions which start fresh on every invocation).

**generator expression**
An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```python
>>> sum(i*i for i in range(10))  # sum of 0, 1, 4, ... 81
285
```

**generic function**
A function composed of multiple functions implementing the same
operation for different types. Which implementation should be used during a call is determined by the dispatch algorithm.

See also the single dispatch glossary entry, the `functools.singledispatch()` decorator, and PEP 443.

**GIL**

See global interpreter lock.

**global interpreter lock**

The mechanism used by the CPython interpreter to assure that only one thread executes Python bytecode at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a “free-threaded” interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

**hashable**

An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be
compared to other objects (it needs an \_\_eq\_\_( ) method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python’s immutable built-in objects are hashable, while no mutable containers (such as lists or dictionaries) are. Objects which are instances of user-defined classes are hashable by default; they all compare unequal (except with themselves), and their hash value is derived from their id() .

**IDLE**

An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

**immutable**

An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

**import path**

A list of locations (or path entries) that are searched by the path based finder for modules to import. During import, this list of locations usually comes from sys.path, but for subpackages it may also come from the parent package’s __path__ attribute.

**importing**

The process by which Python code in one module is made available to Python code in another module.
**importer**

An object that both finds and loads a module; both a finder and loader object.

**interactive**

Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch python with no arguments (possibly by selecting it from your computer’s main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember help(x)).

**interpreted**

Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also interactive.

**interpreter shutdown**

When asked to shut down, the Python interpreter enters a special phase where it gradually releases all allocated resources, such as modules and various critical internal structures. It also makes several calls to the garbage collector. This can trigger the execution of code in user-defined destructors or weakref callbacks. Code executed during the shutdown phase can encounter various exceptions as the resources it relies on may not function anymore (common examples are library modules or the warnings machinery).

The main reason for interpreter shutdown is that the __main__ module or the script being run has finished executing.
**iterable**

An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict`, `file` objects, and objects of any classes you define with an `__iter__()`, `__getitem__()`, or `__getitem__()` method. Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also `iterator`, `sequence`, and `generator`.

**iterator**

An object representing a stream of data. Repeated calls to the iterator’s `__next__()` method (or passing it to the built-in function `next()`)) return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `__next__()` method just raise a `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.
More information can be found in Iterator Types.

**key function**

A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.merge()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example, the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, a key function can be built from a lambda expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the Sorting HOW TO for examples of how to create and use key functions.

**keyword argument**

See argument.

**lambda**

An anonymous inline function consisting of a single expression which is evaluated when the function is called. The syntax to create a lambda function is `lambda [arguments]: expression`

**LBYL**

Look before you leap. This coding style explicitly tests for pre-
conditions before making calls or lookups. This style contrasts with the EAFP approach and is characterized by the presence of many if statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between “the looking” and “the leaping”. For example, the code, if key in mapping: return mapping[key] can fail if another thread removes key from mapping after the test, but before the lookup. This issue can be solved with locks or by using the EAFP approach.

**list**

A built-in Python sequence. Despite its name it is more akin to an array in other languages than to a linked list since access to elements are O(1).

**list comprehension**

A compact way to process all or part of the elements in a sequence and return a list with the results. result = ['{:04x}'.format(x) for x in range(256) if x % 2 == 0] generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The if clause is optional. If omitted, all elements in range(256) are processed.

**loader**

An object that loads a module. It must define a method named load_module(). A loader is typically returned by a finder. See PEP 302 for details and importlib.abc.Loader for an abstract base class.

**mapping**

A container object that supports arbitrary key lookups and implements the methods specified in the Mapping or MutableMapping abstract base classes. Examples include dict,
collections.defaultdict, collections.OrderedDict and collections.Counter.

**meta path finder**
A finder returned by a search of `sys.meta_path`. Meta path finders are related to, but different from path entry finders.

**metaclass**
The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in Customizing class creation.

**method**
A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first argument (which is usually called `self`). See function and nested scope.

**method resolution order**
Method Resolution Order is the order in which base classes are searched for a member during lookup. See The Python 2.3 Method Resolution Order.

**module**
An object that serves as an organizational unit of Python code. Modules have a namespace containing arbitrary Python objects.
Modules are loaded into Python by the process of importing.

See also package.

**module spec**
A namespace containing the import-related information used to load a module.

**MRO**
See method resolution order.

**mutable**
Mutable objects can change their value but keep their id(). See also immutable.

**named tuple**
Any tuple-like class whose indexable elements are also accessible using named attributes (for example, time.localtime() returns a tuple-like object where the year is accessible either with an index such as t[0] or with a named attribute like t.tm_year).

A named tuple can be a built-in type such as time.struct_time, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function collections.namedtuple(). The latter approach automatically provides extra features such as a self-documenting representation like Employee(name='jones', title='programmer').

**namespace**
The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions builtins.open and os.open() are distinguished by their namespaces. Namespaces
also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.islice()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

**namespace package**

A [PEP 420](https://www.python.org/dev/peps/pep-0420/) package which serves only as a container for subpackages. Namespace packages may have no physical representation, and specifically are not like a regular package because they have no `__init__.py` file.

See also [module](https).

**nested scope**

The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes by default work only for reference and not for assignment. Local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace. The `nonlocal` allows writing to outer scopes.

**new-style class**

Old name for the flavor of classes now used for all class objects. In earlier Python versions, only new-style classes could use Python’s newer, versatile features like `__slots__`, descriptors, properties, `__getattribute__()` , class methods, and static methods.

**object**

Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any new-style class.

**package**

A Python [module](https://docs.python.org/3/library/module.html) which can contain submodules or recursively,
subpackages. Technically, a package is a Python module with an
__path__ attribute.

See also regular package and namespace package.

**parameter**

A named entity in a function (or method) definition that specifies an argument (or in some cases, arguments) that the function can accept. There are five kinds of parameter:

- **positional-or-keyword**: specifies an argument that can be passed either positionally or as a keyword argument. This is the default kind of parameter, for example foo and bar in the following:

  ```python
def func(foo, bar=None): ...
  ```

- **positional-only**: specifies an argument that can be supplied only by position. Python has no syntax for defining positional-only parameters. However, some built-in functions have positional-only parameters (e.g. `abs()`).

- **keyword-only**: specifies an argument that can be supplied only by keyword. Keyword-only parameters can be defined by including a single var-positional parameter or bare * in the parameter list of the function definition before them, for example `kw_only1` and `kw_only2` in the following:

  ```python
def func(arg, *, kw_only1, kw_only2): ...
  ```

- **var-positional**: specifies that an arbitrary sequence of positional arguments can be provided (in addition to any positional arguments already accepted by other parameters).
Such a parameter can be defined by prepending the parameter name with *, for example *args in the following:

```python
def func(*args, **kwargs):
    ...
```

- var-keyword: specifies that arbitrarily many keyword arguments can be provided (in addition to any keyword arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with **, for example **kwargs in the example above.

Parameters can specify both optional and required arguments, as well as default values for some optional arguments.

See also the argument glossary entry, the FAQ question on the difference between arguments and parameters, the inspect.Parameter class, the Function definitions section, and PEP 362.

**path entry**
A single location on the import path which the path based finder consults to find modules for importing.

**path entry finder**
A finder returned by a callable on sys.path_hooks (i.e. a path entry hook) which knows how to locate modules given a path entry.

**path entry hook**
A callable on the sys.path_hook list which returns a path entry finder if it knows how to find modules on a specific path entry.

**path based finder**
One of the default meta path finders which searches an import path for modules.
portion

A set of files in a single directory (possibly stored in a zip file) that contribute to a namespace package, as defined in PEP 420.

positional argument

See argument.

provisional API

A provisional API is one which has been deliberately excluded from the standard library's backwards compatibility guarantees. While major changes to such interfaces are not expected, as long as they are marked provisional, backwards incompatible changes (up to and including removal of the interface) may occur if deemed necessary by core developers. Such changes will not be made gratuitously – they will occur only if serious fundamental flaws are uncovered that were missed prior to the inclusion of the API.

Even for provisional APIs, backwards incompatible changes are seen as a “solution of last resort” - every attempt will still be made to find a backwards compatible resolution to any identified problems.

This process allows the standard library to continue to evolve over time, without locking in problematic design errors for extended periods of time. See PEP 411 for more details.

provisional package

See provisional API.

Python 3000

Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated “Py3k”.

Pythonic
An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don’t have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```python
for i in range(len(food)):
    print(food[i])
```

As opposed to the cleaner, Pythonic method:

```python
for piece in food:
    print(piece)
```

**qualified name**

A dotted name showing the “path” from a module’s global scope to a class, function or method defined in that module, as defined in PEP 3155. For top-level functions and classes, the qualified name is the same as the object’s name:

```python
>>> class C:
...     class D:
...         def meth(self):
...             pass
...
>>> C.__qualname__
'C'
>>> C.D.__qualname__
'C.D'
>>> C.D.meth.__qualname__
'C.D.meth'
```
When used to refer to modules, the *fully qualified name* means the entire dotted path to the module, including any parent packages, e.g. `email.mime.text`:

```python
>>> import email.mime.text
>>> email.mime.text.__name__
'email.mime.text'
```

**reference count**

The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the CPython implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

**regular package**

A traditional package, such as a directory containing an `__init__.py` file.

See also namespace package.

**__slots__**

A declaration inside a class that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

**sequence**

An iterable which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `__len__()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `bytes`. Note
that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary immutable keys rather than integers.

The `collections.abc.Sequence` abstract base class defines a much richer interface that goes beyond just `__getitem__()` and `__len__()`, adding `count()`, `index()`, `__contains__()`, and `__reversed__()`. Types that implement this expanded interface can be registered explicitly using `register()`.

**single dispatch**
A form of generic function dispatch where the implementation is chosen based on the type of a single argument.

**slice**
An object usually containing a portion of a `sequence`. A slice is created using the subscript notation, `[ ]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally.

**special method**
A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in Special method names.

**statement**
A statement is part of a suite (a “block” of code). A statement is either an `expression` or one of several constructs with a keyword, such as `if`, `while` or `for`.

**struct sequence**
A tuple with named elements. Struct sequences expose an interface similar to `named tuple` in that elements can either be
accessed either by index or as an attribute. However, they do not have any of the named tuple methods like \_make() or \_asdict(). Examples of struct sequences include \texttt{sys.float\_info} and the return value of \texttt{os.stat()}.

\textbf{text encoding}

A codec which encodes Unicode strings to bytes.

\textbf{text file}

A file object able to read and write \texttt{str} objects. Often, a text file actually accesses a byte-oriented datastream and handles the \textit{text encoding} automatically.

\textbf{See also:} A binary file reads and write \texttt{bytes} objects.

\textbf{triple-quoted string}

A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don’t provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

\textbf{type}

The type of a Python object determines what kind of object it is; every object has a type. An object’s type is accessible as its \texttt{\_\_class\_} attribute or can be retrieved with \texttt{type(obj)}.

\textbf{universal newlines}

A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention '\n', the Windows convention '\r\n', and the old Macintosh convention '\r'. See \texttt{PEP 278} and \texttt{PEP 3116}, as well as \texttt{bytes.splitlines()} for an additional use.
virtual environment
A cooperatively isolated runtime environment that allows Python users and applications to install and upgrade Python distribution packages without interfering with the behaviour of other Python applications running on the same system.

See also pyenv - Creating virtual environments.

virtual machine
A computer defined entirely in software. Python’s virtual machine executes the bytecode emitted by the bytecode compiler.

Zen of Python
Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing “import this” at the interactive prompt.
About these documents

These documents are generated from reStructuredText sources by Sphinx, a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain is an entirely volunteer effort, just like Python itself. If you want to contribute, please take a look at the Reporting Bugs page for information on how to do so. New volunteers are always welcome!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the Docutils project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his Alternative Python Reference project from which Sphinx got many good ideas.
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It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!
null
Reporting Bugs

Python is a mature programming language which has established a reputation for stability. In order to maintain this reputation, the developers would like to know of any deficiencies you find in Python.
Documentation bugs

If you find a bug in this documentation or would like to propose an improvement, please submit a bug report on the tracker. If you have a suggestion how to fix it, include that as well.

If you’re short on time, you can also email your bug report to docs@python.org. ‘docs@’ is a mailing list run by volunteers; your request will be noticed, though it may take a while to be processed.

See also: Documentation bugs on the Python issue tracker
Using the Python issue tracker

Bug reports for Python itself should be submitted via the Python Bug Tracker (https://bugs.python.org/). The bug tracker offers a Web form which allows pertinent information to be entered and submitted to the developers.

The first step in filing a report is to determine whether the problem has already been reported. The advantage in doing so, aside from saving the developers time, is that you learn what has been done to fix it; it may be that the problem has already been fixed for the next release, or additional information is needed (in which case you are welcome to provide it if you can!). To do this, search the bug database using the search box on the top of the page.

If the problem you’re reporting is not already in the bug tracker, go back to the Python Bug Tracker and log in. If you don’t already have a tracker account, select the “Register” link or, if you use OpenID, one of the OpenID provider logos in the sidebar. It is not possible to submit a bug report anonymously.

Being now logged in, you can submit a bug. Select the “Create New” link in the sidebar to open the bug reporting form.

The submission form has a number of fields. For the “Title” field, enter a very short description of the problem; less than ten words is good. In the “Type” field, select the type of your problem; also select the “Component” and “Versions” to which the bug relates.

In the “Comment” field, describe the problem in detail, including what you expected to happen and what did happen. Be sure to include whether any extension modules were involved, and what hardware
and software platform you were using (including version information as appropriate).

Each bug report will be assigned to a developer who will determine what needs to be done to correct the problem. You will receive an update each time action is taken on the bug.

See also:

**How to Report Bugs Effectively**
Article which goes into some detail about how to create a useful bug report. This describes what kind of information is useful and why it is useful.

**Bug Writing Guidelines**
Information about writing a good bug report. Some of this is specific to the Mozilla project, but describes general good practices.
Getting started contributing to Python yourself

Beyond just reporting bugs that you find, you are also welcome to submit patches to fix them. You can find more information on how to get started patching Python in the Python Developer’s Guide. If you have questions, the core-mentorship mailing list is a friendly place to get answers to any and all questions pertaining to the process of fixing issues in Python.
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History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see http://www.cwi.nl/) in the Netherlands as a successor of a language called ABC. Guido remains Python’s principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see http://www.cnri.reston.va.us/) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see http://www.zope.com/). In 2001, the Python Software Foundation (PSF, see https://www.python.org/psf/) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

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Mersenne Twister

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A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.

Before using, initialize the state by using init_genrand(seed) or init_by_array(init_key, key_length).

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Any feedback is very welcome.
http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/emt.html
email: m-mat @ math.sci.hiroshima-u.ac.jp (remove space)

Sockets

The socket module uses the functions, getaddrinfo(), and getnameinfo(), which are coded in separate source files from the WIDE Project, http://www.wide.ad.jp/.

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Modified by Jack Jansen, CWI, July 1995:
- Use binascii module to do the actual line-by-line conversion between ascii and binary. This results in a 1000-fold speedup. The C version is still 5 times faster, though.
- Arguments more compliant with Python standard

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Original location:
https://github.com/majek/csiphash/

Solution inspired by code from:
strtod and dtoa

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Jean-loup Gailly  Mark Adler
jloup@gzip.org   madler@alumni.caltech.edu
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cfuhash

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What’s New in Python

The “What’s New in Python” series of essays takes tours through the most important changes between major Python versions. They are a “must read” for anyone wishing to stay up-to-date after a new release.

- What’s New In Python 3.5
  - Summary – Release highlights
  - New Features
  - Other Language Changes
  - New Modules
  - Improved Modules
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- PEP 397: Python Launcher for Windows
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- Builtin functions and types
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- PEP 389: Argparse Command Line Parsing Module
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The “Changelog” is a HTML version of the file Misc/NEWS which contains all nontrivial changes to Python for the current version.

- **Changelog**
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  - Python 3.5.1 release candidate 1?
  - Python 3.5.0 final?
  - Python 3.5.0 release candidate 4?
  - Python 3.5.0 release candidate 3?
  - Python 3.5.0 release candidate 2?
  - Python 3.5.0 release candidate 1?
  - Python 3.5.0 beta 4?
  - Python 3.5.0 beta 3?
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  - Python 3.4.0 release candidate 2?
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  - Python 3.4.0 Beta 2?
  - Python 3.4.0 Beta 1?
  - Python 3.4.0 Alpha 4?
  - Python 3.4.0 Alpha 3?
  - Python 3.4.0 Alpha 2?
  - Python 3.4.0 Alpha 1?
The Python Tutorial

Python is an easy to learn, powerful programming language. It has efficient high-level data structures and a simple but effective approach to object-oriented programming. Python’s elegant syntax and dynamic typing, together with its interpreted nature, make it an ideal language for scripting and rapid application development in many areas on most platforms.

The Python interpreter and the extensive standard library are freely available in source or binary form for all major platforms from the Python Web site, https://www.python.org/, and may be freely distributed. The same site also contains distributions of and pointers to many free third party Python modules, programs and tools, and additional documentation.

The Python interpreter is easily extended with new functions and data types implemented in C or C++ (or other languages callable from C). Python is also suitable as an extension language for customizable applications.

This tutorial introduces the reader informally to the basic concepts and features of the Python language and system. It helps to have a Python interpreter handy for hands-on experience, but all examples are self-contained, so the tutorial can be read off-line as well.

For a description of standard objects and modules, see The Python Standard Library. The Python Language Reference gives a more formal definition of the language. To write extensions in C or C++, read Extending and Embedding the Python Interpreter and Python/C API Reference Manual. There are also several books covering Python in depth.
This tutorial does not attempt to be comprehensive and cover every single feature, or even every commonly used feature. Instead, it introduces many of Python’s most noteworthy features, and will give you a good idea of the language's flavor and style. After reading it, you will be able to read and write Python modules and programs, and you will be ready to learn more about the various Python library modules described in The Python Standard Library.

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The Python Standard Library

While The Python Language Reference describes the exact syntax and semantics of the Python language, this library reference manual describes the standard library that is distributed with Python. It also describes some of the optional components that are commonly included in Python distributions.

Python’s standard library is very extensive, offering a wide range of facilities as indicated by the long table of contents listed below. The library contains built-in modules (written in C) that provide access to system functionality such as file I/O that would otherwise be inaccessible to Python programmers, as well as modules written in Python that provide standardized solutions for many problems that occur in everyday programming. Some of these modules are explicitly designed to encourage and enhance the portability of Python programs by abstracting away platform-specifics into platform-neutral APIs.

The Python installers for the Windows platform usually include the entire standard library and often also include many additional components. For Unix-like operating systems Python is normally provided as a collection of packages, so it may be necessary to use the packaging tools provided with the operating system to obtain some or all of the optional components.

In addition to the standard library, there is a growing collection of several thousand components (from individual programs and modules to packages and entire application development frameworks), available from the Python Package Index.

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  - 35.10. pipes — Interface to shell pipelines
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35.12. nis — Interface to Sun's NIS (Yellow Pages)
35.13. syslog — Unix syslog library routines

36. Superseded Modules
   36.1. optparse — Parser for command line options
   36.2. imp — Access the import internals

37. Undocumented Modules
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The Python Language Reference

This reference manual describes the syntax and “core semantics” of the language. It is terse, but attempts to be exact and complete. The semantics of non-essential built-in object types and of the built-in functions and modules are described in The Python Standard Library. For an informal introduction to the language, see The Python Tutorial. For C or C++ programmers, two additional manuals exist: Extending and Embedding the Python Interpreter describes the high-level picture of how to write a Python extension module, and the Python/C API Reference Manual describes the interfaces available to C/C++ programmers in detail.

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- 3. Data model
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- 7.7. The `yield` statement
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- **8. Compound statements**
  - 8.1. The `if` statement
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  - 8.3. The `for` statement
  - 8.4. The `try` statement
  - 8.5. The `with` statement
  - 8.6. Function definitions
  - 8.7. Class definitions
  - 8.8. Coroutines
- **9. Top-level components**
  - 9.1. Complete Python programs
  - 9.2. File input
  - 9.3. Interactive input
  - 9.4. Expression input
- **10. Full Grammar specification**
Python Setup and Usage

This part of the documentation is devoted to general information on the setup of the Python environment on different platform, the invocation of the interpreter and things that make working with Python easier.

- **1. Command line and environment**
  - 1.1. Command line
    - 1.1.1. Interface options
    - 1.1.2. Generic options
    - 1.1.3. Miscellaneous options
    - 1.1.4. Options you shouldn’t use
  - 1.2. Environment variables
    - 1.2.1. Debug-mode variables

- **2. Using Python on Unix platforms**
  - 2.1. Getting and installing the latest version of Python
    - 2.1.1. On Linux
    - 2.1.2. On FreeBSD and OpenBSD
    - 2.1.3. On OpenSolaris
  - 2.2. Building Python
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- **3. Using Python on Windows**
  - 3.1. Installing Python
    - 3.1.1. Installation Steps
    - 3.1.2. Installing Without UI
    - 3.1.3. Installing Without Downloading
    - 3.1.4. Other Platforms
  - 3.2. Alternative bundles
  - 3.3. Configuring Python
    - 3.3.1. Excursus: Setting environment variables
3.3.2. Finding the Python executable
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    3.4.1.1. From the command-line
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5. Additional Tools and Scripts
5.1. pyvenv - Creating virtual environments
Python HOWTOs

Python HOWTOs are documents that cover a single, specific topic, and attempt to cover it fairly completely. Modelled on the Linux Documentation Project’s HOWTO collection, this collection is an effort to foster documentation that’s more detailed than the Python Library Reference.

Currently, the HOWTOs are:

- Porting Python 2 Code to Python 3
- Porting Extension Modules to Python 3
- Curses Programming with Python
- Descriptor HowTo Guide
- Functional Programming HOWTO
- Logging HOWTO
- Logging Cookbook
- Regular Expression HOWTO
- Socket Programming HOWTO
- Sorting HOW TO
- Unicode HOWTO
- HOWTO Fetch Internet Resources Using The urllib Package
- HOWTO Use Python in the web
- Argparse Tutorial
- An introduction to the ipaddress module
- Argument Clinic How-To
As a popular open source development project, Python has an active supporting community of contributors and users that also make their software available for other Python developers to use under open source license terms.

This allows Python users to share and collaborate effectively, benefiting from the solutions others have already created to common (and sometimes even rare!) problems, as well as potentially contributing their own solutions to the common pool.

This guide covers the installation part of the process. For a guide to creating and sharing your own Python projects, refer to the distribution guide.

**Note:** For corporate and other institutional users, be aware that many organisations have their own policies around using and contributing to open source software. Please take such policies into account when making use of the distribution and installation tools provided with Python.
Key terms

- **pip** is the preferred installer program. Starting with Python 3.4, it is included by default with the Python binary installers.
- A **virtual environment** is a semi-isolated Python environment that allows packages to be installed for use by a particular application, rather than being installed system wide.
- **pyvenv** is the standard tool for creating virtual environments, and has been part of Python since Python 3.3. Starting with Python 3.4, it defaults to installing pip into all created virtual environments.
- **virtualenv** is a third party alternative (and predecessor) to pyvenv. It allows virtual environments to be used on versions of Python prior to 3.4, which either don't provide pyvenv at all, or aren't able to automatically install pip into created environments.
- The **Python Packaging Index** is a public repository of open source licensed packages made available for use by other Python users.
- The **Python Packaging Authority** are the group of developers and documentation authors responsible for the maintenance and evolution of the standard packaging tools and the associated metadata and file format standards. They maintain a variety of tools, documentation and issue trackers on both GitHub and BitBucket.
- **distutils** is the original build and distribution system first added to the Python standard library in 1998. While direct use of distutils is being phased out, it still laid the foundation for the current packaging and distribution infrastructure, and it not only remains part of the standard library, but its name lives on in other ways (such as the name of the mailing list used to coordinate Python packaging standards development).
Basic usage

The standard packaging tools are all designed to be used from the command line.

The following command will install the latest version of a module and its dependencies from the Python Packaging Index:

```bash
python -m pip install SomePackage
```

**Note:** For POSIX users (including Mac OS X and Linux users), the examples in this guide assume the use of a virtual environment.

For Windows users, the examples in this guide assume that the option to adjust the system PATH environment variable was selected when installing Python.

It's also possible to specify an exact or minimum version directly on the command line:

```bash
python -m pip install SomePackage==1.0.4  # specific version
python -m pip install 'SomePackage>=1.0.4'  # minimum version
```

Normally, if a suitable module is already installed, attempting to install it again will have no effect. Upgrading existing modules must be requested explicitly:

```bash
python -m pip install --upgrade SomePackage
```

More information and resources regarding pip and its capabilities can be found in the Python Packaging User Guide.
pyvenv has its own documentation at pyvenv - Creating virtual environments. Installing into an active virtual environment uses the commands shown above.

See also: Python Packaging User Guide: Installing Python Distribution Packages
How do I ...?

These are quick answers or links for some common tasks.

... install pip in versions of Python prior to Python 3.4?

Python only started bundling pip with Python 3.4. For earlier versions, pip needs to be “bootstrapped” as described in the Python Packaging User Guide.

**See also:** Python Packaging User Guide: Setup for Installing Distribution Packages

... install packages just for the current user?

Passing the --user option to python -m pip install will install a package just for the current user, rather than for all users of the system.

... install scientific Python packages?

A number of scientific Python packages have complex binary dependencies, and aren’t currently easy to install using pip directly. At this point in time, it will often be easier for users to install these packages by other means rather than attempting to install them with pip.

**See also:** Python Packaging User Guide: Installing Scientific Packages
... work with multiple versions of Python installed in parallel?

On Linux, Mac OS X and other POSIX systems, use the versioned Python commands in combination with the -m switch to run the appropriate copy of pip:

```
python2   -m pip install SomePackage  # default Python 2
python2.7 -m pip install SomePackage  # specifically Python 2.7
python3   -m pip install SomePackage  # default Python 3
python3.4 -m pip install SomePackage  # specifically Python 3.4
```

(appropriately versioned pip commands may also be available)

On Windows, use the py Python launcher in combination with the -m switch:

```
py   -2   -m pip install SomePackage  # default Python 2
py   -2.7 -m pip install SomePackage  # specifically Python 2.7
py   -3   -m pip install SomePackage  # default Python 3
py   -3.4 -m pip install SomePackage  # specifically Python 3.4
```
Common installation issues

Installing into the system Python on Linux

On Linux systems, a Python installation will typically be included as part of the distribution. Installing into this Python installation requires root access to the system, and may interfere with the operation of the system package manager and other components of the system if a component is unexpectedly upgraded using pip.

On such systems, it is often better to use a virtual environment or a per-user installation when installing packages with pip.

Installing binary extensions

Python has typically relied heavily on source based distribution, with end users being expected to compile extension modules from source as part of the installation process.

With the introduction of support for the binary wheel format, and the ability to publish wheels for at least Windows and Mac OS X through the Python Packaging Index, this problem is expected to diminish over time, as users are more regularly able to install pre-built extensions rather than needing to build them themselves.

Some of the solutions for installing scientific software that is not yet available as pre-built wheel files may also help with obtaining other binary extensions without needing to build them locally.

See also: Python Packaging User Guide: Binary Extensions
Distributing Python Modules

Email: distutils-sig@python.org

As a popular open source development project, Python has an active supporting community of contributors and users that also make their software available for other Python developers to use under open source license terms.

This allows Python users to share and collaborate effectively, benefiting from the solutions others have already created to common (and sometimes even rare!) problems, as well as potentially contributing their own solutions to the common pool.

This guide covers the distribution part of the process. For a guide to installing other Python projects, refer to the installation guide.

Note: For corporate and other institutional users, be aware that many organisations have their own policies around using and contributing to open source software. Please take such policies into account when making use of the distribution and installation tools provided with Python.
Key terms

- the **Python Packaging Index** is a public repository of open source licensed packages made available for use by other Python users.
- the **Python Packaging Authority** are the group of developers and documentation authors responsible for the maintenance and evolution of the standard packaging tools and the associated metadata and file format standards. They maintain a variety of tools, documentation and issue trackers on both GitHub and BitBucket.
- **distutils** is the original build and distribution system first added to the Python standard library in 1998. While direct use of **distutils** is being phased out, it still laid the foundation for the current packaging and distribution infrastructure, and it not only remains part of the standard library, but its name lives on in other ways (such as the name of the mailing list used to coordinate Python packaging standards development).
- **setuptools** is a (largely) drop-in replacement for **distutils** first published in 2004. Its most notable addition over the unmodified **distutils** tools was the ability to declare dependencies on other packages. It is currently recommended as a more regularly updated alternative to **distutils** that offers consistent support for more recent packaging standards across a wide range of Python versions.
- **wheel** (in this context) is a project that adds the `bdist_wheel` command to **distutils/setuptools**. This produces a cross platform binary packaging format (called “wheels” or “wheel files” and defined in **PEP 427**) that allows Python libraries, even those including binary extensions, to be installed on a system without needing to be built locally.
Open source licensing and collaboration

In most parts of the world, software is automatically covered by copyright. This means that other developers require explicit permission to copy, use, modify and redistribute the software.

Open source licensing is a way of explicitly granting such permission in a relatively consistent way, allowing developers to share and collaborate efficiently by making common solutions to various problems freely available. This leaves many developers free to spend more time focusing on the problems that are relatively unique to their specific situation.

The distribution tools provided with Python are designed to make it reasonably straightforward for developers to make their own contributions back to that common pool of software if they choose to do so.

The same distribution tools can also be used to distribute software within an organisation, regardless of whether that software is published as open source software or not.
Installing the tools

The standard library does not include build tools that support modern Python packaging standards, as the core development team has found that it is important to have standard tools that work consistently, even on older versions of Python.

The currently recommended build and distribution tools can be installed by invoking the `pip` module at the command line:

```
python -m pip install setuptools wheel twine
```

**Note:** For POSIX users (including Mac OS X and Linux users), these instructions assume the use of a virtual environment.

For Windows users, these instructions assume that the option to adjust the system PATH environment variable was selected when installing Python.

The Python Packaging User Guide includes more details on the currently recommended tools.
Reading the guide

The Python Packaging User Guide covers the various key steps and elements involved in creating a project:

- Project structure
- Building and packaging the project
- Uploading the project to the Python Packaging Index
How do I...?

These are quick answers or links for some common tasks.

... choose a name for my project?

This isn't an easy topic, but here are a few tips:

- check the Python Packaging Index to see if the name is already in use
- check popular hosting sites like GitHub, BitBucket, etc to see if there is already a project with that name
- check what comes up in a web search for the name you’re considering
- avoid particularly common words, especially ones with multiple meanings, as they can make it difficult for users to find your software when searching for it

... create and distribute binary extensions?

This is actually quite a complex topic, with a variety of alternatives available depending on exactly what you’re aiming to achieve. See the Python Packaging User Guide for more information and recommendations.

See also: Python Packaging User Guide: Binary Extensions
Extending and Embedding the Python Interpreter

This document describes how to write modules in C or C++ to extend the Python interpreter with new modules. Those modules can not only define new functions but also new object types and their methods. The document also describes how to embed the Python interpreter in another application, for use as an extension language. Finally, it shows how to compile and link extension modules so that they can be loaded dynamically (at run time) into the interpreter, if the underlying operating system supports this feature.

This document assumes basic knowledge about Python. For an informal introduction to the language, see The Python Tutorial. The Python Language Reference gives a more formal definition of the language. The Python Standard Library documents the existing object types, functions and modules (both built-in and written in Python) that give the language its wide application range.

For a detailed description of the whole Python/C API, see the separate Python/C API Reference Manual.
Recommended third party tools

This guide only covers the basic tools for creating extensions provided as part of this version of CPython. Third party tools like Cython, cffi, SWIG and Numba offer both simpler and more sophisticated approaches to creating C and C++ extensions for Python.

See also:

**Python Packaging User Guide: Binary Extensions**

The Python Packaging User Guide not only covers several available tools that simplify the creation of binary extensions, but also discusses the various reasons why creating an extension module may be desirable in the first place.
Creating extensions without third party tools

This section of the guide covers creating C and C++ extensions without assistance from third party tools. It is intended primarily for creators of those tools, rather than being a recommended way to create your own C extensions.

- 1. Extending Python with C or C++
  - 1.1. A Simple Example
  - 1.2. Intermezzo: Errors and Exceptions
  - 1.3. Back to the Example
  - 1.4. The Module’s Method Table and Initialization Function
  - 1.5. Compilation and Linkage
  - 1.6. Calling Python Functions from C
  - 1.7. Extracting Parameters in Extension Functions
  - 1.8. Keyword Parameters for Extension Functions
  - 1.9. Building Arbitrary Values
  - 1.10. Reference Counts
  - 1.11. Writing Extensions in C++
  - 1.12. Providing a C API for an Extension Module

- 2. Defining New Types
  - 2.1. The Basics
  - 2.2. Type Methods

- 3. Building C and C++ Extensions
  - 3.1. Building C and C++ Extensions with distutils
  - 3.2. Distributing your extension modules

- 4. Building C and C++ Extensions on Windows
  - 4.1. A Cookbook Approach
  - 4.2. Differences Between Unix and Windows
  - 4.3. Using DLLs in Practice
Embedding the CPython runtime in a larger application

Sometimes, rather than creating an extension that runs inside the Python interpreter as the main application, it is desirable to instead embed the CPython runtime inside a larger application. This section covers some of the details involved in doing that successfully.

- 1. Embedding Python in Another Application
  - 1.1. Very High Level Embedding
  - 1.2. Beyond Very High Level Embedding: An overview
  - 1.3. Pure Embedding
  - 1.4. Extending Embedded Python
  - 1.5. Embedding Python in C++
  - 1.6. Compiling and Linking under Unix-like systems
Python/C API Reference Manual

This manual documents the API used by C and C++ programmers who want to write extension modules or embed Python. It is a companion to Extending and Embedding the Python Interpreter, which describes the general principles of extension writing but does not document the API functions in detail.

- Introduction
  - Include Files
  - Objects, Types and Reference Counts
  - Exceptions
  - Embedding Python
  - Debugging Builds
- Stable Application Binary Interface
- The Very High Level Layer
- Reference Counting
- Exception Handling
  - Printing and clearing
  - Raising exceptions
  - Issuing warnings
  - Querying the error indicator
  - Signal Handling
  - Exception Classes
  - Exception Objects
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  - Recursion Control
  - Standard Exceptions
- Utilities
  - Operating System Utilities
  - System Functions
  - Process Control
• Importing Modules
  • Data marshalling support
  • Parsing arguments and building values
  • String conversion and formatting
  • Reflection
  • Codec registry and support functions

• Abstract Objects Layer
  • Object Protocol
  • Number Protocol
  • Sequence Protocol
  • Mapping Protocol
  • Iterator Protocol
  • Buffer Protocol
  • Old Buffer Protocol

• Concrete Objects Layer
  • Fundamental Objects
  • Numeric Objects
  • Sequence Objects
  • Container Objects
  • Function Objects
  • Other Objects

• Initialization, Finalization, and Threads
  • Initializing and finalizing the interpreter
  • Process-wide parameters
  • Thread State and the Global Interpreter Lock
  • Sub-interpreter support
  • Asynchronous Notifications
  • Profiling and Tracing
  • Advanced Debugger Support

• Memory Management
  • Overview
  • Raw Memory Interface
  • Memory Interface
  • Customize Memory Allocators
- Customize PyObject Arena Allocator
- Examples
  - Object Implementation Support
    - Allocating Objects on the Heap
    - Common Object Structures
    - Type Objects
    - Number Object Structures
    - Mapping Object Structures
    - Sequence Object Structures
    - Buffer Object Structures
    - Async Object Structures
    - Supporting Cyclic Garbage Collection
  - API and ABI Versioning
Python Frequently Asked Questions

- General Python FAQ
- Programming FAQ
- Design and History FAQ
- Library and Extension FAQ
- Extending/Embedding FAQ
- Python on Windows FAQ
- Graphic User Interface FAQ
- “Why is Python Installed on my Computer?” FAQ
Python Documentation contents

- What's New in Python
  - What's New In Python 3.5
    - Summary – Release highlights
    - New Features
      - PEP 492 - Coroutines with async and await syntax
      - PEP 465 - A dedicated infix operator for matrix multiplication
      - PEP 448 - Additional Unpacking Generalizations
      - PEP 461 - % formatting support for bytes and bytearray
      - PEP 484 - Type Hints
      - PEP 471 - os.scandir() function – a better and faster directory iterator
      - PEP 475: Retry system calls failing with EINTR
      - PEP 479: Change StopIteration handling inside generators
      - PEP 485: A function for testing approximate equality
      - PEP 486: Make the Python Launcher aware of virtual environments
      - PEP 488: Elimination of PYO files
      - PEP 489: Multi-phase extension module initialization
  - Other Language Changes
  - New Modules
    - typing
    - zipapp
  - Improved Modules
    - argparse
    - asyncio
    - bz2
    - cgi
    - cmath
- code
- collections
- collections.abc
- compileall
- concurrent.futures
- configparser
- contextlib
- csv
- curses
- dbm
- difflib
- distutils
- doctest
- email
- enum
- faulthandler
- functools
- glob
- gzip
- heapq
- http
- http.client
- idlelib and IDLE
- imaplib
- imghdr
- importlib
- inspect
- io
- ipaddress
- json
- linecache
- locale
- logging
- lzma
- math
- multiprocessing
- operator
- os
- pathlib
- pickle
- poplib
- re
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  - Other Changes
- sqlite3
- subprocess
- sys
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- tarfile
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- unittest
- unittest.mock
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- xmlrpc
- xml.sax
- zipfile
- Other module-level changes
- Optimizations
- Build and C API Changes
- Deprecated
  - New Keywords
  - Deprecated Python Behavior
  - Unsupported Operating Systems
  - Deprecated Python modules, functions and methods
- Removed
  - API and Feature Removals
- Porting to Python 3.5
  - Changes in Python behavior
  - Changes in the Python API
  - Changes in the C API
- What's New In Python 3.4
  - Summary – Release Highlights
  - New Features
    - PEP 453: Explicit Bootstrapping of PIP in Python Installations
      - Bootstrapping pip By Default
      - Documentation Changes
    - PEP 446: Newly Created File Descriptors Are Non-Inheritable
    - Improvements to Codec Handling
    - PEP 451: A ModuleSpec Type for the Import System
    - Other Language Changes
  - New Modules
    - asyncio
    - ensurepip
- enum
- pathlib
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- statistics
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**Improved Modules**
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- audioop
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- select
- shelve
- shutil
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- smtplib
- socket
- sqlite3
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- tarfile
- textwrap
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- unittest
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- weakref
- xml.etree
- zipfile

- **CPython Implementation Changes**
  - PEP 445: Customization of CPython Memory Allocators
  - PEP 442: Safe Object Finalization
  - PEP 456: Secure and Interchangeable Hash Algorithm
  - PEP 436: Argument Clinic
  - Other Build and C API Changes
  - Other Improvements
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- **Deprecated**
  - Deprecations in the Python API
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- **Removed**
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- **Porting to Python 3.4**
  - Changes in ‘python’ Command Behavior
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- **Changed in 3.4.3**
  - PEP 476: Enabling certificate verification by default for stdlib http clients

- **What's New In Python 3.3**
  - Summary – Release highlights
  - PEP 405: Virtual Environments
  - PEP 420: Implicit Namespace Packages
  - PEP 3118: New memoryview implementation and buffer protocol documentation
    - Features
    - API changes
- PEP 393: Flexible String Representation
  - Functionality
  - Performance and resource usage
- PEP 397: Python Launcher for Windows
- PEP 3151: Reworking the OS and IO exception hierarchy
- PEP 380: Syntax for Delegating to a Subgenerator
- PEP 409: Suppressing exception context
- PEP 414: Explicit Unicode literals
- PEP 3155: Qualified name for classes and functions
- PEP 412: Key-Sharing Dictionary
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- Why is there no goto?
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- Why doesn’t Python have a “with” statement for attribute assignments?
- Why are colons required for the if/while/def/class statements?
- Why does Python allow commas at the end of lists and tuples?

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10. API Reference
10.1. distutils.core — Core Distutils functionality

The distutils.core module is the only module that needs to be installed to use the Distutils. It provides the setup() (which is called from the setup script). Indirectly provides the distutils.dist.Distribution and distutils.cmd.Command class.

distutils.core.setup(arguments)

The basic do-everything function that does most everything you could ever ask for from a Distutils method.

The setup function takes a large number of arguments. These are laid out in the following table.

<table>
<thead>
<tr>
<th>argument name</th>
<th>value</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>The name of the package</td>
<td>a string</td>
</tr>
<tr>
<td>version</td>
<td>The version number of the package; see distutils.version</td>
<td>a string</td>
</tr>
<tr>
<td>description</td>
<td>A single line describing the package</td>
<td>a string</td>
</tr>
<tr>
<td>long_description</td>
<td>Longer description of the package</td>
<td>a string</td>
</tr>
<tr>
<td>author</td>
<td>The name of the package author</td>
<td>a string</td>
</tr>
<tr>
<td>author_email</td>
<td>The email address of the package author</td>
<td>a string</td>
</tr>
<tr>
<td><strong>maintainer</strong></td>
<td>The name of the current maintainer, if different from the author. Note that if the maintainer is provided, distutils will use it as the author in <strong>PKG-INFO</strong>.</td>
<td>a string</td>
</tr>
<tr>
<td><strong>maintainer_email</strong></td>
<td>The email address of the current maintainer, if different from the author</td>
<td>a string</td>
</tr>
<tr>
<td><strong>url</strong></td>
<td>A URL for the package (homepage)</td>
<td>a string</td>
</tr>
<tr>
<td><strong>download_url</strong></td>
<td>A URL to download the package</td>
<td>a string</td>
</tr>
<tr>
<td><strong>packages</strong></td>
<td>A list of Python packages that distutils will manipulate</td>
<td>a list of strings</td>
</tr>
<tr>
<td><strong>py_modules</strong></td>
<td>A list of Python modules that distutils will manipulate</td>
<td>a list of strings</td>
</tr>
<tr>
<td><strong>scripts</strong></td>
<td>A list of standalone script files to be built and installed</td>
<td>a list of strings</td>
</tr>
<tr>
<td><strong>ext_modules</strong></td>
<td>A list of Python extensions to be built</td>
<td>a list of instances of <code>distutils.core.Extension</code></td>
</tr>
<tr>
<td><strong>classifiers</strong></td>
<td>A list of categories for the package</td>
<td>a list of strings; valid classifiers are listed on <strong>PyPI</strong>.</td>
</tr>
<tr>
<td><strong>distclass</strong></td>
<td>the <strong>Distribution</strong> class to use</td>
<td>a subclass of <code>distutils.core.Distribution</code></td>
</tr>
<tr>
<td></td>
<td>The name of the setup.py script</td>
<td></td>
</tr>
<tr>
<td><strong>script_name</strong></td>
<td>defaults to sys.argv[0]</td>
<td>a string</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------------</td>
<td>----------</td>
</tr>
<tr>
<td><strong>script_args</strong></td>
<td>Arguments to supply to the setup script</td>
<td>a list of strings</td>
</tr>
<tr>
<td><strong>options</strong></td>
<td>default options for the setup script</td>
<td>a dictionary</td>
</tr>
<tr>
<td><strong>license</strong></td>
<td>The license for the package</td>
<td>a string</td>
</tr>
<tr>
<td><strong>keywords</strong></td>
<td>Descriptive meta-data, see PEP 314</td>
<td>a list of strings or a comma-separated string</td>
</tr>
<tr>
<td><strong>platforms</strong></td>
<td>a list of strings or a comma-separated string</td>
<td></td>
</tr>
<tr>
<td><strong>cmdclass</strong></td>
<td>A mapping of command names to Command subclasses</td>
<td>a dictionary</td>
</tr>
<tr>
<td><strong>data_files</strong></td>
<td>A list of data files to install</td>
<td>a list</td>
</tr>
<tr>
<td><strong>package_dir</strong></td>
<td>A mapping of package to directory names</td>
<td>a dictionary</td>
</tr>
</tbody>
</table>

distutils.core.run_setup(script_name[, script_args=None, stop_after='run'])

Run a setup script in a somewhat controlled environment, and return the distutils.dist.Distribution instance that drives things. This is useful if you need to find out the distribution meta-data (passed as keyword args from script to setup()), or the contents of the config files or command-line.

*script_name* is a file that will be read and run with exec(). sys.argv[0] will be replaced with *script* for the duration of the
call. `script_args` is a list of strings; if supplied, `sys.argv[1:]` will be replaced by `script_args` for the duration of the call.

`stop_after` tells `setup()` when to stop processing; possible values:

<table>
<thead>
<tr>
<th>value</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>init</code></td>
<td>Stop after the <code>Distribution</code> instance has been created and populated with the keyword arguments to <code>setup()</code></td>
</tr>
<tr>
<td><code>config</code></td>
<td>Stop after config files have been parsed (and their data stored in the <code>Distribution</code> instance)</td>
</tr>
<tr>
<td><code>commandline</code></td>
<td>Stop after the command-line (<code>sys.argv[1:]</code> or <code>script_args</code>) have been parsed (and the data stored in the <code>Distribution</code> instance.)</td>
</tr>
<tr>
<td><code>run</code></td>
<td>Stop after all commands have been run (the same as if <code>setup()</code> had been called in the usual way). This is the default value.</td>
</tr>
</tbody>
</table>

In addition, the `distutils.core` module exposed a number of classes that live elsewhere.

- Extension from `distutils.extension`
- `Command` from `distutils.cmd`
- `Distribution` from `distutils.dist`

A short description of each of these follows, but see the relevant module for the full reference.

**class distutils.core.Extension**

The Extension class describes a single C or C++extension module in a setup script. It accepts the following keyword arguments in its constructor:
<table>
<thead>
<tr>
<th>argument name</th>
<th>value</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>name</strong></td>
<td>the full name of the extension, including any packages — ie. not a filename or pathname, but Python dotted name</td>
<td>a string</td>
</tr>
<tr>
<td><strong>sources</strong></td>
<td>list of source filenames, relative to the distribution root (where the setup script lives), in Unix form (slash-separated) for portability. Source files may be C, C++, SWIG (.i), platform-specific resource files, or whatever else is recognized by the build_ext command as source for a Python extension.</td>
<td>a list of strings</td>
</tr>
<tr>
<td><strong>include_dirs</strong></td>
<td>list of directories to search for C/C++ header files (in Unix form for portability)</td>
<td>a list of strings</td>
</tr>
<tr>
<td><strong>define_macros</strong></td>
<td>list of macros to define; each macro is defined using a 2-tuple (name, value), where value is either the string to define it to or None to define it without a particular value (equivalent of #define FOO in</td>
<td>a list of tuples</td>
</tr>
<tr>
<td><strong>variable</strong></td>
<td>Description</td>
<td>Type</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>source or -DF00 on Unix C compiler command line</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>undef_macros</strong></td>
<td>list of macros to undefine explicitly</td>
<td>a list of strings</td>
</tr>
<tr>
<td><strong>library_dirs</strong></td>
<td>list of directories to search for C/C++ libraries at link time</td>
<td>a list of strings</td>
</tr>
<tr>
<td><strong>libraries</strong></td>
<td>list of library names (not filenames or paths) to link against</td>
<td>a list of strings</td>
</tr>
<tr>
<td><strong>runtime_library_dirs</strong></td>
<td>list of directories to search for C/C++ libraries at run time (for shared extensions, this is when the extension is loaded)</td>
<td>a list of strings</td>
</tr>
<tr>
<td><strong>extra_objects</strong></td>
<td>list of extra files to link with (eg. object files not implied by ‘sources’, static library that must be explicitly specified, binary resource files, etc.)</td>
<td>a list of strings</td>
</tr>
<tr>
<td><strong>extra_compile_args</strong></td>
<td>any extra platform- and compiler-specific information to use when compiling the source files in ‘sources’. For platforms and compilers where a command line makes sense, this is typically a list of command-line</td>
<td>a list of strings</td>
</tr>
<tr>
<td>Argument</td>
<td>Description</td>
<td>Type</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>extra_link_args</td>
<td>any extra platform- and compiler-specific information to use when linking object files together to create the extension (or to create a new static Python interpreter). Similar interpretation as for 'extra_compile_args'.</td>
<td>a list of strings</td>
</tr>
<tr>
<td>export_symbols</td>
<td>list of symbols to be exported from a shared extension. Not used on all platforms, and not generally necessary for Python extensions, which typically export exactly one symbol: init + extension_name.</td>
<td>a list of strings</td>
</tr>
<tr>
<td>depends</td>
<td>list of files that the extension depends on</td>
<td>a list of strings</td>
</tr>
<tr>
<td>language</td>
<td>extension language (i.e. 'c', 'c++', 'objc'). Will be detected from the source extensions if not provided.</td>
<td>a string</td>
</tr>
<tr>
<td>optional</td>
<td>specifies that a build failure in the extension should not abort the build process, but</td>
<td>a boolean</td>
</tr>
</tbody>
</table>
class distutils.core.Distribution

A Distribution describes how to build, install and package up a Python software package.

See the setup() function for a list of keyword arguments accepted by the Distribution constructor. setup() creates a Distribution instance.

class distutils.core.Command

A Command class (or rather, an instance of one of its subclasses) implement a single distutils command.
10.2. distutils.ccompiler — CCompiler base class

This module provides the abstract base class for the `CCompiler` classes. A `CCompiler` instance can be used for all the compile and link steps needed to build a single project. Methods are provided to set options for the compiler — macro definitions, include directories, link path, libraries and the like.

This module provides the following functions.

```python
distutils.ccompiler.gen_lib_options(compiler, library_dirs, runtime_library_dirs, libraries)
```
Generate linker options for searching library directories and linking with specific libraries. `libraries` and `library_dirs` are, respectively, lists of library names (not filenames!) and search directories. Returns a list of command-line options suitable for use with some compiler (depending on the two format strings passed in).

```python
distutils.ccompiler.gen_preprocess_options(macros, include_dirs)
```
Generate C pre-processor options (-D, -U, -I) as used by at least two types of compilers: the typical Unix compiler and Visual C++. `macros` is the usual thing, a list of 1- or 2-tuples, where `(name,)` means undefine (-U) macro `name`, and `(name, value)` means define (-D) macro `name` to `value`. `include_dirs` is just a list of directory names to be added to the header file search path (-I). Returns a list of command-line options suitable for either Unix compilers or Visual C++.

```python
distutils.ccompiler.get_default_compiler(osname, compiler)
```

platform)

Determine the default compiler to use for the given platform.

*osname* should be one of the standard Python OS names (i.e. the ones returned by *os.name*) and *platform* the common value returned by *sys.platform* for the platform in question.

The default values are *os.name* and *sys.platform* in case the parameters are not given.

distutils.ccompiler.new_compiler(*plat=None, compiler=None, verbose=0, dry_run=0, force=0*)

Factory function to generate an instance of some CCompiler subclass for the supplied platform/compiler combination. *plat* defaults to *os.name* (eg. 'posix', 'nt'), and *compiler* defaults to the default compiler for that platform. Currently only 'posix' and 'nt' are supported, and the default compilers are “traditional Unix interface” (UnixCCompiler class) and Visual C++ (MSVCCompiler class). Note that it's perfectly possible to ask for a Unix compiler object under Windows, and a Microsoft compiler object under Unix—if you supply a value for *compiler*, *plat* is ignored.

distutils.ccompiler.show_compilers()  
Print list of available compilers (used by the --help-compiler options to *build, build_ext, build_clib*).

class distutils.ccompiler.CCompiler([verbose=0, dry_run=0, force=0])

The abstract base class *CCompiler* defines the interface that must be implemented by real compiler classes. The class also has some utility methods used by several compiler classes.
The basic idea behind a compiler abstraction class is that each instance can be used for all the compile/link steps in building a single project. Thus, attributes common to all of those compile and link steps — include directories, macros to define, libraries to link against, etc. — are attributes of the compiler instance. To allow for variability in how individual files are treated, most of those attributes may be varied on a per-compilation or per-link basis.

The constructor for each subclass creates an instance of the Compiler object. Flags are `verbose` (show verbose output), `dry_run` (don’t actually execute the steps) and `force` (rebuild everything, regardless of dependencies). All of these flags default to 0 (off). Note that you probably don’t want to instantiate `CCompiler` or one of its subclasses directly - use the `distutils.CCompiler.new_compiler()` factory function instead.

The following methods allow you to manually alter compiler options for the instance of the Compiler class.

**add_include_dir(dir)**

Add `dir` to the list of directories that will be searched for header files. The compiler is instructed to search directories in the order in which they are supplied by successive calls to `add_include_dir()`.

**set_include_dirs(dirs)**

Set the list of directories that will be searched to `dirs` (a list of strings). Overrides any preceding calls to `add_include_dir()`. Subsequent calls to `add_include_dir()` add to the list passed to `set_include_dirs()`. This does not affect any list of
standard include directories that the compiler may search by default.

**add_library(libname)**

Add *libname* to the list of libraries that will be included in all links driven by this compiler object. Note that *libname* should *not* be the name of a file containing a library, but the name of the library itself: the actual filename will be inferred by the linker, the compiler, or the compiler class (depending on the platform).

The linker will be instructed to link against libraries in the order they were supplied to `add_library()` and/or `set_libraries()`. It is perfectly valid to duplicate library names; the linker will be instructed to link against libraries as many times as they are mentioned.

**set_libraries(libnames)**

Set the list of libraries to be included in all links driven by this compiler object to *libnames* (a list of strings). This does not affect any standard system libraries that the linker may include by default.

**add_library_dir(dir)**

Add *dir* to the list of directories that will be searched for libraries specified to `add_library()` and `set_libraries()`. The linker will be instructed to search for libraries in the order they are supplied to `add_library_dir()` and/or `set_library_dirs()`.

**set_library_dirs(dirs)**

Set the list of library search directories to *dirs* (a list of strings). This does not affect any standard library search path that the
The linker may search by default.

**add_runtime_library_dir(dir)**
Add `dir` to the list of directories that will be searched for shared libraries at runtime.

**set_runtime_library_dirs(dirs)**
Set the list of directories to search for shared libraries at runtime to `dirs` (a list of strings). This does not affect any standard search path that the runtime linker may search by default.

**define_macro(name[, value=None])**
Define a preprocessor macro for all compilations driven by this compiler object. The optional parameter `value` should be a string; if it is not supplied, then the macro will be defined without an explicit value and the exact outcome depends on the compiler used.

**undefine_macro(name)**
Undefine a preprocessor macro for all compilations driven by this compiler object. If the same macro is defined by `define_macro()` and undefined by `undefine_macro()` the last call takes precedence (including multiple redefinitions or undefinitions). If the macro is redefined/undefined on a per-compilation basis (ie. in the call to `compile()`), then that takes precedence.

**add_link_object(object)**
Add `object` to the list of object files (or analogues, such as explicitly named library files or the output of “resource compilers”) to be included in every link driven by this compiler object.
object.

**set_link_objects**(objects)

Set the list of object files (or analogues) to be included in every link to `objects`. This does not affect any standard object files that the linker may include by default (such as system libraries).

The following methods implement methods for autodetection of compiler options, providing some functionality similar to GNU autoconf.

**detect_language**(sources)

Detect the language of a given file, or list of files. Uses the instance attributes `language_map` (a dictionary), and `language_order` (a list) to do the job.

**find_library_file**(dirs, lib[, debug=0])

Search the specified list of directories for a static or shared library file `lib` and return the full path to that file. If `debug` is true, look for a debugging version (if that makes sense on the current platform). Return None if `lib` wasn’t found in any of the specified directories.

**has_function**(funcname[, includes=None, include_dirs=None, libraries=None, library_dirs=None])

Return a boolean indicating whether `funcname` is supported on the current platform. The optional arguments can be used to augment the compilation environment by providing additional include files and paths and libraries and paths.

**library_dir_option**(dir)

Return the compiler option to add `dir` to the list of directories
searched for libraries.

**library_option**(lib)

Return the compiler option to add *lib* to the list of libraries linked into the shared library or executable.

**runtime_library_dir_option**(dir)

Return the compiler option to add *dir* to the list of directories searched for runtime libraries.

**set_executables**(**args**)

Define the executables (and options for them) that will be run to perform the various stages of compilation. The exact set of executables that may be specified here depends on the compiler class (via the ‘executables’ class attribute), but most will have:

<table>
<thead>
<tr>
<th>attribute</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>compiler</em></td>
<td>the C/C++ compiler</td>
</tr>
<tr>
<td><em>linker_so</em></td>
<td>linker used to create shared objects and libraries</td>
</tr>
<tr>
<td><em>linker_exe</em></td>
<td>linker used to create binary executables</td>
</tr>
<tr>
<td><em>archiver</em></td>
<td>static library creator</td>
</tr>
</tbody>
</table>

On platforms with a command-line (Unix, DOS/Windows), each of these is a string that will be split into executable name and (optional) list of arguments. (Splitting the string is done similarly to how Unix shells operate: words are delimited by spaces, but quotes and backslashes can override this. See distutils.util.split_quoted().)

The following methods invoke stages in the build process.
**compile**

```
compile(sources, output_dir=None, macros=None, include_dirs=None, debug=0, extra_preargs=None, extra_postargs=None, depends=None)
```

Compile one or more source files. Generates object files (e.g. transforms a .c file to a .o file.)

*sources* must be a list of filenames, most likely C/C++ files, but in reality anything that can be handled by a particular compiler and compiler class (eg. MSVCCompiler can handle resource files in *sources*). Return a list of object filenames, one per source filename in *sources*. Depending on the implementation, not all source files will necessarily be compiled, but all corresponding object filenames will be returned.

If *output_dir* is given, object files will be put under it, while retaining their original path component. That is, foo/bar.c normally compiles to foo/bar.o (for a Unix implementation); if *output_dir* is *build*, then it would compile to build/foo/bar.o.

*macros*, if given, must be a list of macro definitions. A macro definition is either a (name, value) 2-tuple or a (name,) 1-tuple. The former defines a macro; if the value is None, the macro is defined without an explicit value. The 1-tuple case undefines a macro. Later definitions/redefinitions/undefinitions take precedence.

*include_dirs*, if given, must be a list of strings, the directories to add to the default include file search path for this compilation only.

*debug* is a boolean; if true, the compiler will be instructed to
output debug symbols in (or alongside) the object file(s).

`extra_preargs` and `extra_postargs` are implementation-dependent. On platforms that have the notion of a command-line (e.g. Unix, DOS/Windows), they are most likely lists of strings: extra command-line arguments to prepend/append to the compiler command line. On other platforms, consult the implementation class documentation. In any event, they are intended as an escape hatch for those occasions when the abstract compiler framework doesn’t cut the mustard.

`depends`, if given, is a list of filenames that all targets depend on. If a source file is older than any file in depends, then the source file will be recompiled. This supports dependency tracking, but only at a coarse granularity.

Raises `CompileError` on failure.

```python
create_static_lib(objects, output_libname[, output_dir=None, debug=0, target_lang=None])
```

Link a bunch of stuff together to create a static library file. The “bunch of stuff” consists of the list of object files supplied as `objects`, the extra object files supplied to `add_link_object()` and/or `set_link_objects()`, the libraries supplied to `add_library()` and/or `set_libraries()`, and the libraries supplied as `libraries` (if any).

`output_libname` should be a library name, not a filename; the filename will be inferred from the library name. `output_dir` is the directory where the library file will be put.

`debug` is a boolean; if true, debugging information will be included in the library (note that on most platforms, it is the
compile step where this matters: the debug flag is included here just for consistency).

`target_lang` is the target language for which the given objects are being compiled. This allows specific linkage time treatment of certain languages.

Raises LibError on failure.

```
link(target_desc, objects, output_filename[, output_dir=None,
libraries=None, library_dirs=None, runtime_library_dirs=None,
export_symbols=None, debug=0, extra_prearargs=None,
extra_postargs=None, build_temp=None, target_lang=None])
```

Link a bunch of stuff together to create an executable or shared library file.

The “bunch of stuff” consists of the list of object files supplied as `objects`. `output_filename` should be a filename. If `output_dir` is supplied, `output_filename` is relative to it (i.e. `output_filename` can provide directory components if needed).

`libraries` is a list of libraries to link against. These are library names, not filenames, since they’re translated into filenames in a platform-specific way (eg. foo becomes libfoo.a on Unix and foo.lib on DOS/Windows). However, they can include a directory component, which means the linker will look in that specific directory rather than searching all the normal locations.

`library_dirs`, if supplied, should be a list of directories to search for libraries that were specified as bare library names (ie. no directory component). These are on top of the system default and those supplied to `add_library_dir()` and/or `set_library_dirs()`. `runtime_library_dirs` is a list of
directories that will be embedded into the shared library and used to search for other shared libraries that *it* depends on at run-time. (This may only be relevant on Unix.)

`export_symbols` is a list of symbols that the shared library will export. (This appears to be relevant only on Windows.)

d`debug` is as for `compile()` and `create_static_lib()`, with the slight distinction that it actually matters on most platforms (as opposed to `create_static_lib()`), which includes a `debug` flag mostly for form’s sake).

`extra_preargs` and `extra_postargs` are as for `compile()` (except of course that they supply command-line arguments for the particular linker being used).

t`arget_lang` is the target language for which the given objects are being compiled. This allows specific linkage time treatment of certain languages.

Raises LinkError on failure.

`linkExecutable(objects, output_progname[, output_dir=None, libraries=None, library_dirs=None, runtime_library_dirs=None, debug=0, extra_preargs=None, extra_postargs=None, target_lang=None])`

Link an executable. `output_progname` is the name of the file executable, while `objects` are a list of object filenames to link in. Other arguments are as for the `link()` method.

`linkSharedLib(objects, output_libname[, output_dir=None, libraries=None, library_dirs=None, runtime_library_dirs=None, export_symbols=None, debug=0, export_symbols=None, debug=0, export_symbols=None, debug=0,)`
Link a shared library. output_libname is the name of the output library, while objects is a list of object filenames to link in. Other arguments are as for the link() method.

**link_shared_object**

\[
\text{link_shared_object}(\text{objects}, \quad \text{output_filename}[, \quad \text{output_dir}=	ext{None}, \quad \text{libraries}=	ext{None}, \quad \text{library_dirs}=	ext{None}, \quad \text{runtime_library_dirs}=	ext{None}, \quad \text{export_symbols}=	ext{None}, \quad \text{debug}=	ext{0}, \quad \text{extra_preargs}=	ext{None}, \quad \text{extra_postargs}=	ext{None}, \quad \text{build_temp}=	ext{None}, \quad \text{target_lang}=	ext{None}]])
\]

Link a shared object. output_filename is the name of the shared object that will be created, while objects is a list of object filenames to link in. Other arguments are as for the link() method.

**preprocess**

\[
\text{preprocess}(\text{source}[, \quad \text{output_file}=	ext{None}, \quad \text{macros}=	ext{None}, \quad \text{include_dirs}=	ext{None}, \quad \text{extra_preargs}=	ext{None}, \quad \text{extra_postargs}=	ext{None}])
\]

Preprocess a single C/C++ source file, named in source. Output will be written to file named output_file, or stdout if output_file not supplied. macros is a list of macro definitions as for compile(), which will augment the macros set with define_macro() and undefine_macro(). include_dirs is a list of directory names that will be added to the default list, in the same way as add_include_dir().

Raises PreprocessError on failure.

The following utility methods are defined by the CCompiler class, for use by the various concrete subclasses.
**executable_filename** *(basename[, strip_dir=0, output_dir=''])*

Returns the filename of the executable for the given *basename*. Typically for non-Windows platforms this is the same as the basename, while Windows will get a .exe added.

**library_filename** *(libname[, lib_type='static', strip_dir=0, output_dir=''])*

Returns the filename for the given library name on the current platform. On Unix a library with *lib_type* of 'static' will typically be of the form liblibname.a, while a *lib_type* of 'dynamic' will be of the form liblibname.so.

**object_filenames** *(source_filenames[, strip_dir=0, output_dir=''])*

Returns the name of the object files for the given source files. *source_filenames* should be a list of filenames.

**shared_object_filename** *(basename[, strip_dir=0, output_dir=''])*

Returns the name of a shared object file for the given file name *basename*.

**execute** *(func, args[, msg=None, level=1])*

Invokes `distutils.util.execute()`. This method invokes a Python function *func* with the given arguments *args*, after logging and taking into account the *dry_run* flag.

**spawn** *(cmd)*

Invokes `distutils.util.spawn()`. This invokes an external
process to run the given command.

\textbf{mkpath}(\texttt{name}, \texttt{mode=511})

Invokes \texttt{distutils.dir_util.mkpath()}. This creates a directory and any missing ancestor directories.

\textbf{move\_file}(\texttt{src}, \texttt{dst})

Invokes \texttt{distutils.file_util.move\_file()}. Renames \texttt{src} to \texttt{dst}.

\textbf{announce}(\texttt{msg}, \texttt{level=1})

Write a message using \texttt{distutils.log.debug()}. 

\textbf{warn}(\texttt{msg})

Write a warning message \texttt{msg} to standard error.

\textbf{debug\_print}(\texttt{msg})

If the \texttt{debug} flag is set on this \texttt{CCompiler} instance, print \texttt{msg} to standard output, otherwise do nothing.
10.3. distutils.unixccompiler — Unix C Compiler

This module provides the UnixCCompiler class, a subclass of CCompiler that handles the typical Unix-style command-line C compiler:

- macros defined with -Dname[=value]
- macros undefined with -Uname
- include search directories specified with -I dir
- libraries specified with -l LIB
- library search directories specified with -L dir
- compile handled by `cc` (or similar) executable with `-c` option: compiles `.c` to `.o`
- link static library handled by `ar` command (possibly with `ranlib`)
- link shared library handled by `cc -shared`
10.4. distutils.msvccompiler — Microsoft Compiler

This module provides MSVCCompiler, an implementation of the abstract CCompiler class for Microsoft Visual Studio. Typically, extension modules need to be compiled with the same compiler that was used to compile Python. For Python 2.3 and earlier, the compiler was Visual Studio 6. For Python 2.4 and 2.5, the compiler is Visual Studio .NET 2003. The AMD64 and Itanium binaries are created using the Platform SDK.

MSVCCompiler will normally choose the right compiler, linker etc. on its own. To override this choice, the environment variables DISTUTILS_USE_SDK and MSSdk must be both set. MSSdk indicates that the current environment has been setup by the SDK’s SetEnv.Cmd script, or that the environment variables had been registered when the SDK was installed; DISTUTILS_USE_SDK indicates that the distutils user has made an explicit choice to override the compiler selection by MSVCCompiler.
This module provides BorlandCCompiler, an subclass of the abstract CCompiler class for the Borland C++ compiler.
10.6. distutils.cygwincompiler — Cygwin Compiler

This module provides the CygwinCCompiler class, a subclass of UnixCCompiler that handles the Cygwin port of the GNU C compiler to Windows. It also contains the Mingw32CCompiler class which handles the mingw32 port of GCC (same as cygwin in no-cygwin mode).
10.7. `distutils.archive_util` — Archiving utilities

This module provides a few functions for creating archive files, such as tarballs or zipfiles.

`distutils.archive_util.make_archive(base_name, format[, root_dir=None, base_dir=None, verbose=0, dry_run=0])`

Create an archive file (eg. zip or tar). `base_name` is the name of the file to create, minus any format-specific extension; `format` is the archive format: one of zip, tar, gztar, bztar, xztar, or ztar. `root_dir` is a directory that will be the root directory of the archive; ie. we typically chdir into `root_dir` before creating the archive. `base_dir` is the directory where we start archiving from; ie. `base_dir` will be the common prefix of all files and directories in the archive. `root_dir` and `base_dir` both default to the current directory. Returns the name of the archive file.

`distutils.archive_util.make_tarball(base_name, base_dir[, compress='gzip', verbose=0, dry_run=0])`

Create an (optional compressed) archive as a tar file from all files in and under `base_dir`. `compress` must be 'gzip' (the default), 'bzip2', 'xz', 'compress', or None. For the 'compress' method the compression utility named by `compress` must be on the default program search path, so this is probably Unix-specific. The output tar file will be named `base_dir.tar`, possibly plus the appropriate compression extension (.gz, .bz2, .xz or .Z). Return the output filename.

`distutils.archive_util.make_zipfile(base_name,`
Create a zip file from all files in and under *base_dir*. The output zip file will be named *base_name* + .zip. Uses either the `zipfile` Python module (if available) or the InfoZIP zip utility (if installed and found on the default search path). If neither tool is available, raises `DistutilsExecError`. Returns the name of the output zip file.
10.8. **distutils.dep_util** — Dependency checking

This module provides functions for performing simple, timestamp-based dependency of files and groups of files; also, functions based entirely on such timestamp dependency analysis.

**distutils.dep_util.**\newer\((source, target)\)

Return true if \textit{source} exists and is more recently modified than \textit{target}, or if \textit{source} exists and \textit{target} doesn't. Return false if both exist and \textit{target} is the same age or newer than \textit{source}. Raise \texttt{DistutilsFileError} if \textit{source} does not exist.

**distutils.dep_util.**\newer_pairwise\((sources, targets)\)

Walk two filename lists in parallel, testing if each source is newer than its corresponding target. Return a pair of lists \((sources, targets)\) where source is newer than target, according to the semantics of newer().

**distutils.dep_util.**\newer_group\((sources, target[, missing='error'])\)

Return true if \textit{target} is out-of-date with respect to any file listed in \textit{sources}. In other words, if \textit{target} exists and is newer than every file in \textit{sources}, return false; otherwise return true. \texttt{missing} controls what we do when a source file is missing; the default ('error') is to blow up with an \texttt{OSError} from inside \texttt{os.stat()}; if it is 'ignore', we silently drop any missing source files; if it is 'newer', any missing source files make us assume that \textit{target} is out-of-date (this is handy in “dry-run” mode: it'll make you pretend to carry out commands that wouldn’t work because inputs are
missing, but that doesn't matter because you're not actually going to run the commands).
10.9. **distutils.dir_util** — Directory tree operations

This module provides functions for operating on directories and trees of directories.

`distutils.dir_util.mkpath(name[, mode=0o777, verbose=0, dry_run=0])`

Create a directory and any missing ancestor directories. If the directory already exists (or if name is the empty string, which means the current directory, which of course exists), then do nothing. Raise `DistutilsFileError` if unable to create some directory along the way (e.g. some sub-path exists, but is a file rather than a directory). If `verbose` is true, print a one-line summary of each `mkdir` to stdout. Return the list of directories actually created.

`distutils.dir_util.create_tree(base_dir, files[, mode=0o777, verbose=0, dry_run=0])`

Create all the empty directories under `base_dir` needed to put `files` there. `base_dir` is just the name of a directory which doesn’t necessarily exist yet; `files` is a list of filenames to be interpreted relative to `base_dir`. `base_dir` + the directory portion of every file in `files` will be created if it doesn’t already exist. `mode`, `verbose` and `dry_run` flags are as for `mkpath()`.

`distutils.dir_util.copy_tree(src, dst[, preserve_mode=1, preserve_times=1, preserve_symlinks=0, update=0, verbose=0, dry_run=0])`

Copy an entire directory tree `src` to a new location `dst`. Both `src` and
$dst$ must be directory names. If $src$ is not a directory, raise DistutilsFileError. If $dst$ does not exist, it is created with mkpath(). The end result of the copy is that every file in $src$ is copied to $dst$, and directories under $src$ are recursively copied to $dst$. Return the list of files that were copied or might have been copied, using their output name. The return value is unaffected by $update$ or $dry_run$: it is simply the list of all files under $src$, with the names changed to be under $dst$.

$preserve_mode$ and $preserve_times$ are the same as for distutils.file_util.copy_file(); note that they only apply to regular files, not to directories. If $preserve_symlinks$ is true, symlinks will be copied as symlinks (on platforms that support them!); otherwise (the default), the destination of the symlink will be copied. $update$ and $verbose$ are the same as for copy_file().

Files in $src$ that begin with .nfs are skipped (more information on these files is available in answer D2 of the NFS FAQ page).

*Changed in version 3.3.1:* NFS files are ignored.

distutils.dir_util.remove_tree($directory$, $verbose=0, $dry_run=0)$

Recursively remove $directory$ and all files and directories underneath it. Any errors are ignored (apart from being reported to sys.stdout if $verbose$ is true).
10.10. **distutils.file_util** — Single file operations

This module contains some utility functions for operating on individual files.

`distutils.file_util.copy_file(src, dst[, preserve_mode=1, preserve_times=1, update=0, link=None, verbose=0, dry_run=0])`

Copy file `src` to `dst`. If `dst` is a directory, then `src` is copied there with the same name; otherwise, it must be a filename. (If the file exists, it will be ruthlessly clobbered.) If `preserve_mode` is true (the default), the file's mode (type and permission bits, or whatever is analogous on the current platform) is copied. If `preserve_times` is true (the default), the last-modified and last-access times are copied as well. If `update` is true, `src` will only be copied if `dst` does not exist, or if `dst` does exist but is older than `src`.

`link` allows you to make hard links (using `os.link()`) or symbolic links (using `os.symlink()`) instead of copying: set it to 'hard' or 'sym'; if it is None (the default), files are copied. Don't set `link` on systems that don't support it: `copy_file()` doesn't check if hard or symbolic linking is available. It uses `_copy_file_contents()` to copy file contents.

Return a tuple `(dest_name, copied)`: `dest_name` is the actual name of the output file, and `copied` is true if the file was copied (or would have been copied, if `dry_run` true).

`distutils.file_util.move_file(src, dst[, verbose, dry_run])`

Move file `src` to `dst`. If `dst` is a directory, the file will be moved into it.
with the same name; otherwise, src is just renamed to dst. Returns
the new full name of the file.

**Warning:** Handles cross-device moves on Unix using
`copy_file()`. What about other systems?

distutils.file_util.write_file(filename, contents)

Create a file called `filename` and write `contents` (a sequence of
strings without line terminators) to it.
10.11. `distutils.util` — Miscellaneous other utility functions

This module contains other assorted bits and pieces that don’t fit into any other utility module.

`distutils.util.get_platform()`

Return a string that identifies the current platform. This is used mainly to distinguish platform-specific build directories and platform-specific built distributions. Typically includes the OS name and version and the architecture (as supplied by `os.uname()`), although the exact information included depends on the OS; eg. for IRIX the architecture isn’t particularly important (IRIX only runs on SGI hardware), but for Linux the kernel version isn’t particularly important.

Examples of returned values:

- `linux-i586`
- `linux-alpha`
- `solaris-2.6-sun4u`
- `irix-5.3`
- `irix64-6.2`

For non-POSIX platforms, currently just returns `sys.platform`.

For Mac OS X systems the OS version reflects the minimal version on which binaries will run (that is, the value of `MACOSX_DEPLOYMENT_TARGET` during the build of Python), not the OS version of the current system.

For universal binary builds on Mac OS X the architecture value
reflects the universal binary status instead of the architecture of the current processor. For 32-bit universal binaries the architecture is fat, for 64-bit universal binaries the architecture is fat64, and for 4-way universal binaries the architecture is universal. Starting from Python 2.7 and Python 3.2 the architecture fat3 is used for a 3-way universal build (ppc, i386, x86_64) and intel is used for a universal build with the i386 and x86_64 architectures.

Examples of returned values on Mac OS X:

- macosx-10.3-ppc
- macosx-10.3-fat
- macosx-10.5-universal
- macosx-10.6-intel

**distutils.util.convert_path(pathname)**

Return `pathname` as a name that will work on the native filesystem, i.e. split it on ‘/’ and put it back together again using the current directory separator. Needed because filenames in the setup script are always supplied in Unix style, and have to be converted to the local convention before we can actually use them in the filesystem. Raises `ValueError` on non-Unix-ish systems if `pathname` either starts or ends with a slash.

**distutils.util.change_root(new_root, pathname)**

Return `pathname` with `new_root` prepended. If `pathname` is relative, this is equivalent to `os.path.join(new_root, pathname)` Otherwise, it requires making `pathname` relative and then joining the two, which is tricky on DOS/Windows.

**distutils.util.check_environ()**
Ensure that ‘os.environ’ has all the environment variables we guarantee that users can use in config files, command-line options, etc. Currently this includes:

- HOME - user's home directory (Unix only)
- PLAT - description of the current platform, including hardware and OS (see get_platform())

**distutils.util.subst_vars**(*s, local_vars*)

Perform shell/Perl-style variable substitution on *s*. Every occurrence of $ followed by a name is considered a variable, and variable is substituted by the value found in the *local_vars* dictionary, or in *os.environ* if it's not in *local_vars*. *os.environ* is first checked/augmented to guarantee that it contains certain values: see check_environ(). Raise **ValueError** for any variables not found in either *local_vars* or *os.environ*.

Note that this is not a fully-fledged string interpolation function. A valid $variable can consist only of upper and lower case letters, numbers and an underscore. No {} or () style quoting is available.

**distutils.util.split_quoted**(*s*)

Split a string up according to Unix shell-like rules for quotes and backslashes. In short: words are delimited by spaces, as long as those spaces are not escaped by a backslash, or inside a quoted string. Single and double quotes are equivalent, and the quote characters can be backslash-escaped. The backslash is stripped from any two-character escape sequence, leaving only the escaped character. The quote characters are stripped from any quoted string. Returns a list of words.

**distutils.util.execute**(*func, args*, *msg=None, verbose=0,*)
Perform some action that affects the outside world (for instance, writing to the filesystem). Such actions are special because they are disabled by the `dry_run` flag. This method takes care of all that bureaucracy for you; all you have to do is supply the function to call and an argument tuple for it (to embody the "external action" being performed), and an optional message to print.

**distutils.util.strtobool(val)**

Convert a string representation of truth to true (1) or false (0).

True values are y, yes, t, true, on and 1; false values are n, no, f, false, off and 0. Raises `ValueError` if `val` is anything else.

**distutils.util.byte_compile(py_files[, optimize=0, force=0, prefix=None, base_dir=None, verbose=1, dry_run=0, direct=None])**

Byte-compile a collection of Python source files to .pyc files in a __pycache__ subdirectory (see PEP 3147 and PEP 488). `py_files` is a list of files to compile; any files that don't end in .py are silently skipped. `optimize` must be one of the following:

- 0 - don’t optimize
- 1 - normal optimization (like `python -O`)
- 2 - extra optimization (like `python -OO`)

If `force` is true, all files are recompiled regardless of timestamps.

The source filename encoded in each bytecode file defaults to the filenames listed in `py_files`; you can modify these with `prefix` and `basedir`. `prefix` is a string that will be stripped off of each source filename, and `base_dir` is a directory name that will be prepended (after `prefix` is stripped). You can supply either or both (or neither)
of prefix and base_dir, as you wish.

If dry_run is true, doesn't actually do anything that would affect the filesystem.

Byte-compile is either done directly in this interpreter process with the standard py_compile module, or indirectly by writing a temporary script and executing it. Normally, you should let byte_compile() figure out to use direct compilation or not (see the source for details). The direct flag is used by the script generated in indirect mode; unless you know what you're doing, leave it set to None.

Changed in version 3.2.3: Create .pyc files with an import magic tag in their name, in a __pycache__ subdirectory instead of files without tag in the current directory.

distutils.util.rfc822_escape(header)

Return a version of header escaped for inclusion in an RFC 822 header, by ensuring there are 8 spaces space after each newline. Note that it does no other modification of the string.
10.12. `distutils.dist` — The Distribution class

This module provides the `Distribution` class, which represents the module distribution being built/installed/distributed.
10.13. distutils.extension — The Extension class

This module provides the Extension class, used to describe C/C++ extension modules in setup scripts.
10.14. distutils.debug — Distutils debug mode

This module provides the DEBUG flag.
10.15. distutils.errors — Distutils exceptions

Provides exceptions used by the Distutils modules. Note that Distutils modules may raise standard exceptions; in particular, SystemExit is usually raised for errors that are obviously the end-user’s fault (eg. bad command-line arguments).

This module is safe to use in from ... import * mode; it only exports symbols whose names start with Distutils and end with Error.
10.16. **distutils.fancy_getopt** —
Wrapper around the standard getopt module

This module provides a wrapper around the standard `getopt` module that provides the following additional features:

- short and long options are tied together
- options have help strings, so `fancy_getopt()` could potentially create a complete usage summary
- options set attributes of a passed-in object
- boolean options can have “negative aliases” — eg. if `--quiet` is the “negative alias” of `--verbose`, then `--quiet` on the command line sets `verbose` to false.

```python
distutils.fancy_getopt.fancy_getopt(options, negative_opt, object, args)

Wrapper function. `options` is a list of (long_option, short_option, help_string) 3-tuples as described in the constructor for `FancyGetopt`. `negative_opt` should be a dictionary mapping option names to option names, both the key and value should be in the `options` list. `object` is an object which will be used to store values (see the `getopt()` method of the `FancyGetopt` class). `args` is the argument list. Will use `sys.argv[1:]` if you pass None as `args`.
```

```python
distutils.fancy_getopt.wrap_text(text, width)

Wraps `text` to less than `width` wide.
```

```python
class
distutils.fancy_getopt.FancyGetopt([option_table=None])
```
The option_table is a list of 3-tuples: (long_option, short_option, help_string)

If an option takes an argument, its long_option should have '=' appended; short_option should just be a single character, no ':' in any case. short_option should be None if a long_option doesn't have a corresponding short_option. All option tuples must have long options.

The FancyGetopt class provides the following methods:

FancyGetopt.getopt([args=None, object=None])
Parse command-line options in args. Store as attributes on object.

If args is None or not supplied, uses sys.argv[1:]. If object is None or not supplied, creates a new OptionDummy instance, stores option values there, and returns a tuple (args, object). If object is supplied, it is modified in place and getopt() just returns args; in both cases, the returned args is a modified copy of the passed-in args list, which is left untouched.

FancyGetopt.get_option_order()
Returns the list of (option, value) tuples processed by the previous run of getopt() Raises RuntimeError if getopt() hasn't been called yet.

FancyGetopt.generate_help([header=None])
Generate help text (a list of strings, one per suggested line of output) from the option table for this FancyGetopt object.

If supplied, prints the supplied header at the top of the help.
10.17. `distutils.filelist` — The FileList class

This module provides the FileList class, used for poking about the filesystem and building lists of files.
10.18. distutils.log — Simple PEP 282-style logging
10.19. distutils.spawn — Spawn a sub-process

This module provides the spawn() function, a front-end to various platform-specific functions for launching another program in a sub-process. Also provides find_executable() to search the path for a given executable name.
10.20. **distutils.sysconfig** —

System configuration information

The **distutils.sysconfig** module provides access to Python’s low-level configuration information. The specific configuration variables available depend heavily on the platform and configuration. The specific variables depend on the build process for the specific version of Python being run; the variables are those found in the Makefile and configuration header that are installed with Python on Unix systems. The configuration header is called `pyconfig.h` for Python versions starting with 2.2, and `config.h` for earlier versions of Python.

Some additional functions are provided which perform some useful manipulations for other parts of the **distutils** package.

**distutils.sysconfig.PREFIX**

The result of `os.path.normpath(sys.prefix)`.

**distutils.sysconfig.EXEC_PREFIX**

The result of `os.path.normpath(sys.exec_prefix)`.

**distutils.sysconfig.get_config_var(name)**

Return the value of a single variable. This is equivalent to `get_config_vars().get(name)`.

**distutils.sysconfig.get_config_vars(...)**

Return a set of variable definitions. If there are no arguments, this returns a dictionary mapping names of configuration variables to values. If arguments are provided, they should be strings, and the return value will be a sequence giving the associated values. If a
given name does not have a corresponding value, None will be included for that variable.

distutils.sysconfig.get_config_h_filename()
Return the full path name of the configuration header. For Unix, this will be the header generated by the configure script; for other platforms the header will have been supplied directly by the Python source distribution. The file is a platform-specific text file.

distutils.sysconfig.get_makefile_filename()
Return the full path name of the Makefile used to build Python. For Unix, this will be a file generated by the configure script; the meaning for other platforms will vary. The file is a platform-specific text file, if it exists. This function is only useful on POSIX platforms.

distutils.sysconfig.get_python_inc([plat_specific[, prefix]])
Return the directory for either the general or platform-dependent C include files. If plat_specific is true, the platform-dependent include directory is returned; if false or omitted, the platform-independent directory is returned. If prefix is given, it is used as either the prefix instead of PREFIX, or as the exec-prefix instead of EXEC_PREFIX if plat_specific is true.

distutils.sysconfig.get_python_lib([plat_specific[, standard_lib[, prefix]]])
Return the directory for either the general or platform-dependent library installation. If plat_specific is true, the platform-dependent include directory is returned; if false or omitted, the platform-independent directory is returned. If prefix is given, it is used as either the prefix instead of PREFIX, or as the exec-prefix instead of
EXEC_PREFIX if plat_specific is true. If standard_lib is true, the directory for the standard library is returned rather than the directory for the installation of third-party extensions.

The following function is only intended for use within the distutils package.

distutils.sysconfig.customize_compiler(compiler)
Do any platform-specific customization of a distutils.ccompiler.CCompiler instance.

This function is only needed on Unix at this time, but should be called consistently to support forward-compatibility. It inserts the information that varies across Unix flavors and is stored in Python's Makefile. This information includes the selected compiler, compiler and linker options, and the extension used by the linker for shared objects.

This function is even more special-purpose, and should only be used from Python's own build procedures.

distutils.sysconfig.set_python_build()
Inform the distutils.sysconfig module that it is being used as part of the build process for Python. This changes a lot of relative locations for files, allowing them to be located in the build area rather than in an installed Python.
10.21. `distutils.text_file` — The TextFile class

This module provides the `TextFile` class, which gives an interface to text files that (optionally) takes care of stripping comments, ignoring blank lines, and joining lines with backslashes.

```python
class distutils.text_file.TextFile([filename=None, file=None, **options])
```

This class provides a file-like object that takes care of all the things you commonly want to do when processing a text file that has some line-by-line syntax: strip comments (as long as `#` is your comment character), skip blank lines, join adjacent lines by escaping the newline (i.e. backslash at end of line), strip leading and/or trailing whitespace. All of these are optional and independently controllable.

The class provides a `warn()` method so you can generate warning messages that report physical line number, even if the logical line in question spans multiple physical lines. Also provides `unreadline()` for implementing line-at-a-time lookahead.

`TextFile` instances are create with either `filename`, `file`, or both. `RuntimeError` is raised if both are None. `filename` should be a string, and `file` a file object (or something that provides `readline()` and `close()` methods). It is recommended that you supply at least `filename`, so that `TextFile` can include it in warning messages. If `file` is not supplied, `TextFile` creates its own using the `open()` built-in function.
The options are all boolean, and affect the values returned by `readline()`

<table>
<thead>
<tr>
<th>option name</th>
<th>description</th>
<th>default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>strip_comments</code></td>
<td>strip from '//' to end-of-line, as well as any whitespace leading up to the '//'—unless it is escaped by a backslash</td>
<td>true</td>
</tr>
<tr>
<td><code>lstrip_ws</code></td>
<td>strip leading whitespace from each line before returning it</td>
<td>false</td>
</tr>
<tr>
<td><code>rstrip_ws</code></td>
<td>strip trailing whitespace (including line terminator!) from each line before returning it.</td>
<td>true</td>
</tr>
<tr>
<td><code>skip_blanks</code></td>
<td>skip lines that are empty <em>after</em> stripping comments and whitespace. (If both <code>lstrip_ws</code> and <code>rstrip_ws</code> are false, then some lines may consist of solely whitespace: these will <em>not</em> be skipped, even if <code>skip_blanks</code> is true.)</td>
<td>true</td>
</tr>
<tr>
<td><code>join_lines</code></td>
<td>if a backslash is the last non-newline character on a line after stripping comments and whitespace, join the following line to it to form one logical line; if N consecutive lines end with a backslash, then N+1 physical lines will be joined to form one logical line.</td>
<td>false</td>
</tr>
<tr>
<td><code>collapse_join</code></td>
<td>strip leading whitespace from lines that are joined to their predecessor; only matters if <code>join_lines</code> and not <code>lstrip_ws</code></td>
<td>false</td>
</tr>
</tbody>
</table>
Note that since `rstrip_ws` can strip the trailing newline, the semantics of `readline()` must differ from those of the built-in file object’s `readline()` method! In particular, `readline()` returns None for end-of-file: an empty string might just be a blank line (or an all-whitespace line), if `rstrip_ws` is true but `skip_blanks` is not.

**open**(`filename`)

Open a new file `filename`. This overrides any `file` or `filename` constructor arguments.

**close**()

Close the current file and forget everything we know about it (including the filename and the current line number).

**warn**(`msg [, line=None]`)

Print (to stderr) a warning message tied to the current logical line in the current file. If the current logical line in the file spans multiple physical lines, the warning refers to the whole range, such as "lines 3-5". If `line` is supplied, it overrides the current line number; it may be a list or tuple to indicate a range of physical lines, or an integer for a single physical line.

**readline**()

Read and return a single logical line from the current file (or from an internal buffer if lines have previously been “unread” with `unreadline()`). If the `join_lines` option is true, this may involve reading multiple physical lines concatenated into a single string. Updates the current line number, so calling `warn()` after `readline()` emits a warning about the physical line(s) just read. Returns None on end-of-file, since the empty string can occur if `rstrip_ws` is true but `stripblanks` is not.
readlines()
Read and return the list of all logical lines remaining in the current file. This updates the current line number to the last line of the file.

unreadline(line)
Push line (a string) onto an internal buffer that will be checked by future readline() calls. Handy for implementing a parser with line-at-a-time lookahead. Note that lines that are “unread” with unreadline() are not subsequently re-cleansed (whitespace stripped, or whatever) when read with readline(). If multiple calls are made to unreadline() before a call to readline(), the lines will be returned most in most recent first order.
10.22. **distutils.version** — Version number classes
10.23. **distutils.cmd** — Abstract base class for Distutils commands

This module supplies the abstract base class **Command**.

```python
class distutils.cmd.Command(dist)
```

Abstract base class for defining command classes, the “worker bees” of the Distutils. A useful analogy for command classes is to think of them as subroutines with local variables called **options**. The options are declared in `initialize_options()` and defined (given their final values) in `finalize_options()`, both of which must be defined by every command class. The distinction between the two is necessary because option values might come from the outside world (command line, config file, ...), and any options dependent on other options must be computed after these outside influences have been processed — hence `finalize_options()`. The body of the subroutine, where it does all its work based on the values of its options, is the **run()** method, which must also be implemented by every command class.

The class constructor takes a single argument **dist**, a **Distribution** instance.
10.24. Creating a new Distutils command

This section outlines the steps to create a new Distutils command.

A new command lives in a module in the distutils.command package. There is a sample template in that directory called command_template. Copy this file to a new module with the same name as the new command you’re implementing. This module should implement a class with the same name as the module (and the command). So, for instance, to create the command peel_banana (so that users can run setup.py peel_banana), you’d copy command_template to distutils/command/peel_banana.py, then edit it so that it’s implementing the class peel_banana, a subclass of distutils.cmd.Command.

Subclasses of Command must define the following methods.

Command.initialize_options()

Set default values for all the options that this command supports. Note that these defaults may be overridden by other commands, by the setup script, by config files, or by the command-line. Thus, this is not the place to code dependencies between options; generally, initialize_options() implementations are just a bunch of self.foo = None assignments.

Command.finalize_options()

Set final values for all the options that this command supports. This is always called as late as possible, ie. after any option assignments from the command-line or from other commands have been done. Thus, this is the place to code option dependencies: if foo depends on bar, then it is safe to set foo from bar as long as
foo still has the same value it was assigned in initialize_options().

Command.run()

A command's raison d'être: carry out the action it exists to perform, controlled by the options initialized in initialize_options(), customized by other commands, the setup script, the command-line, and config files, and finalized in finalize_options(). All terminal output and filesystem interaction should be done by run().

Command.sub_commands

sub_commands formalizes the notion of a “family” of commands, e.g. install as the parent with sub-commands install_lib, install_headers, etc. The parent of a family of commands defines sub_commands as a class attribute; it's a list of 2-tuples (command_name, predicate), with command_name a string and predicate a function, a string or None. predicate is a method of the parent command that determines whether the corresponding command is applicable in the current situation. (E.g. install_headers is only applicable if we have any C header files to install.) If predicate is None, that command is always applicable.

sub_commands is usually defined at the end of a class, because predicates can be methods of the class, so they must already have been defined. The canonical example is the install command.
10.25. distutils.command — Individual Distutils commands
10.26. `distutils.command.bdist` —
Build a binary installer
10.27. distutils.command.bdist_packager
— Abstract base class for packagers
10.28.
distutils.command.bdist_dumb —
Build a “dumb” installer
10.29.
```
distutils.command.bdist_msi —
Build a Microsoft Installer binary package
```

```python
class distutils.command.bdist_msi.bdist_msi

    Builds a Windows Installer (.msi) binary package.
```

In most cases, the `bdist_msi` installer is a better choice than the `bdist_wininst` installer, because it provides better support for Win64 platforms, allows administrators to perform non-interactive installations, and allows installation through group policies.
10.30. 
**distutils.command.bdist_rpm** — Build a binary distribution as a Redhat RPM and SRPM
10.31.
distutils.command.bdist_wininst
— Build a Windows installer
10.32. `distutils.command.sdist` — Build a source distribution
10.33. `distutils.command.build` — Build all files of a package
10.34.
\texttt{distutils.command.build\_clib} —
Build any C libraries in a package
10.35.
\texttt{distutils.command.build_ext} —
Build any extensions in a package
10.36. `distutils.command.build_py` — Build the `.py/.pyc` files of a package

```python
class distutils.command.build_py.build_py

class distutils.command.build_py.build_py_2to3
    Alternative implementation of `build_py` which also runs the 2to3 conversion library on each `.py` file that is going to be installed. To use this in a `setup.py` file for a distribution that is designed to run with both Python 2.x and 3.x, add:

```python
try:
    from distutils.command.build_py import build_py
except ImportError:
    from distutils.command.build_py import build_py

```

to your `setup.py`, and later:

```python
cmdclass = {'build_py': build_py}
```

to the invocation of `setup()`.
10.37.  
`distutils.command.build_scripts`  
— Build the scripts of a package
10.38. distutils.command.clean — Clean a package build area

This command removes the temporary files created by build and its subcommands, like intermediary compiled object files. With the --all option, the complete build directory will be removed.

Extension modules built in place will not be cleaned, as they are not in the build directory.
10.39. distutils.command.config —
Perform package configuration
10.40. distutils.command.install
— Install a package
distutils.command.install_data
— Install data files from a package
10.42. `distutils.command.install_header` — Install C/C++ header files from a package
10.43.

distutils.command.install_lib —
Install library files from a package
10.44.  
distutils.command.install_script  
— Install script files from a package
10.45. `distutils.command.register` — Register a module with the Python Package Index

The register command registers the package with the Python Package Index. This is described in more detail in PEP 301.
10.46. `distutils.command.check` — Check the meta-data of a package

The check command performs some tests on the meta-data of a package. For example, it verifies that all required meta-data are provided as the arguments passed to the `setup()` function.
Installing Python Modules (Legacy version)

Author: Greg Ward

This document describes the Python Distribution Utilities ("Distutils") from the end-user's point-of-view, describing how to extend the capabilities of a standard Python installation by building and installing third-party Python modules and extensions.

Note: This guide only covers the basic tools for building and distributing extensions that are provided as part of this version of Python. Third party tools offer easier to use and more secure alternatives. Refer to the quick recommendations section in the Python Packaging User Guide for more information.
Introduction

Although Python’s extensive standard library covers many programming needs, there often comes a time when you need to add some new functionality to your Python installation in the form of third-party modules. This might be necessary to support your own programming, or to support an application that you want to use and that happens to be written in Python.

In the past, there has been little support for adding third-party modules to an existing Python installation. With the introduction of the Python Distribution Utilities (Distutils for short) in Python 2.0, this changed.

This document is aimed primarily at the people who need to install third-party Python modules: end-users and system administrators who just need to get some Python application running, and existing Python programmers who want to add some new goodies to their toolbox. You don’t need to know Python to read this document; there will be some brief forays into using Python’s interactive mode to explore your installation, but that’s it. If you’re looking for information on how to distribute your own Python modules so that others may use them, see the Distributing Python Modules (Legacy version) manual. Debugging the setup script may also be of interest.

Best case: trivial installation

In the best case, someone will have prepared a special version of the module distribution you want to install that is targeted specifically at your platform and is installed just like any other software on your platform. For example, the module developer might make an executable installer available for Windows users, an RPM package for
users of RPM-based Linux systems (Red Hat, SuSE, Mandrake, and many others), a Debian package for users of Debian-based Linux systems, and so forth.

In that case, you would download the installer appropriate to your platform and do the obvious thing with it: run it if it's an executable installer, rpm --install it if it's an RPM, etc. You don't need to run Python or a setup script, you don't need to compile anything—you might not even need to read any instructions (although it's always a good idea to do so anyway).

Of course, things will not always be that easy. You might be interested in a module distribution that doesn't have an easy-to-use installer for your platform. In that case, you'll have to start with the source distribution released by the module's author/maintainer. Installing from a source distribution is not too hard, as long as the modules are packaged in the standard way. The bulk of this document is about building and installing modules from standard source distributions.

**The new standard: Distutils**

If you download a module source distribution, you can tell pretty quickly if it was packaged and distributed in the standard way, i.e. using the Distutils. First, the distribution's name and version number will be featured prominently in the name of the downloaded archive, e.g. foo-1.0.tar.gz or widget-0.9.7.zip. Next, the archive will unpack into a similarly-named directory: foo-1.0 or widget-0.9.7. Additionally, the distribution will contain a setup script setup.py, and a file named README.txt or possibly just README, which should explain that building and installing the module distribution is a simple matter of running one command from a terminal:
python setup.py install

For Windows, this command should be run from a command prompt window (Start • Accessories):

setup.py install

If all these things are true, then you already know how to build and install the modules you’ve just downloaded: Run the command above. Unless you need to install things in a non-standard way or customize the build process, you don’t really need this manual. Or rather, the above command is everything you need to get out of this manual.
Standard Build and Install

As described in section *The new standard: Distutils*, building and installing a module distribution using the Distutils is usually one simple command to run from a terminal:

```
python setup.py install
```

Platform variations

You should always run the setup command from the distribution root directory, i.e. the top-level subdirectory that the module source distribution unpacks into. For example, if you've just downloaded a module source distribution `foo-1.0.tar.gz` onto a Unix system, the normal thing to do is:

```
gunzip -c foo-1.0.tar.gz | tar xf -  # unpacks into directory foo-1.0
cd foo-1.0
python setup.py install
```

On Windows, you'd probably download `foo-1.0.zip`. If you downloaded the archive file to `C:\Temp`, then it would unpack into `C:\Temp\foo-1.0`; you can use either an archive manipulator with a graphical user interface (such as WinZip) or a command-line tool (such as `unzip` or `pkunzip`) to unpack the archive. Then, open a command prompt window and run:

```
cd c:\Temp\foo-1.0
python setup.py install
```
Splitting the job up

Running `setup.py install` builds and installs all modules in one run. If you prefer to work incrementally—especially useful if you want to customize the build process, or if things are going wrong—you can use the setup script to do one thing at a time. This is particularly helpful when the build and install will be done by different users—for example, you might want to build a module distribution and hand it off to a system administrator for installation (or do it yourself, with super-user privileges).

For example, you can build everything in one step, and then install everything in a second step, by invoking the setup script twice:

```python
python setup.py build
python setup.py install
```

If you do this, you will notice that running the `install` command first runs the `build` command, which—in this case—quickly notices that it has nothing to do, since everything in the build directory is up-to-date.

You may not need this ability to break things down often if all you do is install modules downloaded off the ‘net, but it’s very handy for more advanced tasks. If you get into distributing your own Python modules and extensions, you’ll run lots of individual Distutils commands on their own.

How building works

As implied above, the `build` command is responsible for putting the files to install into a `build directory`. By default, this is `build` under the
distribution root; if you’re excessively concerned with speed, or want to keep the source tree pristine, you can change the build directory with the --build-base option. For example:

```
python setup.py build --build-base=/path/to/pybuild/
```

(Or you could do this permanently with a directive in your system or personal Distutils configuration file; see section Distutils Configuration Files.) Normally, this isn’t necessary.

The default layout for the build tree is as follows:

```
--- build/ --- lib/
or
--- build/ --- lib.<plat>/
temp.<plat>/
```

where <plat> expands to a brief description of the current OS/hardware platform and Python version. The first form, with just a lib directory, is used for “pure module distributions”—that is, module distributions that include only pure Python modules. If a module distribution contains any extensions (modules written in C/C++), then the second form, with two <plat> directories, is used. In that case, the temp.<plat> directory holds temporary files generated by the compile/link process that don’t actually get installed. In either case, the lib (or lib.<plat>) directory contains all Python modules (pure Python and extensions) that will be installed.

In the future, more directories will be added to handle Python scripts, documentation, binary executables, and whatever else is needed to handle the job of installing Python modules and applications.
How installation works

After the build command runs (whether you run it explicitly, or the install command does it for you), the work of the install command is relatively simple: all it has to do is copy everything under build/lib (or build/lib.plat) to your chosen installation directory.

If you don't choose an installation directory—i.e., if you just run setup.py install—then the install command installs to the standard location for third-party Python modules. This location varies by platform and by how you built/installed Python itself. On Unix (and Mac OS X, which is also Unix-based), it also depends on whether the module distribution being installed is pure Python or contains extensions (“non-pure”):

<table>
<thead>
<tr>
<th>Platform</th>
<th>Standard installation location</th>
<th>Default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unix (pure)</td>
<td>prefix/lib/pythonX.Y/site-packages</td>
<td>/usr/local/lib/packages</td>
</tr>
<tr>
<td>Unix (non-pure)</td>
<td>exec-prefix/lib/pythonX.Y/site-packages</td>
<td>/usr/local/lib/packages</td>
</tr>
<tr>
<td>Windows</td>
<td>prefix\Lib\site-packages</td>
<td>C:\PythonXY\Lib</td>
</tr>
</tbody>
</table>

Notes:

1. Most Linux distributions include Python as a standard part of the system, so prefix and exec-prefix are usually both /usr on Linux. If you build Python yourself on Linux (or any Unix-like system), the default prefix and exec-prefix are /usr/local.
2. The default installation directory on Windows was C:\Program Files\Python under Python 1.6a1, 1.5.2, and earlier.
prefix and exec-prefix stand for the directories that Python is installed to, and where it finds its libraries at run-time. They are always the same under Windows, and very often the same under Unix and Mac OS X. You can find out what your Python installation uses for prefix and exec-prefix by running Python in interactive mode and typing a few simple commands. Under Unix, just type python at the shell prompt. Under Windows, choose Start ➤ Programs ➤ Python X.Y ➤ Python (command line). Once the interpreter is started, you type Python code at the prompt. For example, on my Linux system, I type the three Python statements shown below, and get the output as shown, to find out my prefix and exec-prefix:

```
Python 2.4 (#26, Aug 7 2004, 17:19:02)
Type "help", "copyright", "credits" or "license" for more information.
>>> import sys
>>> sys.prefix
'/usr'
>>> sys.exec_prefix
'/usr'
```

A few other placeholders are used in this document: X.Y stands for the version of Python, for example 3.2; abiflags will be replaced by the value of sys.abiflags or the empty string for platforms which don’t define ABI flags; distname will be replaced by the name of the module distribution being installed. Dots and capitalization are important in the paths; for example, a value that uses python3.2 on UNIX will typically use Python32 on Windows.

If you don’t want to install modules to the standard location, or if you don’t have permission to write there, then you need to read about alternate installations in section Alternate Installation. If you want to customize your installation directories more heavily, see section
Custom Installation on custom installations.
Alternate Installation

Often, it is necessary or desirable to install modules to a location other than the standard location for third-party Python modules. For example, on a Unix system you might not have permission to write to the standard third-party module directory. Or you might wish to try out a module before making it a standard part of your local Python installation. This is especially true when upgrading a distribution already present: you want to make sure your existing base of scripts still works with the new version before actually upgrading.

The Distutils install command is designed to make installing module distributions to an alternate location simple and painless. The basic idea is that you supply a base directory for the installation, and the install command picks a set of directories (called an installation scheme) under this base directory in which to install files. The details differ across platforms, so read whichever of the following sections applies to you.

Note that the various alternate installation schemes are mutually exclusive: you can pass --user, or --home, or --prefix and --exec-prefix, or --install-base and --install-platbase, but you can’t mix from these groups.

Alternate installation: the user scheme

This scheme is designed to be the most convenient solution for users that don’t have write permission to the global site-packages directory or don’t want to install into it. It is enabled with a simple option:

```
python setup.py install --user
```
Files will be installed into subdirectories of `site.USER_BASE` (written as `userbase` hereafter). This scheme installs pure Python modules and extension modules in the same location (also known as `site.USER_SITE`). Here are the values for UNIX, including Mac OS X:

<table>
<thead>
<tr>
<th>Type of file</th>
<th>Installation directory</th>
</tr>
</thead>
<tbody>
<tr>
<td>modules</td>
<td><code>userbase/lib/pythonX.Y/site-packages</code></td>
</tr>
<tr>
<td>scripts</td>
<td><code>userbase/bin</code></td>
</tr>
<tr>
<td>data</td>
<td><code>userbase</code></td>
</tr>
<tr>
<td>C headers</td>
<td><code>userbase/include/pythonX.Yabiflags/distname</code></td>
</tr>
</tbody>
</table>

And here are the values used on Windows:

<table>
<thead>
<tr>
<th>Type of file</th>
<th>Installation directory</th>
</tr>
</thead>
<tbody>
<tr>
<td>modules</td>
<td><code>userbase\PythonXY\site-packages</code></td>
</tr>
<tr>
<td>scripts</td>
<td><code>userbase\PythonXY\Scripts</code></td>
</tr>
<tr>
<td>data</td>
<td><code>userbase</code></td>
</tr>
<tr>
<td>C headers</td>
<td><code>userbase\PythonXY\Include\distname</code></td>
</tr>
</tbody>
</table>

The advantage of using this scheme compared to the other ones described below is that the user site-packages directory is under normal conditions always included in `sys.path` (see `site` for more information), which means that there is no additional step to perform after running the `setup.py` script to finalize the installation.

The `build_ext` command also has a `--user` option to add `userbase/include` to the compiler search path for header files and
userbase/lib to the compiler search path for libraries as well as to the runtime search path for shared C libraries (rpath).

Alternate installation: the home scheme

The idea behind the “home scheme” is that you build and maintain a personal stash of Python modules. This scheme’s name is derived from the idea of a “home” directory on Unix, since it’s not unusual for a Unix user to make their home directory have a layout similar to /usr/ or /usr/local/. This scheme can be used by anyone, regardless of the operating system they are installing for.

Installing a new module distribution is as simple as

```
python setup.py install --home=<dir>
```

where you can supply any directory you like for the --home option. On Unix, lazy typists can just type a tilde (~); the install command will expand this to your home directory:

```
python setup.py install --home=~
```

To make Python find the distributions installed with this scheme, you may have to modify Python’s search path or edit sitecustomize (see site) to call site.addsitedir() or edit sys.path.

The --home option defines the installation base directory. Files are installed to the following directories under the installation base as follows:

<table>
<thead>
<tr>
<th>Type of file</th>
<th>Installation directory</th>
</tr>
</thead>
<tbody>
<tr>
<td>modules</td>
<td>home/lib/python</td>
</tr>
</tbody>
</table>
(Mentally replace slashes with backslashes if you're on Windows.)

## Alternate installation: Unix (the prefix scheme)

The “prefix scheme” is useful when you wish to use one Python installation to perform the build/install (i.e., to run the setup script), but install modules into the third-party module directory of a different Python installation (or something that looks like a different Python installation). If this sounds a trifle unusual, it is—that’s why the user and home schemes come before. However, there are at least two known cases where the prefix scheme will be useful.

First, consider that many Linux distributions put Python in `/usr`, rather than the more traditional `/usr/local`. This is entirely appropriate, since in those cases Python is part of “the system” rather than a local add-on. However, if you are installing Python modules from source, you probably want them to go in `/usr/local/lib/python2.X` rather than `/usr/lib/python2.X`. This can be done with

```bash
/usr/bin/python setup.py install --prefix=/usr/local
```

Another possibility is a network filesystem where the name used to write to a remote directory is different from the name used to read it: for example, the Python interpreter accessed as `/usr/local/bin/python` might search for modules in `/usr/local/lib/python2.X`, but those modules would have to be
installed to, say, /mnt/@server/export/lib/python2.X. This could be done with

```shell
/usr/local/bin/python setup.py install --prefix=/mnt/@server/export
```

In either case, the --prefix option defines the installation base, and the --exec-prefix option defines the platform-specific installation base, which is used for platform-specific files. (Currently, this just means non-pure module distributions, but could be expanded to C libraries, binary executables, etc.) If --exec-prefix is not supplied, it defaults to --prefix. Files are installed as follows:

<table>
<thead>
<tr>
<th>Type of file</th>
<th>Installation directory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Python modules</td>
<td>prefix/lib/pythonX.Y/site-packages</td>
</tr>
<tr>
<td>extension modules</td>
<td>exec-prefix/lib/pythonX.Y/site-packages</td>
</tr>
<tr>
<td>scripts</td>
<td>prefix/bin</td>
</tr>
<tr>
<td>data</td>
<td>prefix</td>
</tr>
<tr>
<td>C headers</td>
<td>prefix/include/pythonX.Yabiflags/distname</td>
</tr>
</tbody>
</table>

There is no requirement that --prefix or --exec-prefix actually point to an alternate Python installation; if the directories listed above do not already exist, they are created at installation time.

Incidentally, the real reason the prefix scheme is important is simply that a standard Unix installation uses the prefix scheme, but with --prefix and --exec-prefix supplied by Python itself as sys.prefix and sys.exec_prefix. Thus, you might think you'll
never use the prefix scheme, but every time you run python setup.py install without any other options, you’re using it.

Note that installing extensions to an alternate Python installation has no effect on how those extensions are built: in particular, the Python header files (Python.h and friends) installed with the Python interpreter used to run the setup script will be used in compiling extensions. It is your responsibility to ensure that the interpreter used to run extensions installed in this way is compatible with the interpreter used to build them. The best way to do this is to ensure that the two interpreters are the same version of Python (possibly different builds, or possibly copies of the same build). (Of course, if your --prefix and --exec-prefix don’t even point to an alternate Python installation, this is immaterial.)

Alternate installation: Windows (the prefix scheme)

Windows has no concept of a user’s home directory, and since the standard Python installation under Windows is simpler than under Unix, the --prefix option has traditionally been used to install additional packages in separate locations on Windows.

```bash
python setup.py install --prefix="\Temp\Python"
```

to install modules to the \Temp\Python directory on the current drive.

The installation base is defined by the --prefix option; the --exec-prefix option is not supported under Windows, which means that pure Python modules and extension modules are installed into the same location. Files are installed as follows:
<table>
<thead>
<tr>
<th>Type of file</th>
<th>Installation directory</th>
</tr>
</thead>
<tbody>
<tr>
<td>modules</td>
<td><code>prefix\Lib\site-packages</code></td>
</tr>
<tr>
<td>scripts</td>
<td><code>prefix\Scripts</code></td>
</tr>
<tr>
<td>data</td>
<td><code>prefix</code></td>
</tr>
<tr>
<td>C headers</td>
<td><code>prefix\Include\distname</code></td>
</tr>
</tbody>
</table>
Custom Installation

Sometimes, the alternate installation schemes described in section Alternate Installation just don’t do what you want. You might want to tweak just one or two directories while keeping everything under the same base directory, or you might want to completely redefine the installation scheme. In either case, you’re creating a custom installation scheme.

To create a custom installation scheme, you start with one of the alternate schemes and override some of the installation directories used for the various types of files, using these options:

<table>
<thead>
<tr>
<th>Type of file</th>
<th>Override option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Python modules</td>
<td>--install-purelib</td>
</tr>
<tr>
<td>extension modules</td>
<td>--install-platlib</td>
</tr>
<tr>
<td>all modules</td>
<td>--install-lib</td>
</tr>
<tr>
<td>scripts</td>
<td>--install-scripts</td>
</tr>
<tr>
<td>data</td>
<td>--install-data</td>
</tr>
<tr>
<td>C headers</td>
<td>--install-headers</td>
</tr>
</tbody>
</table>

These override options can be relative, absolute, or explicitly defined in terms of one of the installation base directories. (There are two installation base directories, and they are normally the same—they only differ when you use the Unix “prefix scheme” and supply different --prefix and --exec-prefix options; using --install-lib will
override values computed or given for --install-purelib and --install-platlib, and is recommended for schemes that don’t make a difference between Python and extension modules.)

For example, say you’re installing a module distribution to your home directory under Unix—but you want scripts to go in ~/scripts rather than ~/bin. As you might expect, you can override this directory with the --install-scripts option; in this case, it makes most sense to supply a relative path, which will be interpreted relative to the installation base directory (your home directory, in this case):

```bash
python setup.py install --home=~ --install-scripts=scripts
```

Another Unix example: suppose your Python installation was built and installed with a prefix of /usr/local/python, so under a standard installation scripts will wind up in /usr/local/python/bin. If you want them in /usr/local/bin instead, you would supply this absolute directory for the --install-scripts option:

```bash
python setup.py install --install-scripts=/usr/local/bin
```

(This performs an installation using the “prefix scheme,” where the prefix is whatever your Python interpreter was installed with—/usr/local/python in this case.)

If you maintain Python on Windows, you might want third-party modules to live in a subdirectory of prefix, rather than right in prefix itself. This is almost as easy as customizing the script installation directory —you just have to remember that there are two types of modules to worry about, Python and extension modules, which can conveniently be both controlled by one option:
python setup.py install --install-lib=Site

The specified installation directory is relative to prefix. Of course, you also have to ensure that this directory is in Python’s module search path, such as by putting a .pth file in a site directory (see site). See section Modifying Python’s Search Path to find out how to modify Python’s search path.

If you want to define an entire installation scheme, you just have to supply all of the installation directory options. The recommended way to do this is to supply relative paths; for example, if you want to maintain all Python module-related files under python in your home directory, and you want a separate directory for each platform that you use your home directory from, you might define the following installation scheme:

```bash
python setup.py install --home=~ \
   --install-purelib=python/lib \
   --install-platlib=python/lib \
   --install-scripts=python/scripts \
   --install-data=python/data
```

or, equivalently,

```bash
python setup.py install --home=~/.python \
   --install-purelib=lib \
   --install-platlib='lib.$PLAT' \
   --install-scripts=scripts \
   --install-data=data
```

$PLAT is not (necessarily) an environment variable—it will be expanded by the Distutils as it parses your command line options, just
as it does when parsing your configuration file(s).

Obviously, specifying the entire installation scheme every time you install a new module distribution would be very tedious. Thus, you can put these options into your Distutils config file (see section Distutils Configuration Files):

```
[install]
install-base=$HOME
install-purelib=python/lib
install-platlib=python/lib.$PLAT
install-scripts=python/scripts
install-data=python/data
```

or, equivalently,

```
[install]
install-base=$HOME/python
install-purelib=lib
install-platlib=lib.$PLAT
install-scripts=scripts
install-data=data
```

Note that these two are not equivalent if you supply a different installation base directory when you run the setup script. For example,

```
python setup.py install --install-base=/tmp
```

would install pure modules to /tmp/python/lib in the first case, and to /tmp/lib in the second case. (For the second case, you probably want to supply an installation base of /tmp/python.)

You probably noticed the use of $HOME and $PLAT in the sample configuration file input. These are Distutils configuration variables,
which bear a strong resemblance to environment variables. In fact, you can use environment variables in config files on platforms that have such a notion but the Distutils additionally define a few extra variables that may not be in your environment, such as $PLAT$. (And of course, on systems that don’t have environment variables, such as Mac OS 9, the configuration variables supplied by the Distutils are the only ones you can use.) See section Distutils Configuration Files for details.

**Note:** When a virtual environment is activated, any options that change the installation path will be ignored from all distutils configuration files to prevent inadvertently installing projects outside of the virtual environment.

### Modifying Python’s Search Path

When the Python interpreter executes an `import` statement, it searches for both Python code and extension modules along a search path. A default value for the path is configured into the Python binary when the interpreter is built. You can determine the path by importing the `sys` module and printing the value of `sys.path`.

```
$ python
[GCC 2.96 20000731 (Red Hat Linux 7.3 2.96-112)] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>> import sys
>>> sys.path
```
The null string in `sys.path` represents the current working directory.

The expected convention for locally installed packages is to put them in the `./site-packages/` directory, but you may want to install Python modules into some arbitrary directory. For example, your site may have a convention of keeping all software related to the web server under `/www`. Add-on Python modules might then belong in `/www/python`, and in order to import them, this directory must be added to `sys.path`. There are several different ways to add the directory.

The most convenient way is to add a path configuration file to a directory that's already on Python's path, usually to the `./site-packages/` directory. Path configuration files have an extension of `.pth`, and each line must contain a single path that will be appended to `sys.path`. (Because the new paths are appended to `sys.path`, modules in the added directories will not override standard modules. This means you can't use this mechanism for installing fixed versions of standard modules.)

Paths can be absolute or relative, in which case they're relative to the directory containing the `.pth` file. See the documentation of the `site` module for more information.

A slightly less convenient way is to edit the `site.py` file in Python's standard library, and modify `sys.path`. `site.py` is automatically imported when the Python interpreter is executed, unless the `-S` switch is supplied to suppress this behaviour. So you could simply edit `site.py` and add two lines to it:

```python
import sys
sys.path.append('/www/python/')
```
However, if you reinstall the same major version of Python (perhaps when upgrading from 2.2 to 2.2.2, for example) site.py will be overwritten by the stock version. You’d have to remember that it was modified and save a copy before doing the installation.

There are two environment variables that can modify sys.path. PYTHONHOME sets an alternate value for the prefix of the Python installation. For example, if PYTHONHOME is set to /www/python, the search path will be set to ['','/www/python/lib/pythonX.Y/','/www/python/lib/pythonX.Y/plat-linux2',...].

The PYTHONPATH variable can be set to a list of paths that will be added to the beginning of sys.path. For example, if PYTHONPATH is set to /www/python:/opt/py, the search path will begin with ['/www/python', '/opt/py']. (Note that directories must exist in order to be added to sys.path; the site module removes paths that don’t exist.)

Finally, sys.path is just a regular Python list, so any Python application can modify it by adding or removing entries.
Distutils Configuration Files

As mentioned above, you can use Distutils configuration files to record personal or site preferences for any Distutils options. That is, any option to any command can be stored in one of two or three (depending on your platform) configuration files, which will be consulted before the command-line is parsed. This means that configuration files will override default values, and the command-line will in turn override configuration files. Furthermore, if multiple configuration files apply, values from “earlier” files are overridden by “later” files.

Location and names of config files

The names and locations of the configuration files vary slightly across platforms. On Unix and Mac OS X, the three configuration files (in the order they are processed) are:

<table>
<thead>
<tr>
<th>Type of file</th>
<th>Location and filename</th>
</tr>
</thead>
<tbody>
<tr>
<td>system</td>
<td><code>prefix/lib/pythonver/distutils/distutils.cfg</code></td>
</tr>
<tr>
<td>personal</td>
<td><code>$HOME/.pydistutils.cfg</code></td>
</tr>
<tr>
<td>local</td>
<td><code>setup.cfg</code></td>
</tr>
</tbody>
</table>

And on Windows, the configuration files are:

<table>
<thead>
<tr>
<th>Type of file</th>
<th>Location and filename</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>system</td>
<td><code>prefix\Lib\distutils\distutils.cfg</code></td>
<td>(4)</td>
</tr>
<tr>
<td>personal</td>
<td><code>%HOME%\pydistutils.cfg</code></td>
<td>(5)</td>
</tr>
</tbody>
</table>
On all platforms, the “personal” file can be temporarily disabled by passing the --no-user-cfg option.

Notes:

1. Strictly speaking, the system-wide configuration file lives in the directory where the Distutils are installed; under Python 1.6 and later on Unix, this is as shown. For Python 1.5.2, the Distutils will normally be installed to prefix/lib/python1.5/site-packages/distutils, so the system configuration file should be put there under Python 1.5.2.

2. On Unix, if the HOME environment variable is not defined, the user’s home directory will be determined with the getpwuid() function from the standard pwd module. This is done by the os.path.expanduser() function used by Distutils.

3. I.e., in the current directory (usually the location of the setup script).

4. (See also note (1).) Under Python 1.6 and later, Python’s default “installation prefix” is C:\Python, so the system configuration file is normally C:\Python\Lib\distutils\distutils.cfg. Under Python 1.5.2, the default prefix was C:\Program Files\Python, and the Distutils were not part of the standard library—so the system configuration file would be C:\Program Files\Python\distutils\distutils.cfg in a standard Python 1.5.2 installation under Windows.

5. On Windows, if the HOME environment variable is not defined, USERPROFILE then HOMEDRIVE and HOMEPATH will be tried. This is done by the os.path.expanduser() function used by Distutils.

Syntax of config files
The Distutils configuration files all have the same syntax. The config files are grouped into sections. There is one section for each Distutils command, plus a global section for global options that affect every command. Each section consists of one option per line, specified as option=value.

For example, the following is a complete config file that just forces all commands to run quietly by default:

```
[global]
verbose=0
```

If this is installed as the system config file, it will affect all processing of any Python module distribution by any user on the current system. If it is installed as your personal config file (on systems that support them), it will affect only module distributions processed by you. And if it is used as the setup.cfg for a particular module distribution, it affects only that distribution.

You could override the default “build base” directory and make the **build** commands always forcibly rebuild all files with the following:

```
[build]
build-base=blib
force=1
```

which corresponds to the command-line arguments

```
python setup.py build --build-base=blib --force
```

except that including the **build** command on the command-line means that command will be run. Including a particular command in config files has no such implication; it only means that if the command is run,
the options in the config file will apply. (Or if other commands that derive values from it are run, they will use the values in the config file.)

You can find out the complete list of options for any command using the `--help` option, e.g.:

```
python setup.py build --help
```

and you can find out the complete list of global options by using `--help` without a command:

```
python setup.py --help
```

See also the “Reference” section of the “Distributing Python Modules” manual.
Building Extensions: Tips and Tricks

Whenever possible, the Dist-utils try to use the configuration information made available by the Python interpreter used to run the setup.py script. For example, the same compiler and linker flags used to compile Python will also be used for compiling extensions. Usually this will work well, but in complicated situations this might be inappropriate. This section discusses how to override the usual Dist-utils behaviour.

Tweaking compiler/linker flags

Compiling a Python extension written in C or C++ will sometimes require specifying custom flags for the compiler and linker in order to use a particular library or produce a special kind of object code. This is especially true if the extension hasn't been tested on your platform, or if you're trying to cross-compile Python.

In the most general case, the extension author might have foreseen that compiling the extensions would be complicated, and provided a Setup file for you to edit. This will likely only be done if the module distribution contains many separate extension modules, or if they often require elaborate sets of compiler flags in order to work.

A Setup file, if present, is parsed in order to get a list of extensions to build. Each line in a Setup describes a single module. Lines have the following structure:

```
module ... [sourcefile ...] [cpparg ...] [library ..
```

Let's examine each of the fields in turn.
- **module** is the name of the extension module to be built, and should be a valid Python identifier. You can't just change this in order to rename a module (edits to the source code would also be needed), so this should be left alone.
- **sourcefile** is anything that's likely to be a source code file, at least judging by the filename. Filenames ending in `.c` are assumed to be written in C, filenames ending in `.C`, `.cc`, and `.c++` are assumed to be C++, and filenames ending in `.m` or `.mm` are assumed to be in Objective C.
- **cpparg** is an argument for the C preprocessor, and is anything starting with `-I`, `-D`, `-U` or `-C`.
- **library** is anything ending in `.a` or beginning with `-l` or `-L`.

If a particular platform requires a special library on your platform, you can add it by editing the Setup file and running `python setup.py build`. For example, if the module defined by the line

```
foo foomodule.c
```

must be linked with the math library `libm.a` on your platform, simply add `-lm` to the line:

```
foo foomodule.c -lm
```

Arbitrary switches intended for the compiler or the linker can be supplied with the `-Xcompiler arg` and `-Xlinker arg` options:

```
foo foomodule.c -Xcompiler -o32 -Xlinker -shared -lm
```

The next option after `-Xcompiler` and `-Xlinker` will be appended to the proper command line, so in the above example the compiler will be passed the `-o32` option, and the linker will be passed `-shared`. If
a compiler option requires an argument, you’ll have to supply multiple
-Xcompiler options; for example, to pass -x c++ the Setup file
would have to contain -Xcompiler -x -Xcompiler c++.

Compiler flags can also be supplied through setting the CFLAGS
environment variable. If set, the contents of CFLAGS will be added to
the compiler flags specified in the Setup file.

Using non-Microsoft compilers on Windows
Borland/CodeGear C++

This subsection describes the necessary steps to use Distutils with the
Borland C++ compiler version 5.5. First you have to know that
Borland’s object file format (OMF) is different from the format used by
the Python version you can download from the Python or ActiveState
Web site. (Python is built with Microsoft Visual C++, which uses COFF
as the object file format.) For this reason you have to convert Python's
library python25.lib into the Borland format. You can do this as
follows:

```
coff2omf python25.lib python25_bcpp.lib
```

The coff2omf program comes with the Borland compiler. The file
python25.lib is in the Libs directory of your Python installation. If
your extension uses other libraries (zlib, ...) you have to convert them
too.

The converted files have to reside in the same directories as the
normal libraries.

How does Distutils manage to use these libraries with their changed
names? If the extension needs a library (eg. foo) Distutils checks first if it finds a library with suffix _bcpp (eg. foo_bcpp.lib) and then uses this library. In the case it doesn’t find such a special library it uses the default name (foo.lib.) [1]

To let Distutils compile your extension with Borland C++ you now have to type:

```bash
github.com/dlave/Project3
```

If you want to use the Borland C++ compiler as the default, you could specify this in your personal or system-wide configuration file for Distutils (see section Distutils Configuration Files.)

See also:

**C++Builder Compiler**
Information about the free C++ compiler from Borland, including links to the download pages.

**Creating Python Extensions Using Borland’s Free Compiler**
Document describing how to use Borland's free command-line C++ compiler to build Python.

**GNU C / Cygwin / MinGW**

This section describes the necessary steps to use Distutils with the GNU C/C++ compilers in their Cygwin and MinGW distributions. [2] For a Python interpreter that was built with Cygwin, everything should work without any of these following steps.

Not all extensions can be built with MinGW or Cygwin, but many can. Extensions most likely to not work are those that use C++ or depend
on Microsoft Visual C extensions.

To let Distutils compile your extension with Cygwin you have to type:

```
python setup.py build --compiler=cygwin
```

and for Cygwin in no-cygwin mode [3] or for MinGW type:

```
python setup.py build --compiler=mingw32
```

If you want to use any of these options/compilers as default, you should consider writing it in your personal or system-wide configuration file for Distutils (see section Distutils Configuration Files.)

**Older Versions of Python and MinGW**

The following instructions only apply if you’re using a version of Python inferior to 2.4.1 with a MinGW inferior to 3.0.0 (with binutils-2.13.90-20030111-1).

These compilers require some special libraries. This task is more complex than for Borland's C++, because there is no program to convert the library. First you have to create a list of symbols which the Python DLL exports. (You can find a good program for this task at http://sourceforge.net/projects/mingw/files/MinGW/Extension/pexports/)

```
pexports python25.dll >python25.def
```

The location of an installed python25.dll will depend on the installation options and the version and language of Windows. In a “just for me” installation, it will appear in the root of the installation directory. In a shared installation, it will be located in the system directory.
Then you can create from these information an import library for gcc.

```bash
/cygwin/bin/dlltool --dllname python25.dll --def python25.def --output-lib libpython25.a
```

The resulting library has to be placed in the same directory as python25.lib. (Should be the `libs` directory under your Python installation directory.)

If your extension uses other libraries (zlib,...) you might have to convert them too. The converted files have to reside in the same directories as the normal libraries do.

**See also:**

**Building Python modules on MS Windows platform with MinGW**

Information about building the required libraries for the MinGW environment.

**Footnotes**

[1] This also means you could replace all existing COFF-libraries with OMF-libraries of the same name.


[3] Then you have no POSIX emulation available, but you also don't need cygwin1.dll.
Created using Sphinx 1.3.1.
Distributing Python Modules (Legacy version)

||
| Authors: | Greg Ward, Anthony Baxter |
| Email:   | distutils-sig@python.org |

This document describes the Python Distribution Utilities ("Distutils") from the module developer’s point of view, describing how to use the Distutils to make Python modules and extensions easily available to a wider audience with very little overhead for build/release/install mechanics.

**Note:** This guide only covers the basic tools for building and distributing extensions that are provided as part of this version of Python. Third party tools offer easier to use and more secure alternatives. Refer to the quick recommendations section in the Python Packaging User Guide for more information.

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8. Extending Distutils

Distutils can be extended in various ways. Most extensions take the form of new commands or replacements for existing commands. New commands may be written to support new types of platform-specific packaging, for example, while replacements for existing commands may be made to modify details of how the command operates on a package.

Most extensions of the distutils are made within setup.py scripts that want to modify existing commands; many simply add a few file extensions that should be copied into packages in addition to .py files as a convenience.

Most distutils command implementations are subclasses of the distutils.cmd.Command class. New commands may directly inherit from Command, while replacements often derive from Command indirectly, directly subclassing the command they are replacing. Commands are required to derive from Command.
8.1. Integrating new commands

There are different ways to integrate new command implementations into distutils. The most difficult is to lobby for the inclusion of the new features in distutils itself, and wait for (and require) a version of Python that provides that support. This is really hard for many reasons.

The most common, and possibly the most reasonable for most needs, is to include the new implementations with your setup.py script, and cause the `distutils.core.setup()` function use them:

```python
from distutils.command.build_py import build_py as _build_py
from distutils.core import setup

class build_py(_build_py):
    """Specialized Python source builder.""

        # implement whatever needs to be different...

setup(cmdclass={'build_py': build_py},
      ...

This approach is most valuable if the new implementations must be used to use a particular package, as everyone interested in the package will need to have the new command implementation.

Beginning with Python 2.4, a third option is available, intended to allow new commands to be added which can support existing setup.py scripts without requiring modifications to the Python installation. This is expected to allow third-party extensions to provide support for additional packaging systems, but the commands can be used for anything distutils commands can be used for. A new configuration
option, command_packages (command-line option --command-packages), can be used to specify additional packages to be searched for modules implementing commands. Like all distutils options, this can be specified on the command line or in a configuration file. This option can only be set in the [global] section of a configuration file, or before any commands on the command line. If set in a configuration file, it can be overridden from the command line; setting it to an empty string on the command line causes the default to be used. This should never be set in a configuration file provided with a package.

This new option can be used to add any number of packages to the list of packages searched for command implementations; multiple package names should be separated by commas. When not specified, the search is only performed in the distutils.command package. When setup.py is run with the option --command-packages distcmds,buildcmds, however, the packages distutils.command, distcmds, and buildcmds will be searched in that order. New commands are expected to be implemented in modules of the same name as the command by classes sharing the same name. Given the example command line option above, the command bdist_openpkg could be implemented by the class distcmds.bdist_openpkg.bdist_openpkg or buildcmds.bdist_openpkg.bdist_openpkg.
8.2. Adding new distribution types

Commands that create distributions (files in the dist/ directory) need to add (command, filename) pairs to self.distribution.dist_files so that upload can upload it to PyPI. The filename in the pair contains no path information, only the name of the file itself. In dry-run mode, pairs should still be added to represent what would have been created.
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**provisional package**

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</tr>
<tr>
<td>XML_ERROR_PARTIAL_CHAR (in module xml.parsers.expat.errors)</td>
<td>XML_E</td>
</tr>
<tr>
<td>XML_ERROR_PUBLICID (in module xml.parsers.expat.errors)</td>
<td>XML_E</td>
</tr>
<tr>
<td>XML_ERROR_RECURSIVE_ENTITY_REF (in module xml.parsers.expat.errors)</td>
<td>XML_E</td>
</tr>
<tr>
<td>XML_ERROR_SUSPENDED (in module xml.parsers.expat.errors)</td>
<td>XML_E</td>
</tr>
<tr>
<td>XML_ERROR_SYNTAX (in module xml.parsers.expat.errors)</td>
<td>XML_E</td>
</tr>
<tr>
<td>XML_ERROR_TAG_MISMATCH (in module xml.parsers.expat.errors)</td>
<td>XML_E</td>
</tr>
<tr>
<td>XML_ERROR_TEXT_DECL (in module xml.parsers.expat.errors)</td>
<td>XML_E</td>
</tr>
<tr>
<td>XML_ERROR_UNBOUND_PREFIX (in module xml.parsers.expat.errors)</td>
<td>XML_E</td>
</tr>
<tr>
<td>XML_ERROR_UNCLOSED_CDATA_SECTION (in module xml.parsers.expat.errors)</td>
<td>XML_E</td>
</tr>
<tr>
<td>XML_ERROR_UNCLOSED_TOKEN (in module xml.parsers.expat.errors)</td>
<td>XML_E</td>
</tr>
<tr>
<td>XML_ERROR_UNDECLARING_PREFIX (in module xml.parsers.expat.errors)</td>
<td>XML_E</td>
</tr>
<tr>
<td>XML_ERROR_UNDEFINED_ENTITY (in module xml.parsers.expat.errors)</td>
<td>XML_E</td>
</tr>
</tbody>
</table>
Y

Y2K
ycor() (in module turtle)
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   (datetime.datetime attribute)
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   (calendar.Calendar method)
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9. Command Reference
9.1. Installing modules: the **install** command family

The install command ensures that the build commands have been run and then runs the subcommands **install_lib**, **install_data** and **install_scripts**.

9.1.1. **install_data**

This command installs all data files provided with the distribution.

9.1.2. **install_scripts**

This command installs all (Python) scripts in the distribution.
9.2. Creating a source distribution: the *sdist* command

The manifest template commands are:

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>include pat1 pat2 ...</code></td>
<td>include all files matching any of the listed patterns</td>
</tr>
<tr>
<td><code>exclude pat1 pat2 ...</code></td>
<td>exclude all files matching any of the listed patterns</td>
</tr>
<tr>
<td><code>recursive-include dir pat1 pat2 ...</code></td>
<td>include all files under <code>dir</code> matching any of the listed patterns</td>
</tr>
<tr>
<td><code>recursive-exclude dir pat1 pat2 ...</code></td>
<td>exclude all files under <code>dir</code> matching any of the listed patterns</td>
</tr>
<tr>
<td><code>global-include pat1 pat2 ...</code></td>
<td>include all files anywhere in the source tree matching — &amp; any of the listed patterns</td>
</tr>
<tr>
<td><code>global-exclude pat1 pat2 ...</code></td>
<td>exclude all files anywhere in the source tree matching — &amp; any of the listed patterns</td>
</tr>
<tr>
<td><code>prune dir</code></td>
<td>exclude all files under <code>dir</code></td>
</tr>
<tr>
<td><code>graft dir</code></td>
<td>include all files under <code>dir</code></td>
</tr>
</tbody>
</table>

The patterns here are Unix-style “glob” patterns: * matches any sequence of regular filename characters, ? matches any single regular filename character, and [range] matches any of the characters in range (e.g., a-z, a-zA-Z, a-f0-9_.). The definition of “regular filename character” is platform-specific: on Unix it is anything except slash; on Windows anything except backslash or colon.
3. Writing the Setup Configuration File

Often, it's not possible to write down everything needed to build a distribution \textit{a priori}: you may need to get some information from the user, or from the user's system, in order to proceed. As long as that information is fairly simple—a list of directories to search for C header files or libraries, for example—then providing a configuration file, setup.cfg, for users to edit is a cheap and easy way to solicit it. Configuration files also let you provide default values for any command option, which the installer can then override either on the command-line or by editing the config file.

The setup configuration file is a useful middle-ground between the setup script—which, ideally, would be opaque to installers [1]—and the command-line to the setup script, which is outside of your control and entirely up to the installer. In fact, setup.cfg (and any other Distutils configuration files present on the target system) are processed after the contents of the setup script, but before the command-line. This has several useful consequences:

- installers can override some of what you put in setup.py by editing setup.cfg
- you can provide non-standard defaults for options that are not easily set in setup.py
- installers can override anything in setup.cfg using the command-line options to setup.py

The basic syntax of the configuration file is simple:

```
[command]
```
where `command` is one of the Distutils commands (e.g. `build_py`, `install`), and `option` is one of the options that command supports. Any number of options can be supplied for each command, and any number of command sections can be included in the file. Blank lines are ignored, as are comments, which run from a '#' character until the end of the line. Long option values can be split across multiple lines simply by indenting the continuation lines.

You can find out the list of options supported by a particular command with the universal `--help` option, e.g.

```bash
> python setup.py --help build_ext
[...]
Options for 'build_ext' command:
  --build-lib (-b)    directory for compiled extensions
  --build-temp (-t)   directory for temporary files
  --inplace (-i)      ignore build-lib and put compiled source directory alongside your
  --include-dirs (-I) list of directories to search
  --define (-D)       C preprocessor macros to define
  --undef (-U)        C preprocessor macros to undefine
  --swig-opts         list of SWIG command line options
[...]
```

Note that an option spelled `--foo-bar` on the command-line is spelled `foo_bar` in configuration files.

For example, say you want your extensions to be built “in-place”—that is, you have an extension `pkg.ext`, and you want the compiled extension file (e.g. `ext.so` on Unix, say) to be put in the same source
directory as your pure Python modules pkg.mod1 and pkg.mod2. You can always use the --inplace option on the command-line to ensure this:

```
python setup.py build_ext --inplace
```

But this requires that you always specify the `build_ext` command explicitly, and remember to provide `--inplace`. An easier way is to “set and forget” this option, by encoding it in `setup.cfg`, the configuration file for this distribution:

```
[build_ext]
inplace=1
```

This will affect all builds of this module distribution, whether or not you explicitly specify `build_ext`. If you include `setup.cfg` in your source distribution, it will also affect end-user builds—which is probably a bad idea for this option, since always building extensions in-place would break installation of the module distribution. In certain peculiar cases, though, modules are built right in their installation directory, so this is conceivably a useful ability. (Distributing extensions that expect to be built in their installation directory is almost always a bad idea, though.)

Another example: certain commands take a lot of options that don’t change from run to run; for example, `bdist_rpm` needs to know everything required to generate a “spec” file for creating an RPM distribution. Some of this information comes from the setup script, and some is automatically generated by the Distutils (such as the list of files installed). But some of it has to be supplied as options to `bdist_rpm`, which would be very tedious to do on the command-line for every run. Hence, here is a snippet from the Distutils’ own `setup.cfg`:
[bdist_rpm]
release = 1
packager = Greg Ward <gward@python.net>
doc_files = CHANGES.txt
            README.txt
            USAGE.txt
doc/
examples/

Note that the doc_files option is simply a whitespace-separated string split across multiple lines for readability.

See also:

Syntax of config files in “Installing Python Modules”
More information on the configuration files is available in the manual for system administrators.

Footnotes

[1] This ideal probably won’t be achieved until auto-configuration is fully supported by the Distutils.
2. Writing the Setup Script

The setup script is the centre of all activity in building, distributing, and installing modules using the Distutils. The main purpose of the setup script is to describe your module distribution to the Distutils, so that the various commands that operate on your modules do the right thing. As we saw in section A Simple Example above, the setup script consists mainly of a call to setup(), and most information supplied to the Distutils by the module developer is supplied as keyword arguments to setup().

Here’s a slightly more involved example, which we'll follow for the next couple of sections: the Distutils' own setup script. (Keep in mind that although the Distutils are included with Python 1.6 and later, they also have an independent existence so that Python 1.5.2 users can use them to install other module distributions. The Distutils’ own setup script, shown here, is used to install the package into Python 1.5.2.)

```python
#!/usr/bin/env python

from distutils.core import setup

setup(name='Distutils',
      version='1.0',
      description='Python Distribution Utilities',
      author='Greg Ward',
      author_email='gward@python.net',
      url='https://www.python.org/sigs/distutils-sig/',
      packages=['distutils', 'distutils.command'],
)
```

There are only two differences between this and the trivial one-file
distribution presented in section A Simple Example: more metadata, and the specification of pure Python modules by package, rather than by module. This is important since the Distutils consist of a couple of dozen modules split into (so far) two packages; an explicit list of every module would be tedious to generate and difficult to maintain. For more information on the additional meta-data, see section Additional meta-data.

Note that any pathnames (files or directories) supplied in the setup script should be written using the Unix convention, i.e. slash-separated. The Distutils will take care of converting this platform-neutral representation into whatever is appropriate on your current platform before actually using the pathname. This makes your setup script portable across operating systems, which of course is one of the major goals of the Distutils. In this spirit, all pathnames in this document are slash-separated.

This, of course, only applies to pathnames given to Distutils functions. If you, for example, use standard Python functions such as `glob.glob()` or `os.listdir()` to specify files, you should be careful to write portable code instead of hardcoding path separators:

```python
glob.glob(os.path.join('mydir', 'subdir', '*.html'))
os.listdir(os.path.join('mydir', 'subdir'))
```
2.1. Listing whole packages

The packages option tells the Distutils to process (build, distribute, install, etc.) all pure Python modules found in each package mentioned in the packages list. In order to do this, of course, there has to be a correspondence between package names and directories in the filesystem. The default correspondence is the most obvious one, i.e. package distutils is found in the directory distutils relative to the distribution root. Thus, when you say packages = ['foo'] in your setup script, you are promising that the Distutils will find a file foo/__init__.py (which might be spelled differently on your system, but you get the idea) relative to the directory where your setup script lives. If you break this promise, the Distutils will issue a warning but still process the broken package anyway.

If you use a different convention to lay out your source directory, that’s no problem: you just have to supply the package_dir option to tell the Distutils about your convention. For example, say you keep all Python source under lib, so that modules in the “root package” (i.e., not in any package at all) are in lib, modules in the foo package are in lib/foo, and so forth. Then you would put

```python
package_dir = {'': 'lib'}
```

in your setup script. The keys to this dictionary are package names, and an empty package name stands for the root package. The values are directory names relative to your distribution root. In this case, when you say packages = ['foo'], you are promising that the file lib/foo/__init__.py exists.

Another possible convention is to put the foo package right in lib,
the foo.bar package in lib/bar, etc. This would be written in the setup script as

```python
package_dir = {'foo': 'lib'}
```

A package: dir entry in the package_dir dictionary implicitly applies to all packages below package, so the foo.bar case is automatically handled here. In this example, having packages = ['foo', 'foo.bar'] tells the Distutils to look for lib/__init__.py and lib/bar/__init__.py. (Keep in mind that although package_dir applies recursively, you must explicitly list all packages in packages: the Distutils will not recursively scan your source tree looking for any directory with an __init__.py file.)
2.2. Listing individual modules

For a small module distribution, you might prefer to list all modules rather than listing packages—especially the case of a single module that goes in the “root package” (i.e., no package at all). This simplest case was shown in section A Simple Example; here is a slightly more involved example:

```python
py_modules = ['mod1', 'pkg.mod2']
```

This describes two modules, one of them in the “root” package, the other in the pkg package. Again, the default package/directory layout implies that these two modules can be found in mod1.py and pkg/mod2.py, and that pkg/__init__.py exists as well. And again, you can override the package/directory correspondence using the package_dir option.
2.3. Describing extension modules

Just as writing Python extension modules is a bit more complicated than writing pure Python modules, describing them to the Distutils is a bit more complicated. Unlike pure modules, it's not enough just to list modules or packages and expect the Distutils to go out and find the right files; you have to specify the extension name, source file(s), and any compile/link requirements (include directories, libraries to link with, etc.).

All of this is done through another keyword argument to setup(), the ext_modules option. ext_modules is just a list of Extension instances, each of which describes a single extension module. Suppose your distribution includes a single extension, called foo and implemented by foo.c. If no additional instructions to the compiler/linker are needed, describing this extension is quite simple:

```python
Extension('foo', ['foo.c'])
```

The Extension class can be imported from distutils.core along with setup(). Thus, the setup script for a module distribution that contains only this one extension and nothing else might be:

```python
from distutils.core import setup, Extension
setup(name='foo',
      version='1.0',
      ext_modules=[Extension('foo', ['foo.c'])],
)
```

The Extension class (actually, the underlying extension-building machinery implemented by the build_ext command) supports a great deal of flexibility in describing Python extensions, which is explained in
the following sections.

2.3.1. Extension names and packages

The first argument to the `Extension` constructor is always the name of the extension, including any package names. For example,

```python
Extension('foo', ['src/foo1.c', 'src/foo2.c'])
```

describes an extension that lives in the root package, while

```python
Extension('pkg.foo', ['src/foo1.c', 'src/foo2.c'])
```

describes the same extension in the pkg package. The source files and resulting object code are identical in both cases; the only difference is where in the filesystem (and therefore where in Python’s namespace hierarchy) the resulting extension lives.

If you have a number of extensions all in the same package (or all under the same base package), use the `ext_package` keyword argument to `setup()`. For example,

```python
setup(...,
    ext_package='pkg',
    ext_modules=[
        Extension('foo', ['foo.c']),
        Extension('subpkg.bar', ['bar.c'])
    ]
)
```

will compile foo.c to the extension pkg.foo, and bar.c to pkg.subpkg.bar.

2.3.2. Extension source files
The second argument to the `Extension` constructor is a list of source files. Since the Distutils currently only support C, C++, and Objective-C extensions, these are normally C/C++/Objective-C source files. (Be sure to use appropriate extensions to distinguish C++ source files: .cc and .cpp seem to be recognized by both Unix and Windows compilers.)

However, you can also include SWIG interface (.i) files in the list; the `build_ext` command knows how to deal with SWIG extensions: it will run SWIG on the interface file and compile the resulting C/C++ file into your extension.

This warning notwithstanding, options to SWIG can be currently passed like this:

```python
setup(...,
    ext_modules=[Extension('_foo', ['foo.i'],
                        swig_opts=['-modern', ''],
                        py_modules=['foo'],
        )
```

Or on the commandline like this:

```bash
> python setup.py build_ext --swig-opts="-modern -I..
```

On some platforms, you can include non-source files that are processed by the compiler and included in your extension. Currently, this just means Windows message text (.mc) files and resource definition (.rc) files for Visual C++. These will be compiled to binary resource (.res) files and linked into the executable.

### 2.3.3. Preprocessor options
Three optional arguments to `Extension` will help if you need to specify include directories to search or preprocessor macros to define/undefine: `include_dirs`, `define_macros`, and `undef_macros`.

For example, if your extension requires header files in the `include` directory under your distribution root, use the `include_dirs` option:

```python
Extension('foo', ['foo.c'], include_dirs=['include'])
```

You can specify absolute directories there; if you know that your extension will only be built on Unix systems with X11R6 installed to `/usr`, you can get away with

```python
Extension('foo', ['foo.c'], include_dirs=['/usr/include'])
```

You should avoid this sort of non-portable usage if you plan to distribute your code: it's probably better to write C code like

```c
#include <X11/Xlib.h>
```

If you need to include header files from some other Python extension, you can take advantage of the fact that header files are installed in a consistent way by the Distutils `install_headers` command. For example, the Numerical Python header files are installed (on a standard Unix installation) to `/usr/local/include/python1.5/Numerical`. (The exact location will differ according to your platform and Python installation.) Since the Python include directory — `/usr/local/include/python1.5` in this case—is always
included in the search path when building Python extensions, the best approach is to write C code like

```c
#include <Numerical/arrayobject.h>
```

If you must put the Numerical include directory right into your header search path, though, you can find that directory using the Distutils `distutils.sysconfig` module:

```python
from distutils.sysconfig import get_python_inc
incdir = os.path.join(get_python_inc(plat_specific=1),
    setup(...,
        Extension(..., include_dirs=[incdir]),
    )
```

Even though this is quite portable—it will work on any Python installation, regardless of platform—it’s probably easier to just write your C code in the sensible way.

You can define and undefine pre-processor macros with the `define_macros` and `undef_macros` options. `define_macros` takes a list of `(name, value)` tuples, where `name` is the name of the macro to define (a string) and `value` is its value: either a string or `None`. (Defining a macro `F00` to `None` is the equivalent of a bare `#define F00` in your C source: with most compilers, this sets `F00` to the string `1`.) `undef_macros` is just a list of macros to undefine.

For example:

```python
Extension(...,
    define_macros=[('NDEBUG', '1'), ('HAVE_STRFTIME', None)],
    undef_macros=['HAVE_FOO', 'HAVE_BAR'])
```
is the equivalent of having this at the top of every C source file:

```c
#define NDEBUG 1
#define HAVE_STRFTIME
#undef HAVE_FOO
#undef HAVE_BAR
```

### 2.3.4. Library options

You can also specify the libraries to link against when building your extension, and the directories to search for those libraries. The `libraries` option is a list of libraries to link against, `library_dirs` is a list of directories to search for libraries at link-time, and `runtime_library_dirs` is a list of directories to search for shared (dynamically loaded) libraries at run-time.

For example, if you need to link against libraries known to be in the standard library search path on target systems

```python
Extension(...,
    libraries=['gdbm', 'readline'])
```

If you need to link with libraries in a non-standard location, you'll have to include the location in `library_dirs`:

```python
Extension(...,
    library_dirs=['/usr/X11R6/lib'],
    libraries=['X11', 'Xt'])
```

(Again, this sort of non-portable construct should be avoided if you intend to distribute your code.)

### 2.3.5. Other options
There are still some other options which can be used to handle special cases.

The optional option is a boolean; if it is true, a build failure in the extension will not abort the build process, but instead simply not install the failing extension.

The extra_objects option is a list of object files to be passed to the linker. These files must not have extensions, as the default extension for the compiler is used.

extra_compile_args and extra_link_args can be used to specify additional command line options for the respective compiler and linker command lines.

export_symbols is only useful on Windows. It can contain a list of symbols (functions or variables) to be exported. This option is not needed when building compiled extensions: Distutils will automatically add initmodule to the list of exported symbols.

The depends option is a list of files that the extension depends on (for example header files). The build command will call the compiler on the sources to rebuild extension if any on this files has been modified since the previous build.
2.4. Relationships between Distributions and Packages

A distribution may relate to packages in three specific ways:

1. It can require packages or modules.
2. It can provide packages or modules.
3. It can obsolete packages or modules.

These relationships can be specified using keyword arguments to the `distutils.core.setup()` function.

Dependencies on other Python modules and packages can be specified by supplying the `requires` keyword argument to `setup()`. The value must be a list of strings. Each string specifies a package that is required, and optionally what versions are sufficient.

To specify that any version of a module or package is required, the string should consist entirely of the module or package name. Examples include 'mymodule' and 'xml.parsers.expat'.

If specific versions are required, a sequence of qualifiers can be supplied in parentheses. Each qualifier may consist of a comparison operator and a version number. The accepted comparison operators are:

```
<  >  ==
<=  >=  !=
```

These can be combined by using multiple qualifiers separated by commas (and optional whitespace). In this case, all of the qualifiers must be matched; a logical AND is used to combine the evaluations.
Let's look at a bunch of examples:

<table>
<thead>
<tr>
<th>Requires Expression</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>==1.0</td>
<td>Only version 1.0 is compatible</td>
</tr>
<tr>
<td>&gt;1.0, !=1.5.1, &lt;2.0</td>
<td>Any version after 1.0 and before 2.0 is compatible, except 1.5.1</td>
</tr>
</tbody>
</table>

Now that we can specify dependencies, we also need to be able to specify what we provide that other distributions can require. This is done using the `provides` keyword argument to `setup()`. The value for this keyword is a list of strings, each of which names a Python module or package, and optionally identifies the version. If the version is not specified, it is assumed to match that of the distribution.

Some examples:

<table>
<thead>
<tr>
<th>Provides Expression</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>mypkg</td>
<td>Provide mypkg, using the distribution version</td>
</tr>
<tr>
<td>mypkg (1.1)</td>
<td>Provide mypkg version 1.1, regardless of the distribution version</td>
</tr>
</tbody>
</table>

A package can declare that it obsoletes other packages using the `obsoletes` keyword argument. The value for this is similar to that of the `requires` keyword: a list of strings giving module or package specifiers. Each specifier consists of a module or package name optionally followed by one or more version qualifiers. Version qualifiers are given in parentheses after the module or package name.

The versions identified by the qualifiers are those that are obsoleted by the distribution being described. If no qualifiers are given, all
versions of the named module or package are understood to be obsoleted.
2.5. Installing Scripts

So far we have been dealing with pure and non-pure Python modules, which are usually not run by themselves but imported by scripts.

Scripts are files containing Python source code, intended to be started from the command line. Scripts don’t require Distutils to do anything very complicated. The only clever feature is that if the first line of the script starts with `#!` and contains the word “python”, the Distutils will adjust the first line to refer to the current interpreter location. By default, it is replaced with the current interpreter location. The `--executable` (or `-e`) option will allow the interpreter path to be explicitly overridden.

The `scripts` option simply is a list of files to be handled in this way. From the PyXML setup script:

```python
setup(...,
    scripts=['scripts/xmlproc_parse', 'scripts/xmlproc_val'])
```

*Changed in version 3.1:* All the scripts will also be added to the MANIFEST file if no template is provided. See Specifying the files to distribute.
2.6. Installing Package Data

Often, additional files need to be installed into a package. These files are often data that's closely related to the package's implementation, or text files containing documentation that might be of interest to programmers using the package. These files are called *package data*.

Package data can be added to packages using the `package_data` keyword argument to the `setup()` function. The value must be a mapping from package name to a list of relative path names that should be copied into the package. The paths are interpreted as relative to the directory containing the package (information from the `package_dir` mapping is used if appropriate); that is, the files are expected to be part of the package in the source directories. They may contain glob patterns as well.

The path names may contain directory portions; any necessary directories will be created in the installation.

For example, if a package should contain a subdirectory with several data files, the files can be arranged like this in the source tree:

```
setup.py
src/
    mypkg/
        __init__.py
        module.py
        data/
            tables.dat
            spoons.dat
            forks.dat
```

The corresponding call to `setup()` might be:
```python
setup(...,
    packages=['mypkg'],
    package_dir={'mypkg': 'src/mypkg'},
    package_data={'mypkg': ['data/*.dat']},
)
```

*Changed in version 3.1:* All the files that match `package_data` will be added to the MANIFEST file if no template is provided. See [Specifying the files to distribute](#).
2.7. Installing Additional Files

The data_files option can be used to specify additional files needed by the module distribution: configuration files, message catalogs, data files, anything which doesn’t fit in the previous categories.

data_files specifies a sequence of (directory, files) pairs in the following way:

```python
setup(...,
    data_files=[('bitmaps', ['bm/b1.gif', 'bm/b2.gif']),'config', ['cfg/data.cfg']),
    ('/etc/init.d', ['init-script'])])
```

Note that you can specify the directory names where the data files will be installed, but you cannot rename the data files themselves.

Each (directory, files) pair in the sequence specifies the installation directory and the files to install there. If directory is a relative path, it is interpreted relative to the installation prefix (Python’s sys.prefix for pure-Python packages, sys.exec_prefix for packages that contain extension modules). Each file name in files is interpreted relative to the setup.py script at the top of the package source distribution. No directory information from files is used to determine the final location of the installed file; only the name of the file is used.

You can specify the data_files options as a simple sequence of files without specifying a target directory, but this is not recommended, and the install command will print a warning in this case. To install data files directly in the target directory, an empty string should be
given as the directory.

*Changed in version 3.1:* All the files that match `data_files` will be added to the MANIFEST file if no template is provided. See [Specifying the files to distribute](#).
2.8. Additional meta-data

The setup script may include additional meta-data beyond the name and version. This information includes:

<table>
<thead>
<tr>
<th>Meta-Data</th>
<th>Description</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>name of the package</td>
<td>short string</td>
<td>(1)</td>
</tr>
<tr>
<td>version</td>
<td>version of this release</td>
<td>short string</td>
<td>(1)(2)</td>
</tr>
<tr>
<td>author</td>
<td>package author's name</td>
<td>short string</td>
<td>(3)</td>
</tr>
<tr>
<td>author_email</td>
<td>email address of the package author</td>
<td>email address</td>
<td>(3)</td>
</tr>
<tr>
<td>maintainer</td>
<td>package maintainer's name</td>
<td>short string</td>
<td>(3)</td>
</tr>
<tr>
<td>maintainer_email</td>
<td>email address of the package maintainer</td>
<td>email address</td>
<td>(3)</td>
</tr>
<tr>
<td>url</td>
<td>home page for the package</td>
<td>URL</td>
<td>(1)</td>
</tr>
<tr>
<td>description</td>
<td>short, summary description of the package</td>
<td>short string</td>
<td></td>
</tr>
<tr>
<td>long_description</td>
<td>longer description of the package</td>
<td>long string</td>
<td>(5)</td>
</tr>
<tr>
<td>download_url</td>
<td>location where the package may be downloaded</td>
<td>URL</td>
<td>(4)</td>
</tr>
<tr>
<td>classifiers</td>
<td>a list of classifiers</td>
<td>list of strings</td>
<td>(4)</td>
</tr>
<tr>
<td>platforms</td>
<td>a list of platforms</td>
<td>list of strings</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>---------------------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>license</td>
<td>license for the package</td>
<td>short string</td>
<td>(6)</td>
</tr>
</tbody>
</table>

Notes:

1. These fields are required.
2. It is recommended that versions take the form `major.minor[.patch[.sub]]`.
3. Either the author or the maintainer must be identified. If maintainer is provided, distutils lists it as the author in PKG-INFO.
4. These fields should not be used if your package is to be compatible with Python versions prior to 2.2.3 or 2.3. The list is available from the PyPI website.
5. The `long_description` field is used by PyPI when you are registering a package, to build its home page.
6. The license field is a text indicating the license covering the package where the license is not a selection from the “License” Trove classifiers. See the Classifier field. Notice that there's a licence distribution option which is deprecated but still acts as an alias for license.

‘short string’
A single line of text, not more than 200 characters.

‘long string’
Multiple lines of plain text in reStructuredText format (see http://docutils.sourceforge.net/).

‘list of strings’
See below.

Encoding the version information is an art in itself. Python packages generally adhere to the version format `major.minor[.patch][sub]`. The
major number is 0 for initial, experimental releases of software. It is incremented for releases that represent major milestones in a package. The minor number is incremented when important new features are added to the package. The patch number increments when bug-fix releases are made. Additional trailing version information is sometimes used to indicate sub-releases. These are “a1,a2,...,aN” (for alpha releases, where functionality and API may change), “b1,b2,...,bN” (for beta releases, which only fix bugs) and “pr1,pr2,...,prN” (for final pre-release release testing). Some examples:

0.1.0
    the first, experimental release of a package
1.0.1a2
    the second alpha release of the first patch version of 1.0

classifiers are specified in a Python list:

```python
setup(...,
    classifiers=[
        'Development Status :: 4 - Beta',
        'Environment :: Console',
        'Environment :: Web Environment',
        'Intended Audience :: End Users/Desktop',
        'Intended Audience :: Developers',
        'Intended Audience :: System Administrators',
        'License :: OSI Approved :: Python Software Foundation License',
        'Operating System :: MacOS :: MacOS X',
        'Operating System :: Microsoft :: Windows',
        'Operating System :: POSIX',
        'Programming Language :: Python',
        'Topic :: Communications :: Email',
        'Topic :: Office/Business',
        'Topic :: Software Development :: Bug Tracking',
    ],
)
```
2.9. Debugging the setup script

Sometimes things go wrong, and the setup script doesn’t do what the developer wants.

Distutils catches any exceptions when running the setup script, and print a simple error message before the script is terminated. The motivation for this behaviour is to not confuse administrators who don’t know much about Python and are trying to install a package. If they get a big long traceback from deep inside the guts of Distutils, they may think the package or the Python installation is broken because they don’t read all the way down to the bottom and see that it’s a permission problem.

On the other hand, this doesn’t help the developer to find the cause of the failure. For this purpose, the DISTUTILS_DEBUG environment variable can be set to anything except an empty string, and distutils will now print detailed information about what it is doing, dump the full traceback when an exception occurs, and print the whole command line when an external program (like a C compiler) fails.
1. An Introduction to Distutils

This document covers using the Distutils to distribute your Python modules, concentrating on the role of developer/distributor: if you're looking for information on installing Python modules, you should refer to the Installing Python Modules (Legacy version) chapter.
1.1. Concepts & Terminology

Using the Distutils is quite simple, both for module developers and for users/administrators installing third-party modules. As a developer, your responsibilities (apart from writing solid, well-documented and well-tested code, of course!) are:

- write a setup script (`setup.py` by convention)
- (optional) write a setup configuration file
- create a source distribution
- (optional) create one or more built (binary) distributions

Each of these tasks is covered in this document.

Not all module developers have access to a multitude of platforms, so it's not always feasible to expect them to create a multitude of built distributions. It is hoped that a class of intermediaries, called packagers, will arise to address this need. Packagers will take source distributions released by module developers, build them on one or more platforms, and release the resulting built distributions. Thus, users on the most popular platforms will be able to install most popular Python module distributions in the most natural way for their platform, without having to run a single setup script or compile a line of code.
1.2. A Simple Example

The setup script is usually quite simple, although since it's written in Python, there are no arbitrary limits to what you can do with it, though you should be careful about putting arbitrarily expensive operations in your setup script. Unlike, say, Autoconf-style configure scripts, the setup script may be run multiple times in the course of building and installing your module distribution.

If all you want to do is distribute a module called foo, contained in a file foo.py, then your setup script can be as simple as this:

```python
from distutils.core import setup
setup(name='foo',
      version='1.0',
      py_modules=['foo'],
)
```

Some observations:

- most information that you supply to the Distutils is supplied as keyword arguments to the setup() function
- those keyword arguments fall into two categories: package metadata (name, version number) and information about what's in the package (a list of pure Python modules, in this case)
- modules are specified by module name, not filename (the same will hold true for packages and extensions)
- it's recommended that you supply a little more metadata, in particular your name, email address and a URL for the project (see section Writing the Setup Script for an example)

To create a source distribution for this module, you would create a setup script, setup.py, containing the above code, and run this
command from a terminal:

```
python setup.py sdist
```

For Windows, open a command prompt window (Start › Accessories) and change the command to:

```
setup.py sdist
```

`sdist` will create an archive file (e.g., tarball on Unix, ZIP file on Windows) containing your setup script `setup.py`, and your module `foo.py`. The archive file will be named `foo-1.0.tar.gz` (or `.zip`), and will unpack into a directory `foo-1.0`.

If an end-user wishes to install your `foo` module, all she has to do is download `foo-1.0.tar.gz` (or `.zip`), unpack it, and—from the `foo-1.0` directory—run

```
python setup.py install
```

which will ultimately copy `foo.py` to the appropriate directory for third-party modules in their Python installation.

This simple example demonstrates some fundamental concepts of the Distutils. First, both developers and installers have the same basic user interface, i.e. the setup script. The difference is which Distutils commands they use: the `sdist` command is almost exclusively for module developers, while `install` is more often for installers (although most developers will want to install their own code occasionally).

If you want to make things really easy for your users, you can create one or more built distributions for them. For instance, if you are running on a Windows machine, and want to make things easy for
other Windows users, you can create an executable installer (the most appropriate type of built distribution for this platform) with the `bdist_wininst` command. For example:

```
python setup.py bdist_wininst
```

will create an executable installer, `foo-1.0.win32.exe`, in the current directory.

Other useful built distribution formats are RPM, implemented by the `bdist_rpm` command, Solaris `pkgtool` (bdist_pkgtool), and HP-UX `swinstall` (bdist_sdux). For example, the following command will create an RPM file called `foo-1.0.noarch.rpm`:

```
python setup.py bdist_rpm
```

(The `bdist_rpm` command uses the `rpm` executable, therefore this has to be run on an RPM-based system such as Red Hat Linux, SuSE Linux, or Mandrake Linux.)

You can find out what distribution formats are available at any time by running

```
python setup.py bdist --help-formats
```
1.3. General Python terminology

If you’re reading this document, you probably have a good idea of what modules, extensions, and so forth are. Nevertheless, just to be sure that everyone is operating from a common starting point, we offer the following glossary of common Python terms:

module
the basic unit of code reusability in Python: a block of code imported by some other code. Three types of modules concern us here: pure Python modules, extension modules, and packages.

pure Python module
a module written in Python and contained in a single .py file (and possibly associated .pyc files). Sometimes referred to as a “pure module.”

extension module
a module written in the low-level language of the Python implementation: C/C++ for Python, Java for Jython. Typically contained in a single dynamically loadable pre-compiled file, e.g. a shared object (.so) file for Python extensions on Unix, a DLL (given the .pyd extension) for Python extensions on Windows, or a Java class file for Jython extensions. (Note that currently, the Distutils only handles C/C++ extensions for Python.)

package
a module that contains other modules; typically contained in a directory in the filesystem and distinguished from other directories by the presence of a file __init__.py.

root package
the root of the hierarchy of packages. (This isn’t really a package, since it doesn’t have an __init__.py file. But we have to call it something.) The vast majority of the standard library is in the root
package, as are many small, standalone third-party modules that don't belong to a larger module collection. Unlike regular packages, modules in the root package can be found in many directories: in fact, every directory listed in `sys.path` contributes modules to the root package.
1.4. Distutils-specific terminology

The following terms apply more specifically to the domain of distributing Python modules using the Distutils:

module distribution
   a collection of Python modules distributed together as a single downloadable resource and meant to be installed en masse. Examples of some well-known module distributions are NumPy, SciPy, PIL (the Python Imaging Library), or mxBase. (This would be called a package, except that term is already taken in the Python context: a single module distribution may contain zero, one, or many Python packages.)

pure module distribution
   a module distribution that contains only pure Python modules and packages. Sometimes referred to as a “pure distribution.”

non-pure module distribution
   a module distribution that contains at least one extension module. Sometimes referred to as a “non-pure distribution.”

distribution root
   the top-level directory of your source tree (or source distribution); the directory where setup.py exists. Generally setup.py will be run from this directory.
4. Creating a Source Distribution

As shown in section A Simple Example, you use the sdist command to create a source distribution. In the simplest case,

```
python setup.py sdist
```

(assuming you haven’t specified any sdist options in the setup script or config file), sdist creates the archive of the default format for the current platform. The default format is a gzip’ed tar file (.tar.gz) on Unix, and ZIP file on Windows.

You can specify as many formats as you like using the --formats option, for example:

```
python setup.py sdist --formats=gztar,zip
```

to create a gzipped tarball and a zip file. The available formats are:

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>zip</td>
<td>zip file (.zip)</td>
<td>(1),(3)</td>
</tr>
<tr>
<td>gztar</td>
<td>gzip'ed tar file (.tar.gz)</td>
<td>(2)</td>
</tr>
<tr>
<td>bztar</td>
<td>bzip2'ed tar file (.tar.bz2)</td>
<td></td>
</tr>
<tr>
<td>xztar</td>
<td>xz'ed tar file (.tar.xz)</td>
<td></td>
</tr>
<tr>
<td>ztar</td>
<td>compressed tar file (.tar.Z)</td>
<td>(4)</td>
</tr>
<tr>
<td>tar</td>
<td>tar file (.tar)</td>
<td></td>
</tr>
</tbody>
</table>

*Changed in version 3.5:* Added support for the xz.tar format.
Notes:

1. default on Windows
2. default on Unix
3. requires either external **zip** utility or **zipfile** module (part of the standard Python library since Python 1.6)
4. requires the **compress** program. Notice that this format is now pending for deprecation and will be removed in the future versions of Python.

When using any **tar** format (gztar, bztar, xztar, ztar or tar), under Unix you can specify the owner and group names that will be set for each member of the archive.

For example, if you want all files of the archive to be owned by root:

```
python setup.py sdist --owner=root --group=root
```
4.1. Specifying the files to distribute

If you don’t supply an explicit list of files (or instructions on how to generate one), the `sdist` command puts a minimal default set into the source distribution:

- all Python source files implied by the `py_modules` and `packages` options
- all C source files mentioned in the `ext_modules` or `libraries` options
- scripts identified by the `scripts` option See Installing Scripts.
- anything that looks like a test script: `test/test*.py` (currently, the Distutils don’t do anything with test scripts except include them in source distributions, but in the future there will be a standard for testing Python module distributions)
- `README.txt` (or `README`), `setup.py` (or whatever you called your setup script), and `setup.cfg`
- all files that matches the `package_data` metadata. See Installing Package Data.
- all files that matches the `data_files` metadata. See Installing Additional Files.

Sometimes this is enough, but usually you will want to specify additional files to distribute. The typical way to do this is to write a manifest template, called `MANIFEST.in` by default. The manifest template is just a list of instructions for how to generate your manifest file, `MANIFEST`, which is the exact list of files to include in your source distribution. The `sdist` command processes this template and generates a manifest based on its instructions and what it finds in the filesystem.

If you prefer to roll your own manifest file, the format is simple: one
filename per line, regular files (or symlinks to them) only. If you do supply your own MANIFEST, you must specify everything: the default set of files described above does not apply in this case.

*Changed in version 3.1:* An existing generated MANIFEST will be regenerated without *sdist* comparing its modification time to the one of MANIFEST.in or setup.py.

*Changed in version 3.1.3:* MANIFEST files start with a comment indicating they are generated. Files without this comment are not overwritten or removed.

*Changed in version 3.2.2:* *sdist* will read a MANIFEST file if no MANIFEST.in exists, like it used to do.

The manifest template has one command per line, where each command specifies a set of files to include or exclude from the source distribution. For an example, again we turn to the Distutils’ own manifest template:

```
include *.txt
recursive-include examples *.txt *.py
prune examples/sample/*/build
```

The meanings should be fairly clear: include all files in the distribution root matching *.txt, all files anywhere under the examples directory matching *.txt or *.py, and exclude all directories matching examples/sample/*/build. All of this is done after the standard include set, so you can exclude files from the standard set with explicit instructions in the manifest template. (Or, you can use the **--no-defaults** option to disable the standard set entirely.) There are several other commands available in the manifest template mini-language; see section Creating a source distribution: the *sdist*
The order of commands in the manifest template matters: initially, we have the list of default files as described above, and each command in the template adds to or removes from that list of files. Once we have fully processed the manifest template, we remove files that should not be included in the source distribution:

- all files in the Distutils “build” tree (default build/)
- all files in directories named RCS, CVS, .svn, .hg, .git, .bzr or _darcs

Now we have our complete list of files, which is written to the manifest for future reference, and then used to build the source distribution archive(s).

You can disable the default set of included files with the \--no-defaults option, and you can disable the standard exclude set with \--no-prune.

Following the Distutils’ own manifest template, let’s trace how the sdist command builds the list of files to include in the Distutils source distribution:

1. include all Python source files in the distutils and distutils/command subdirectories (because packages corresponding to those two directories were mentioned in the packages option in the setup script—see section Writing the Setup Script)
2. include README.txt, setup.py, and setup.cfg (standard files)
3. include test/test*.py (standard files)
4. include *.txt in the distribution root (this will find README.txt a
second time, but such redundancies are weeded out later)
5. include anything matching *.txt or *.py in the sub-tree under examples,
6. exclude all files in the sub-trees starting at directories matching examples/sample?/build—this may exclude files included by the previous two steps, so it's important that the prune command in the manifest template comes after the recursive-include command
7. exclude the entire build tree, and any RCS, CVS, .svn, .hg, .git, .bzr and _darcs directories

Just like in the setup script, file and directory names in the manifest template should always be slash-separated; the Distutils will take care of converting them to the standard representation on your platform. That way, the manifest template is portable across operating systems.
4.2. Manifest-related options

The normal course of operations for the `sdist` command is as follows:

- if the manifest file (MANIFEST by default) exists and the first line does not have a comment indicating it is generated from MANIFEST.in, then it is used as is, unaltered
- if the manifest file doesn't exist or has been previously automatically generated, read MANIFEST.in and create the manifest
- if neither MANIFEST nor MANIFEST.in exist, create a manifest with just the default file set
- use the list of files now in MANIFEST (either just generated or read in) to create the source distribution archive(s)

There are a couple of options that modify this behaviour. First, use the `--no-defaults` and `--no-prune` to disable the standard “include” and “exclude” sets.

Second, you might just want to (re)generate the manifest, but not create a source distribution:

```
python setup.py sdist --manifest-only
```

- `o` is a shortcut for `--manifest-only`. 
5. Creating Built Distributions

A “built distribution” is what you’re probably used to thinking of either as a “binary package” or an “installer” (depending on your background). It’s not necessarily binary, though, because it might contain only Python source code and/or byte-code; and we don’t call it a package, because that word is already spoken for in Python. (And “installer” is a term specific to the world of mainstream desktop systems.)

A built distribution is how you make life as easy as possible for installers of your module distribution: for users of RPM-based Linux systems, it’s a binary RPM; for Windows users, it’s an executable installer; for Debian-based Linux users, it’s a Debian package; and so forth. Obviously, no one person will be able to create built distributions for every platform under the sun, so the Distutils are designed to enable module developers to concentrate on their specialty—writing code and creating source distributions—while an intermediary species called packagers springs up to turn source distributions into built distributions for as many platforms as there are packagers.

Of course, the module developer could be his own packager; or the packager could be a volunteer “out there” somewhere who has access to a platform which the original developer does not; or it could be software periodically grabbing new source distributions and turning them into built distributions for as many platforms as the software has access to. Regardless of who they are, a packager uses the setup script and the bdist command family to generate built distributions.

As a simple example, if I run the following command in the Distutils source tree:
python setup.py bdist

then the Distutils builds my module distribution (the Distutils itself in this case), does a “fake” installation (also in the build directory), and creates the default type of built distribution for my platform. The default format for built distributions is a “dumb” tar file on Unix, and a simple executable installer on Windows. (That tar file is considered “dumb” because it has to be unpacked in a specific location to work.)

Thus, the above command on a Unix system creates Distutils-1.0.*.tar.gz; unpacking this tarball from the right place installs the Distutils just as though you had downloaded the source distribution and run python setup.py install. (The “right place” is either the root of the filesystem or Python’s prefix directory, depending on the options given to the bdist_dumb command; the default is to make dumb distributions relative to prefix.)

Obviously, for pure Python distributions, this isn’t any simpler than just running python setup.py install—but for non-pure distributions, which include extensions that would need to be compiled, it can mean the difference between someone being able to use your extensions or not. And creating “smart” built distributions, such as an RPM package or an executable installer for Windows, is far more convenient for users even if your distribution doesn’t include any extensions.

The bdist command has a --formats option, similar to the sdist command, which you can use to select the types of built distribution to generate: for example,

python setup.py bdist --format=zip
would, when run on a Unix system, create Distutils-1.0.*plat*.zip—again, this archive would be unpacked from the root directory to install the Distutils.

The available formats for built distributions are:

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>gztar</td>
<td>gzipped tar file (.tar.gz)</td>
<td>(1)</td>
</tr>
<tr>
<td>bztar</td>
<td>bzipped tar file (.tar.bz2)</td>
<td></td>
</tr>
<tr>
<td>xztar</td>
<td>xzipped tar file (.tar.xz)</td>
<td></td>
</tr>
<tr>
<td>ztar</td>
<td>compressed tar file (.tar.Z)</td>
<td>(3)</td>
</tr>
<tr>
<td>tar</td>
<td>tar file (.tar)</td>
<td></td>
</tr>
<tr>
<td>zip</td>
<td>zip file (.zip)</td>
<td>(2),(4)</td>
</tr>
<tr>
<td>rpm</td>
<td>RPM</td>
<td>(5)</td>
</tr>
<tr>
<td>pkgtool</td>
<td>Solaris pkgtool</td>
<td></td>
</tr>
<tr>
<td>sdux</td>
<td>HP-UX swinstall</td>
<td></td>
</tr>
<tr>
<td>wininst</td>
<td>self-extracting ZIP file for Windows</td>
<td>(4)</td>
</tr>
<tr>
<td>msi</td>
<td>Microsoft Installer.</td>
<td></td>
</tr>
</tbody>
</table>

*Changed in version 3.5:* Added support for the xztar format.

Notes:

1. default on Unix
2. default on Windows
3. requires external *compress* utility.
4. requires either external *zip* utility or *zipfile* module (part of the standard Python library since Python 1.6)
5. requires external *rpm* utility, version 3.0.4 or better (use *rpm* --
version to find out which version you have)

You don’t have to use the **bdist** command with the **--formats** option; you can also use the command that directly implements the format you’re interested in. Some of these **bdist** “sub-commands” actually generate several similar formats; for instance, the **bdist_dumb** command generates all the “dumb” archive formats (tar, gztar, bztar, xztar, ztar, and zip), and **bdist_rpm** generates both binary and source RPMs. The **bdist** sub-commands, and the formats generated by each, are:

<table>
<thead>
<tr>
<th>Command</th>
<th>Formats</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>bdist_dumb</strong></td>
<td>tar, gztar, bztar, xztar, ztar, zip</td>
</tr>
<tr>
<td><strong>bdist_rpm</strong></td>
<td>rpm, srpm</td>
</tr>
<tr>
<td><strong>bdist_wininst</strong></td>
<td>wininst</td>
</tr>
<tr>
<td><strong>bdist_msi</strong></td>
<td>msi</td>
</tr>
</tbody>
</table>

The following sections give details on the individual **bdist_*** commands.
5.1. Creating RPM packages

The RPM format is used by many popular Linux distributions, including Red Hat, SuSE, and Mandrake. If one of these (or any of the other RPM-based Linux distributions) is your usual environment, creating RPM packages for other users of that same distribution is trivial. Depending on the complexity of your module distribution and differences between Linux distributions, you may also be able to create RPMs that work on different RPM-based distributions.

The usual way to create an RPM of your module distribution is to run the `bdist_rpm` command:

```bash
python setup.py bdist_rpm
```

or the `bdist` command with the `--format` option:

```bash
python setup.py bdist --formats=rpm
```

The former allows you to specify RPM-specific options; the latter allows you to easily specify multiple formats in one run. If you need to do both, you can explicitly specify multiple `bdist_*` commands and their options:

```bash
python setup.py bdist_rpm --packager="John Doe <jdoe@example.org>
bdist_wininst --target-version="2.0"
```

Creating RPM packages is driven by a .spec file, much as using the Distutils is driven by the setup script. To make your life easier, the `bdist_rpm` command normally creates a .spec file based on the information you supply in the setup script, on the command line, and in
any Distutils configuration files. Various options and sections in the .spec file are derived from options in the setup script as follows:

<table>
<thead>
<tr>
<th>RPM .spec file option or section</th>
<th>Distutils setup script option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>name</td>
</tr>
<tr>
<td>Summary (in preamble)</td>
<td>description</td>
</tr>
<tr>
<td>Version</td>
<td>version</td>
</tr>
<tr>
<td>Vendor</td>
<td>author and author_email, or — &amp; maintainer and maintainer_email</td>
</tr>
<tr>
<td>Copyright</td>
<td>license</td>
</tr>
<tr>
<td>Url</td>
<td>url</td>
</tr>
<tr>
<td>%description (section)</td>
<td>long_description</td>
</tr>
</tbody>
</table>

Additionally, there are many options in .spec files that don’t have corresponding options in the setup script. Most of these are handled through options to the `bdist_rpm` command as follows:

<table>
<thead>
<tr>
<th>RPM .spec file option or section</th>
<th>bdist_rpm option</th>
<th>default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Release</td>
<td>release</td>
<td>“1”</td>
</tr>
<tr>
<td>Group</td>
<td>group</td>
<td>“Development/Libraries”</td>
</tr>
<tr>
<td>Vendor</td>
<td>vendor</td>
<td>(see above)</td>
</tr>
<tr>
<td>Packager</td>
<td>packager</td>
<td>(none)</td>
</tr>
<tr>
<td>Provides</td>
<td>provides</td>
<td>(none)</td>
</tr>
<tr>
<td>Requires</td>
<td>requires</td>
<td>(none)</td>
</tr>
<tr>
<td>Conflicts</td>
<td>conflicts</td>
<td>(none)</td>
</tr>
</tbody>
</table>
Obviously, supplying even a few of these options on the command-line would be tedious and error-prone, so it’s usually best to put them in the setup configuration file, setup.cfg—see section Writing the Setup Configuration File. If you distribute or package many Python module distributions, you might want to put options that apply to all of them in your personal Distutils configuration file (~/.pydistutils.cfg). If you want to temporarily disable this file, you can pass the --no-user-cfg option to setup.py.

There are three steps to building a binary RPM package, all of which are handled automatically by the Distutils:

1. create a .spec file, which describes the package (analogous to the Distutils setup script; in fact, much of the information in the setup script winds up in the .spec file)
2. create the source RPM
3. create the “binary” RPM (which may or may not contain binary code, depending on whether your module distribution contains Python extensions)

Normally, RPM bundles the last two steps together; when you use the Distutils, all three steps are typically bundled together.

If you wish, you can separate these three steps. You can use the --spec-only option to make bdist_rpm just create the .spec file and exit; in this case, the .spec file will be written to the “distribution directory”—normally dist/, but customizable with the --dist-dir
option. (Normally, the .spec file winds up deep in the “build tree,” in a temporary directory created by `bdist_rpm`.)
5.2. Creating Windows Installers

Executable installers are the natural format for binary distributions on Windows. They display a nice graphical user interface, display some information about the module distribution to be installed taken from the metadata in the setup script, let the user select a few options, and start or cancel the installation.

Since the metadata is taken from the setup script, creating Windows installers is usually as easy as running:

```
python setup.py bdist_wininst
```

or the `bdist` command with the `--formats` option:

```
python setup.py bdist --formats=wininst
```

If you have a pure module distribution (only containing pure Python modules and packages), the resulting installer will be version independent and have a name like `foo-1.0.win32.exe`. These installers can even be created on Unix platforms or Mac OS X.

If you have a non-pure distribution, the extensions can only be created on a Windows platform, and will be Python version dependent. The installer filename will reflect this and now has the form `foo-1.0.win32-py2.0.exe`. You have to create a separate installer for every Python version you want to support.

The installer will try to compile pure modules into bytecode after installation on the target system in normal and optimizing mode. If you don’t want this to happen for some reason, you can run the `bdist_wininst` command with the `--no-target-compile` and/or the
By default the installer will display the cool “Python Powered” logo when it is run, but you can also supply your own 152x261 bitmap which must be a Windows .bmp file with the --bitmap option.

The installer will also display a large title on the desktop background window when it is run, which is constructed from the name of your distribution and the version number. This can be changed to another text by using the --title option.

The installer file will be written to the “distribution directory” — normally dist/, but customizable with the --dist-dir option.
5.3. Cross-compiling on Windows

Starting with Python 2.6, distutils is capable of cross-compiling between Windows platforms. In practice, this means that with the correct tools installed, you can use a 32bit version of Windows to create 64bit extensions and vice-versa.

To build for an alternate platform, specify the --plat-name option to the build command. Valid values are currently ‘win32’, ‘win-amd64’ and ‘win-ia64’. For example, on a 32bit version of Windows, you could execute:

```
python setup.py build --plat-name=win-amd64
```

to build a 64bit version of your extension. The Windows Installers also support this option, so the command:

```
python setup.py build --plat-name=win-amd64 bdist_wininst
```

would create a 64bit installation executable on your 32bit version of Windows.

To cross-compile, you must download the Python source code and cross-compile Python itself for the platform you are targeting - it is not possible from a binary installation of Python (as the .lib etc file for other platforms are not included.) In practice, this means the user of a 32 bit operating system will need to use Visual Studio 2008 to open the PCBuild/PCbuild.sln solution in the Python source tree and build the “x64” configuration of the ‘pythoncore’ project before cross-compiling extensions is possible.

Note that by default, Visual Studio 2008 does not install 64bit
compilers or tools. You may need to reexecute the Visual Studio setup process and select these tools (using Control Panel->[Add/Remove] Programs is a convenient way to check or modify your existing install.)

5.3.1. The Postinstallation script

Starting with Python 2.3, a postinstallation script can be specified with the --install-script option. The basename of the script must be specified, and the script filename must also be listed in the scripts argument to the setup function.

This script will be run at installation time on the target system after all the files have been copied, with argv[1] set to -install, and again at uninstallation time before the files are removed with argv[1] set to -remove.

The installation script runs embedded in the windows installer, every output (sys.stdout, sys.stderr) is redirected into a buffer and will be displayed in the GUI after the script has finished.

Some functions especially useful in this context are available as additional built-in functions in the installation script.

directory_created(path)

file_created(path)

These functions should be called when a directory or file is created by the postinstall script at installation time. It will register path with the uninstaller, so that it will be removed when the distribution is uninstalled. To be safe, directories are only removed if they are empty.

get_special_folder_path(csidl_string)
This function can be used to retrieve special folder locations on Windows like the Start Menu or the Desktop. It returns the full path to the folder. `csidl_string` must be one of the following strings:

- "CSIDL_APPDATA"
- "CSIDL_COMMON_STARTMENU"
- "CSIDL_STARTMENU"
- "CSIDL_COMMON_DESKTOPDIRECTORY"
- "CSIDL_DESKTOPDIRECTORY"
- "CSIDL_COMMON_STARTUP"
- "CSIDL_STARTUP"
- "CSIDL_COMMON_PROGRAMS"
- "CSIDL_PROGRAMS"
- "CSIDL_FONTS"

If the folder cannot be retrieved, `OSError` is raised.

Which folders are available depends on the exact Windows version, and probably also the configuration. For details refer to Microsoft's documentation of the SHGetSpecialFolderPath() function.

```
create_shortcut(target, description, filename[, arguments[, workdir[, iconpath[, iconindex]]]]])
```

This function creates a shortcut. `target` is the path to the program to be started by the shortcut. `description` is the description of the shortcut. `filename` is the title of the shortcut that the user will see. `arguments` specifies the command line arguments, if any. `workdir` is the working directory for the program. `iconpath` is the file containing
the icon for the shortcut, and iconindex is the index of the icon in the file iconpath. Again, for details consult the Microsoft documentation for the IShellLink interface.
5.4. Vista User Access Control (UAC)

Starting with Python 2.6, bdist_wininst supports a --user-access-control option. The default is ‘none’ (meaning no UAC handling is done), and other valid values are ‘auto’ (meaning prompt for UAC elevation if Python was installed for all users) and ‘force’ (meaning always prompt for elevation).
6. The Python Package Index (PyPI)

The Python Package Index (PyPI) stores meta-data describing distributions packaged with distutils, as well as package data like distribution files if a package author wishes.

Distutils provides the register and upload commands for pushing meta-data and distribution files to PyPI, respectively. See Distutils commands for information on these commands.
6.1. PyPI overview

PyPI lets you submit any number of versions of your distribution to the index. If you alter the meta-data for a particular version, you can submit it again and the index will be updated.

PyPI holds a record for each (name, version) combination submitted. The first user to submit information for a given name is designated the Owner of that name. Changes can be submitted through the register command or through the web interface. Owners can designate other users as Owners or Maintainers. Maintainers can edit the package information, but not designate new Owners or Maintainers.

By default PyPI displays only the newest version of a given package. The web interface lets one change this default behavior and manually select which versions to display and hide.

For each version, PyPI displays a home page. The home page is created from the long_description which can be submitted via the register command. See PyPI package display for more information.
6.2. Distutils commands

Distutils exposes two commands for submitting package data to PyPI: the register command for submitting meta-data to PyPI and the upload command for submitting distribution files. Both commands read configuration data from a special file called a .pypirc file.

6.2.1. The register command

The distutils command register is used to submit your distribution’s meta-data to an index server. It is invoked as follows:

```
python setup.py register
```

Distutils will respond with the following prompt:

```
running register
We need to know who you are, so please choose either
  1. use your existing login,
  2. register as a new user,
  3. have the server generate a new password for you
  4. quit
Your selection [default 1]:
```

Note: if your username and password are saved locally, you will not see this menu. Also, refer to The .pypirc file for how to store your credentials in a .pypirc file.

If you have not registered with PyPI, then you will need to do so now. You should choose option 2, and enter your details as required. Soon after submitting your details, you will receive an email which will be used to confirm your registration.
Once you are registered, you may choose option 1 from the menu. You will be prompted for your PyPI username and password, and `register` will then submit your meta-data to the index.

See Additional command options for options to the `register` command.

### 6.2.2. The upload command

The `distutils` command `upload` pushes the distribution files to PyPI.

The command is invoked immediately after building one or more distribution files. For example, the command

```bash
python setup.py sdist bdist_wininst upload
```

will cause the source distribution and the Windows installer to be uploaded to PyPI. Note that these will be uploaded even if they are built using an earlier invocation of `setup.py`, but that only distributions named on the command line for the invocation including the `upload` command are uploaded.

If a `register` command was previously called in the same command, and if the password was entered in the prompt, `upload` will reuse the entered password. This is useful if you do not want to store a password in clear text in a `.pypirc` file.

You can use the `--sign` option to tell `upload` to sign each uploaded file using GPG (GNU Privacy Guard). The `gpg` program must be available for execution on the system `PATH`. You can also specify which key to use for signing using the `--identity=name` option.

See Additional command options for additional options to the `upload` command.
6.2.3. Additional command options

This section describes options common to both the `register` and `upload` commands.

The `--repository` or `-r` option lets you specify a PyPI server different from the default. For example:

```
python setup.py sdist bdist_wininst upload -r https:
```

For convenience, a name can be used in place of the URL when the `.pypirc` file is configured to do so. For example:

```
python setup.py register -r other
```

See The `.pypirc` file for more information on defining alternate servers.

The `--show-response` option displays the full response text from the PyPI server, which is useful when debugging problems with registering and uploading.

6.2.4. The `.pypirc` file

The `register` and `upload` commands both check for the existence of a `.pypirc` file at the location `$HOME/.pypirc`. If this file exists, the command uses the username, password, and repository URL configured in the file. The format of a `.pypirc` file is as follows:

```
[distutils]
index-servers =
pypi
```
The `{distutils}` section defines an `index-servers` variable that lists the name of all sections describing a repository.

Each section describing a repository defines three variables:

- `repository`, that defines the url of the PyPI server. Defaults to `https://www.python.org/pypi`.

- `username`, which is the registered username on the PyPI server.

- `password`, that will be used to authenticate. If omitted the user will be prompt to type it when needed.

If you want to define another server a new section can be created and listed in the `index-servers` variable:
This allows the `register` and `upload` commands to be called with the `--repository` option as described in Additional command options.

Specifically, you might want to add the PyPI Test Repository to your `.pypirc` to facilitate testing before doing your first upload to PyPI itself.
6.3. PyPI package display

The `long_description` field plays a special role at PyPI. It is used by the server to display a home page for the registered package.

If you use the `reStructuredText` syntax for this field, PyPI will parse it and display an HTML output for the package home page.

The `long_description` field can be attached to a text file located in the package:

```python
from distutils.core import setup

with open('README.txt') as file:
    long_description = file.read()

setup(name='Distutils',
       long_description=long_description)
```

In that case, `README.txt` is a regular `reStructuredText` text file located in the root of the package besides `setup.py`.

To prevent registering broken `reStructuredText` content, you can use the `rst2html` program that is provided by the `docutils` package and check the `long_description` from the command line:

```
$ python setup.py --long-description | rst2html.py > output.html
```

docutils will display a warning if there's something wrong with your syntax. Because PyPI applies additional checks (e.g. by passing `--no-raw` to `rst2html.py` in the command above), being able to run the command above without warnings does not guarantee that PyPI
will convert the content successfully.
7. Examples

This chapter provides a number of basic examples to help get started with distutils. Additional information about using distutils can be found in the Distutils Cookbook.

See also:

**Distutils Cookbook**
Collection of recipes showing how to achieve more control over distutils.
7.1. Pure Python distribution (by module)

If you’re just distributing a couple of modules, especially if they don’t live in a particular package, you can specify them individually using the `py_modules` option in the setup script.

In the simplest case, you’ll have two files to worry about: a setup script and the single module you’re distributing, `foo.py` in this example:

```python
<root>/
    setup.py
    foo.py
```

(In all diagrams in this section, `<root>` will refer to the distribution root directory.) A minimal setup script to describe this situation would be:

```python
from distutils.core import setup
setup(name='foo',
      version='1.0',
      py_modules=['foo'],
)
```

Note that the name of the distribution is specified independently with the `name` option, and there’s no rule that says it has to be the same as the name of the sole module in the distribution (although that’s probably a good convention to follow). However, the distribution name is used to generate filenames, so you should stick to letters, digits, underscores, and hyphens.

Since `py_modules` is a list, you can of course specify multiple modules, eg. if you’re distributing modules foo and bar, your setup might look like this:
and the setup script might be

```python
from distutils.core import setup
setup(name='foobar',
      version='1.0',
      py_modules=['foo', 'bar'],
)
```

You can put module source files into another directory, but if you have enough modules to do that, it's probably easier to specify modules by package rather than listing them individually.
7.2. Pure Python distribution (by package)

If you have more than a couple of modules to distribute, especially if they are in multiple packages, it's probably easier to specify whole packages rather than individual modules. This works even if your modules are not in a package; you can just tell the Distutils to process modules from the root package, and that works the same as any other package (except that you don't have to have an __init__.py file).

The setup script from the last example could also be written as

```python
from distutils.core import setup
setup(name='foobar',
      version='1.0',
      packages=[''],
)
```

(The empty string stands for the root package.)

If those two files are moved into a subdirectory, but remain in the root package, e.g.:

```
<root>/
   setup.py
   src/
      foo.py
      bar.py
```

then you would still specify the root package, but you have to tell the Distutils where source files in the root package live:

```python
from distutils.core import setup
setup(name='foobar',
      version='1.0',
      package_dir={'' : 'src'},
)
More typically, though, you will want to distribute multiple modules in the same package (or in sub-packages). For example, if the foo and bar modules belong in package foobar, one way to layout your source tree is

```python
from distutils.core import setup
setup(name='foobar',
      version='1.0',
      packages=['foobar'],
)
```

If you want to put modules in directories not named for their package, then you need to use the package_dir option again. For example, if the src directory holds modules in the foobar package:

```python
setup(name='foobar',
      version='1.0',
      package_dir={'foobar': 'src'},
      packages=['foobar'],
)
```
an appropriate setup script would be

```python
from distutils.core import setup
setup(
    name='foobar',
    version='1.0',
    package_dir={'foobar': 'src'},
    packages=['foobar'],
)
```

Or, you might put modules from your main package right in the distribution root:

```
<root>/
    setup.py
    __init__.py
    foo.py
    bar.py
```

in which case your setup script would be

```python
from distutils.core import setup
setup(
    name='foobar',
    version='1.0',
    package_dir={'foobar': ''},
    packages=['foobar'],
)
```

(The empty string also stands for the current directory.)

If you have sub-packages, they must be explicitly listed in packages, but any entries in package_dir automatically extend to sub-packages. (In other words, the Distutils does not scan your source tree, trying to figure out which directories correspond to Python packages by looking for __init__.py files.) Thus, if the default layout grows a sub-package:

```
<root>/
    setup.py
    __init__.py
    foobar/__init__.py
    foobar/first.py
    foobar/second.py
```
then the corresponding setup script would be

```python
from distutils.core import setup
setup(name='foobar',
      version='1.0',
      packages=['foobar', 'foobar.subfoo'],
      )
```
7.3. Single extension module

Extension modules are specified using the ext_modules option. package_dir has no effect on where extension source files are
found; it only affects the source for pure Python modules. The simplest
case, a single extension module in a single C source file, is:

```python
<root>/
    setup.py
    foo.c
```

If the foo extension belongs in the root package, the setup script for
this could be

```python
from distutils.core import setup
from distutils.extension import Extension
setup(name='foobar',
    version='1.0',
    ext_modules=[Extension('foo', ['foo.c'])],
)
```

If the extension actually belongs in a package, say foopkg, then

With exactly the same source tree layout, this extension can be put in
the foopkg package simply by changing the name of the extension:

```python
from distutils.core import setup
from distutils.extension import Extension
setup(name='foobar',
    version='1.0',
    ext_modules=[Extension('foopkg.foo', ['foo.c'])]
)
7.4. Checking a package

The check command allows you to verify if your package meta-data meet the minimum requirements to build a distribution.

To run it, just call it using your setup.py script. If something is missing, check will display a warning.

Let's take an example with a simple script:

```python
from distutils.core import setup

setup(name='foobar')
```

Running the check command will display some warnings:

```
$ python setup.py check
running check
warning: check: missing required meta-data: version,
warning: check: missing meta-data: either (author and
(maintainer and maintainer_email) must be s
```

If you use the reStructuredText syntax in the long_description field and docutils is installed you can check if the syntax is fine with the check command, using the restructuredtext option.

For example, if the setup.py script is changed like this:

```python
from distutils.core import setup
desc = """
My description
============
```

This is the description of the ``foobar`` package.

```
setup(
    name='foobar', version='1', author='tarek',
    author_email='tarek@ziade.org',
    url='http://example.com', long_description=desc)
```

Where the long description is broken, check will be able to detect it by using the docutils parser:

```
$ python setup.py check --restructuredtext
running check
warning: check: Title underline too short. (line 2)
warning: check: Could not finish the parsing.
```
7.5. Reading the metadata

The `distutils.core.setup()` function provides a command-line interface that allows you to query the metadata fields of a project through the `setup.py` script of a given project:

```
$ python setup.py --name distribute
```

This call reads the name metadata by running the `distutils.core.setup()` function. Although, when a source or binary distribution is created with Distutils, the metadata fields are written in a static file called `PKG-INFO`. When a Distutils-based project is installed in Python, the `PKG-INFO` file is copied alongside the modules and packages of the distribution under `NAME-VERSION-pyX.X.egg-info`, where `NAME` is the name of the project, `VERSION` its version as defined in the Metadata, and `pyX.X` the major and minor version of Python like 2.7 or 3.2.

You can read back this static file, by using the `distutils.dist.DistributionMetadata` class and its `read_pkg_file()` method:

```python
>>> from distutils.dist import DistributionMetadata
>>> metadata = DistributionMetadata()
>>> metadata.read_pkg_file(open('distribute-0.6.8-py2.7.egg-info'))
>>> metadata.name
'distribute'
>>> metadata.version
'0.6.8'
>>> metadata.description
'Easily download, build, install, upgrade, and uninstall Python packages'
```
Notice that the class can also be instantiated with a metadata file path to load its values:

```python
>>> pkg_info_path = 'distribute-0.6.8-py2.7.egg-info'
>>> DistributionMetadata(pkg_info_path).name
'distribute'
```